VOLCANIC ASH:

A GUIDE FOR AIRLINE PILOTS

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1. Introduction and Objective

Over the past 30 years there have been more than 90 incidents in which commercial jet airliners encountered clouds of volcanic ash.
Eight of these involved temporary in- flight engine failure and two barely avoided disaster.

The volcanic ash hazard to aviation is a very real threat on a worldwide scale, given that many of the major air routes are over the world's volcanically active regions. It is estimated that volcanic ash can be expected to be in or around air routes at altitudes greater than 30 000ft for roughly 20 days per year.

There have been many advances in coordinating a dynamic response to the threat of volcanic ash and the havoc it wreaks economically. These include:

- establishing nine Volcanic Ash Advisory Centers (VAAC's) around the world.
- satellite and ground based observations.
- sophisticated computer modeling prediction programs.

Yet, in April 2010 the Eyjafjallajökull Volcano in Iceland erupted and resulted in the prolonged shutdown of most of European Airspace. Criticism was leveled at the authorities for an over cautious response as the economic effects were enormous. In some cases the Pilot in Command was left to make the final decision.

The objective of this paper is thus:

To increase the understanding of the phenomenon of "Volcanic ash" to Flight Crews.

To educate Flight Crews as to how and why it affects aircraft.

To increase their understanding of the advancing worldwide aviation trends and forecasting techniques so that they are equipped to make an informed decision.

2. Brief history of previous aircraft incidents

There are more than 1,330 volcanoes worldwide that have demonstrated activity over many thousands of years.
Approximately 500 have recent histories of activity, resulting in 55 to 60 eruptions per year (an average of more than one a week).
However, constant seismic monitoring is only available on 174 volcanoes.

A brief summary of the major incidents.(Taken from the Boeing Volcanic Ash paper 2010) follows:

Mt St Helens, United States 1980.

A Boeing 727 and a Douglas DC 8 encountered separate ash clouds during this major eruption. Both aircraft experienced damage to their systems and windshields but were able to land safely.

Galunggung Volcano, Indonesia 1982.

Several 747s encountered ash from this eruption. One aircraft lost thrust from all four engines and descended from 36,000 ft. to 12,500 ft. before all four engines were restarted. The aircraft, on a flight from Kuala Lumpur, Malaysia, to Perth, Australia, diverted to Jakarta and landed safely despite major engine damage. This aircraft subsequently had all four engines replaced before returning to service. A few days after the initial encounters, another 747 flew into the ash cloud and suffered significant engine damage. This airplane also diverted to Jakarta and subsequently performed a successful two-engine landing. (British Airways Flight 9)

Mt. Redoubt, United States, 1989.

On a flight from Amsterdam to Anchorage, Alaska, a new 747-400 (only three months old with approximately 900 hr. total flying time) encountered an ash cloud from the erupting Mt. Redoubt near Anchorage. All four engines ingested ash and flamed out. The crew successfully restarted the engines and landed safely at Anchorage. (KLM 867)

All four engines were replaced and many airplane systems also had to be repaired or replaced. For example, the airplane environmental control system was replaced, the fuel tanks were cleaned, and the hydraulic systems were repaired. Several other airplanes encountered ash from this eruption, but most damage was minor because operators had been notified of the eruption. Some operators, such as Alaska Airlines, continued scheduled flights once they had developed processes to safely identify where ash might be encountered. Although information was available about the Mt. Redoubt eruption, the channels for sharing this information were not well developed at the time.

Mt. Pinatubo, Philippines, 1991.

More than 20 volcanic ash encounters occurred after the Mt. Pinatubo eruption. This was the largest volcanic eruption of the past 50 years. The ability to predict where ash was to be found was challenging because of the enormous extent of the ash cloud. Commercial flights and various military operations were affected; one U.S. operator grounded its airplanes in Manila for several days.

Mt. Popocatepetl, Mexico, 1997.

This volcano affected several flights in 1997 and 1998. Although damage was minor in most cases, one flight crew experienced significantly reduced visibility for landing and had to look through the flight deck side windows to taxi after landing. In addition, the airport in Mexico City was closed for up to 24 hours on several occasions during subsequent intermittent eruptions.

Eyjafjallajökull , Iceland 2010 (pronounced eiya fjatla joekutl)

In April 2010, in an unprecedented move, airspace all over Europe was closed due to the presence of volcanic ash in the upper atmosphere from the eruption of the Icelandic volcano Eyjafjallajökull.

There had been some minor seismic activity in the preceding months but on 14 April 2010, the eruption entered a second phase and created an ash cloud that led to the closure of most of Europe's IFR airspace from 15 until 20 April 2010. Consequently, a very high proportion of flights within, to, and from Europe were cancelled, creating the highest level of air travel disruption since the Second World War.

The air space shut down had a massive knock on impact on the economy and cultural events across Europe.

Other volcanic activity that affected Aviation during 2010 included:

Kilauea Volcano Hawaii November 2010

This resulted in the re-routing of air traffic

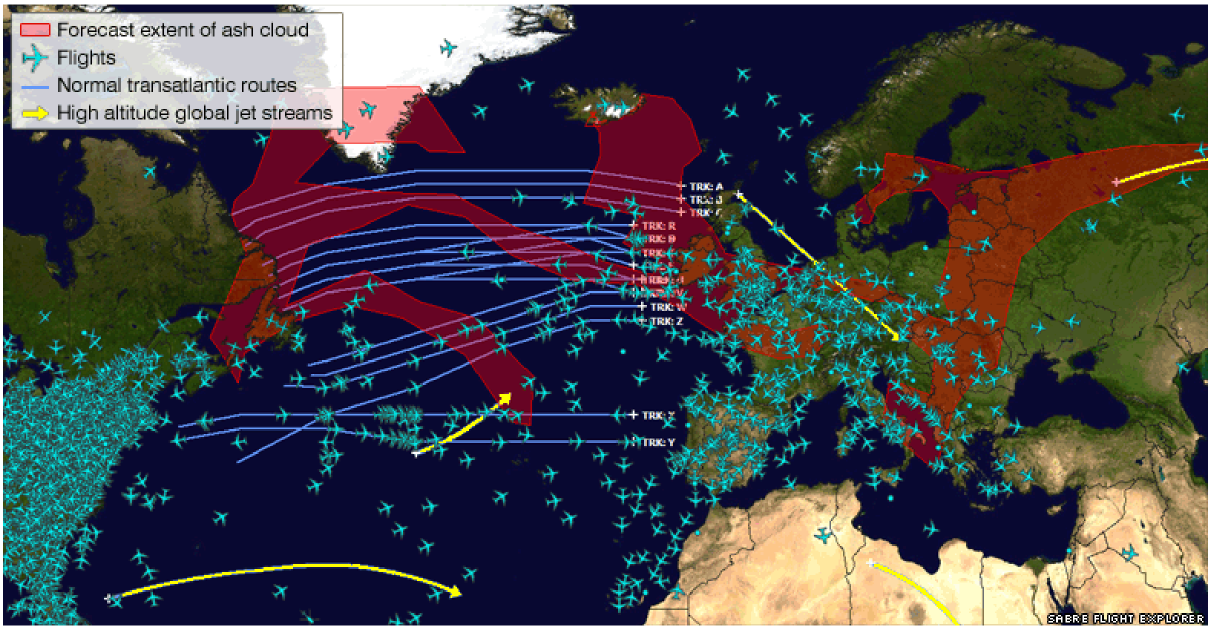
Mount Merapi volcano in Indonesia October 2010

This resulted in the re-routing of air traffic

(Source: Boeing Volcanic Ash paper 2010)

On the following page are some images from the Eyjafjallajökull Eruption

(Pictures: National Geographic and Wikipedia)



The last slide shows the forecast extent of the ash cloud superimposed on a map of normal transatlantic flights.

3. Analysis of the make-up of Volcanic Ash

Volcanic ash is made up of small tephra, which are fragments of pulverized rock and glass created by volcanic eruptions.

The tephra particles are less than 2 millimeters in diameter.

(Light microscope image of ash from the 1980 eruption of Mount St. Helens, Washington. Picture: Wikipedia)

Ash deposited on the ground after an eruption is known as ashfall deposit. Significant accumulations of ashfall can lead to the immediate destruction of most of the local ecosystem, as well the collapse of roofs on man-made structures. Over time, ashfall can lead to the creation of fertile soils. Ashfall can also become cemented together to form a solid rock called tuff. Over geologic time, the ejection of large quantities of ash can produce an ash cone.

(Picture: National Geographic)

There are three mechanisms of volcanic ash formation:

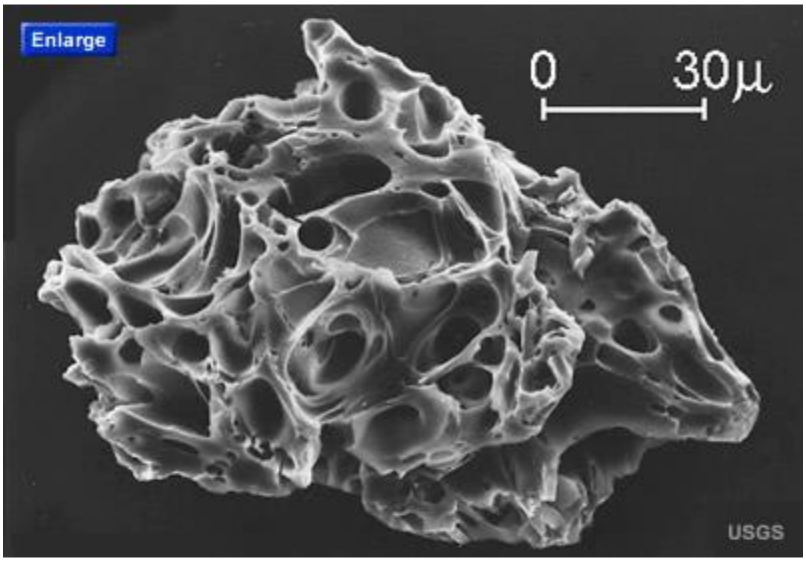
1. Gas release under decompression causing magmatic eruptions;
2. Thermal contraction from chilling on contact with water causing phreatomagmatic eruptions (eruptions as a result of interaction between water and magma).
3. Ejection of entrained particles during steam eruptions causing phreatic eruptions. The violent nature of volcanic eruptions involving steam results in the magma and solid rock surrounding the vent being torn into particles of clay to sand size.

If a volcanic eruption occurs beneath glacial ice, cold water from melted ice chills the lava quickly and fragments it into glass, creating small glass particles that get carried into the eruption plume. This can create a glass-rich plume in the upper atmosphere which is particularly hazardous to aircraft

Ash is also created when solid rock shatters and magma separates into minute particles during explosive volcanic activity. The plume that is often seen above an erupting volcano is composed primarily of ash and steam. The very fine particles may be carried for many miles, settling out as a dust-like layer across the landscape.

If liquid magma is ejected as a spray, the particles will solidify in the air as small fragments of volcanic glass. Unlike the ash that forms from burning wood or other combustible materials, volcanic ash is hard and abrasive. It does not dissolve in water, and it conducts electricity, especially when it is wet.

At first glance, volcanic ash appears as a soft, harmless powder. Instead, volcanic ash is a rock material with a hardness of approximately 5+ on the Mohs Hardness Scale. (The highest level on the scale is 10 being that of a diamond) It is composed of irregularly shaped particles with sharp, jagged edges (see image).



(Picture: National Geographic)

The significant hardness, combined with the irregular particle shape renders volcanic ash an abrasive material. This gives these microscopic particles the ability to damage aircraft windows, irritate the eye, cause abnormal wear on moving parts of equipment and many other problems.

Volcanic ash particles are very small in size and have a vesicular structure with numerous cavities. This gives them a relatively low density for a rock like material. This low density, combined with the very small particle size allows volcanic ash to be carried high into the atmosphere by an eruption and carried long distances by the wind. Volcanic ash can cause problems a long distance from the erupting volcano.

Volcanic ash particles are insoluble in water. When they become wet they form a slurry or a mud that can make highways and runways slick. Wet volcanic ash can dry into a solid, concrete-like mass. This enables it to plug storm water sewers and stick in the fur of animals that are in the open when ash falls at the same time as rain.

Tephra / Pyroclastic Terminology	
Particle Name	**Particle Size**
Blocks / Bombs	over 64 mm (2.5 inches)
Lapilli	under 64 mm (2.5 inches)
Volcanic Ash	under 2 mm (.079 inches)
Volcanic Dust (Fine Volcanic Ash)	under 0.063 mm (0.0025 inches)

"Tephra" and "pyroclastics" are general terms used in reference to particles of igneous rock material of various sizes that have been ejected from volcanoes. They are classified by size. The terms "ash" and "dust" communicate a specific size of tephra or pyroclastic particles. These are summarized in the table above.

Atmospheric effects

When ash begins to fall during daylight hours, the sky turns hazy and a pale yellow colour. The ashfall may become so dense that the sky turns gray to pitch black, with the ash severely restricting visibility and deadening sound. A darkened ash sky lowers temperatures during daylight hours from what would otherwise be expected. Loud thunder, lightning, as well as the strong smell of sulphur accompany an ashfall. If rain accompanies an ashfall, the tiny particles turn into a slurry of slippery mud. Rain and lightning combined with ash can lead to power outages, breakdowns of communication, and disorientation.

Volcanic ash particles have a maximum residence time in the troposphere of a few weeks. The finest tephra particles remain in the stratosphere for only a few months, they have only minor climatic effects, and they can be spread around the world by high-altitude winds. This suspended material contributes to spectacular sunsets. The major climate influence from volcanic eruptions is caused by gaseous sulphur compounds, chiefly sulphur dioxide, which reacts with OH (Hydroxide) and water in the stratosphere to create sulfate aerosols with a residence time of about two to three years.

There are clearly many hazards associated with Volcanic Ash. The next Chapter focuses on the aviation hazards but there are other health hazards to humans.

People exposed to falling ash or living in the dusty environment after an ash fall can suffer a number of problems. Respiratory problems include nose and throat irritation, coughing, bronchitis-like illness and discomfort while breathing. These can be reduced with the use of high efficiency dust masks but exposure to the ash should be avoided if possible.

Long term problems might include the development of a disease known as "silicosis" if the ash has a significant silica content. The U.S. National Institute of Occupational Safety and Health recommends specific types of masks for those exposed to volcanic ash. Anyone who already suffers from problems such as bronchitis, emphysema, or asthma should avoid exposure.

Dry volcanic ash can stick to a moist human eye and the tiny ash particles quickly cause eye irritation. This problem is most severe among people who wear contact lenses. Some skin irritation is reported by people in ashfall areas; however, the number of cases and their severity are low.

Steam explodes from a glacier-topped Iceland volcano in an aerial picture taken April 14, 2010, by the Icelandic Coast Guard.

Sources: Wikipedia and National Geographic websites

4. The Dangers Facing Aircraft

In general the following hazardous substances can be identified:

Dust/rock particles
Glass particles
SO_2 (Sulphur Dioxide)
HCl (hydrochloric acid)

In their gaseous form the latter two constituents of the volcanic ash cloud are considered not to cause significant harmful effects to aircraft.

However, following the eruption, oxidation and hydration of the SO_2 forms H_2SO_4 (sulphuric acid) droplets which are quite a different matter. The resulting ash/acid mix is highly corrosive and can cause damage to jet engines and pitting of windscreens.
This may present a long term maintenance expense for aircraft operating regularly in airspace contaminated with even relatively low concentrations of such ash/acid.

The effect on jet aircraft engines is particularly severe as large amounts of air are sucked in during combustion operation, posing a great danger to aircraft flying near ash clouds. Very fine volcanic ash particles (particularly glass-rich if from an eruption under ice) sucked into a jet engine melt at about 1,100 °C, fusing onto the blades and other parts of the turbine (which operates at about 1,400 °C).

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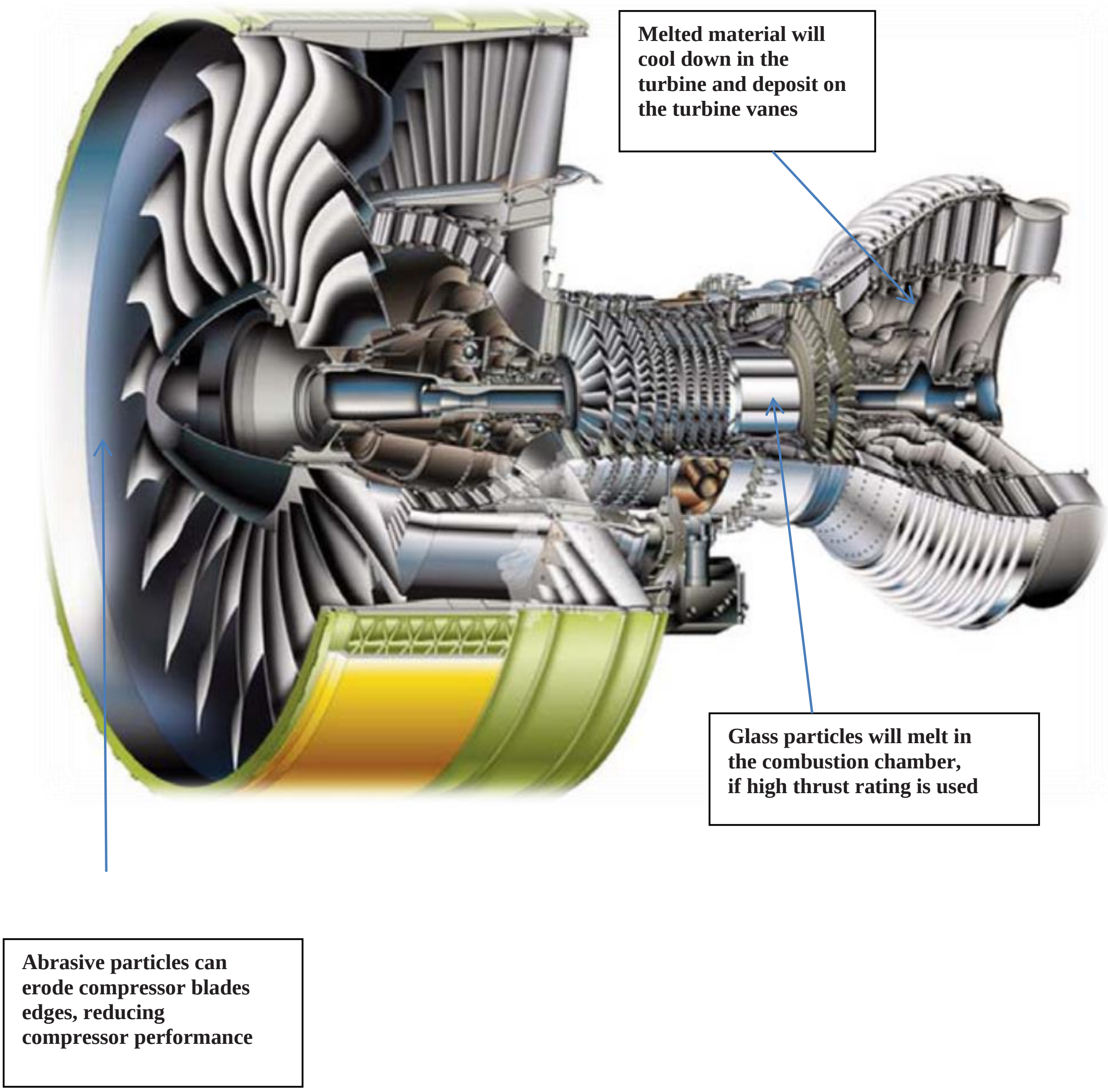
<u>Illustration of the effects of ash on the modern turbo fan engine</u>

(Picture: The Airbus Paper on Volcanic Ash 2010)



Damage to the engine blades of BA Flight 9

(picture: bbs.stardestroyer.net)

Damage to the Windscreen of BA Flight 9

(picture: bbs.stardestroyer.net)

Aircraft Hazards

Several short-term and long-term hazards can be identified and have been encountered in real life in relation to ash encounters.
The hazards that warrant most attention are those affecting aircraft engines and airspeed sensors.

Short-term operational hazards:

- Engine failure
  - Multiple engine malfunctions, such as surge, stalls, increasing Exhaust Gas Temperature (EGT) and torching.
  - Slow or no engine restart
  - In case of loss of thrust on all engines there is a high risk of loss of most electrical, hydraulic and pneumatic components with the ensuing flight control problems and cabin pressurization failure.

- Pitot-static instrument failure
- Communication failure
- Electrical failures
- Impaired vision caused by damaged windows
- Degraded landing performance
- Limited ground operations
- Degraded integrity of composite structure

- Long-term operational hazards:

  - Abrasion of fan-blades, engine inlet, and compressor blades
  - Partial or complete occlusion of turbine blade cooling channels leading to blade overheating with a corresponding reduction of blade life and premature blade failure
  - Abrasion or contamination of pneumatic ducting

- Damage to aircraft exterior e.g. windshields, wing leading edge, landing lights
- Contamination of pitot tubes and static ports
- Health risks to operating crew and passengers
- Corrosion of exterior
- Corrosion of interior
- Health hazards:
- Impaired breathing
- Impaired vision (physically)
- Long term exposure health risks to operating crew and passengers

(Source: IFALPA Position Paper on Volcanic Ash and the Airbus Volcanic Ash Paper)

5. The Economic Effects of Volcanic Activity on Aviation

In dealing with this complex topic, I based my research chiefly on a Paper written by Hauke L. Kite-Powell from Marine Policy Center, Woods Hole Oceanographic Institution in January 2001.

Kite-Powell summarized the problems volcanic ash presents to commercial aviation and considered the potential contribution of data provided by the planned National Polar-Orbiting Operational Environmental Satellite System (NPOESS).

This paper attempted to quantify the economic impact that volcanic ash had on Aviation in order to motivate the huge expense of the National Polar-Orbiting Operational Environmental Satellite System (NPOESS). Although it was written in 2001 it is a useful exercise in quantifying the economic effects.

NPOESS experienced extensive developmental problems with its many sensors, causing its first launch to slide several years. Developmental challenges and changing requirements also prompted the total program costs to more than double from their initial $6.5 billion estimate.

Thus, sadly, this program never came to fruition being a victim of American politics and economic problems and was finally terminated in February 2010.

A brief summary of the paper:

In estimating the economic effects of volcanic ash on aviation, it is useful to distinguish between two main categories:

"airborne" effects due to aircraft encounters with ash clouds, and
"airport" effects due to flight delays and cancellations.

Each year from 1980 to 1995, on average, five commercial jets encountered ash Clouds in flight. About 10 percent of these encounters resulted in loss of power.

The total reported damage to engines, avionics, and airframes from such encounters (1980 to1998) was about $250 million. Some ash damage may not have been reported; it is likely that this number underestimates the actual costs.

Fortunately, no ash encounter to date has led to loss of aircraft or fatalities.

However, observers agree that several encounters (Galunggung 1982; Redoubt 1989/90) had the potential for disastrous consequences. It seems reasonable, therefore, to suggest that there has been about a 1 percent chance of total aircraft loss in the event of an ash cloud encounter.

To estimate the economic risk of "airborne" effects, we add the expected annual equipment damage (some $15 million/year based on historical data), and the estimated annual risk of a total aircraft loss. Assuming 200 passengers and crew, and a value per human life of $5 million (see Gramlich 1990), plus $100 million for the aircraft, the cost of a total aircraft loss is $1.1 billion. The economic risk of total aircraft loss is 1 percent of 5 encounters per year, or $55 million. Thus, the overall economic risk from "airborne" effects historically is approximately $70 million per year.

On the ground, additional costs are incurred when airports are shut down and flights are delayed or cancelled because of ash clouds and ash deposition.

Aircraft may be moved to avoid ash contamination on the ground. Between 1980 and 1998, over 35 airports in 11 countries (USA, Japan, New Zealand, Mexico, Guatemala, Colombia, Argentina, Indonesia, Japan, New Guinea, Philippines, Falkland Islands) have been shut down or severely affected by ash falls (Miller and Casadevall 1999). The historical average in the jet aviation age, therefore, has been approximately two "airport" events per year.

Although the particular effects vary from one incident and airport to another, most fall into one of three categories:

(1) lost revenue to airlines because of cancelled passenger and freight service,
(2) lost revenue to airports from cancelled traffic, and
(3) delay costs incurred by passengers.

Other costs include the removal of ash from airport facilities, the relocation of aircraft to avoid stranding them (for example, a Boing 767 was stranded at Manila airport for 6 days due to ash contamination from Mt. Pinatubo in 1991), and delays associated with rerouting flights around potential ash hazards, among others.

Tuck and Huskey (1994) summarize the economic effects of the 1989/90 Redoubt eruption on the aviation industry. In addition to $80 million in damage to aircraft, they identified $21 million in economic losses due to disruption of air travel at Anchorage International Airport (see below). This is a lower estimate of overall losses, as it does not include the cost of disruptions in international passenger traffic.

domestic passenger traffic $1.7 million
international passenger traffic [not quantified]
domestic freight [minimal]
international freight $15.0 million
Anchorage Int'l Airport revenues (landing fees, concessions, fuel flowage fees) $1.6 million
airport support industries (fuel distribution, ground crews and service, catering, concessions) $1.0 million
passenger waiting time $1.8 million

(Sources: Tuck and Huskey (1994); Casadevall (1994).

Using the Anchorage Airport figures as a representative example, we assume "airport" losses in the event of ash fall of about $20 million. Historically, two airports per year have been affected, for a historical loss of $40 million per year in "airport" losses.

Thus, the historical losses to commercial aviation from volcanic ash over the baseline period 1980 to 1995 have been on the order of $110 million per year.

Source: Benefits of NPOESS for Commercial Aviation –Volcanic Ash Avoidance by
Hauke L. Kite-Powell
Marine Policy Center, Woods Hole Oceanographic Institution
January 2001

This estimated figure of 110 Million USD per year in 2001 will clearly be much higher now.

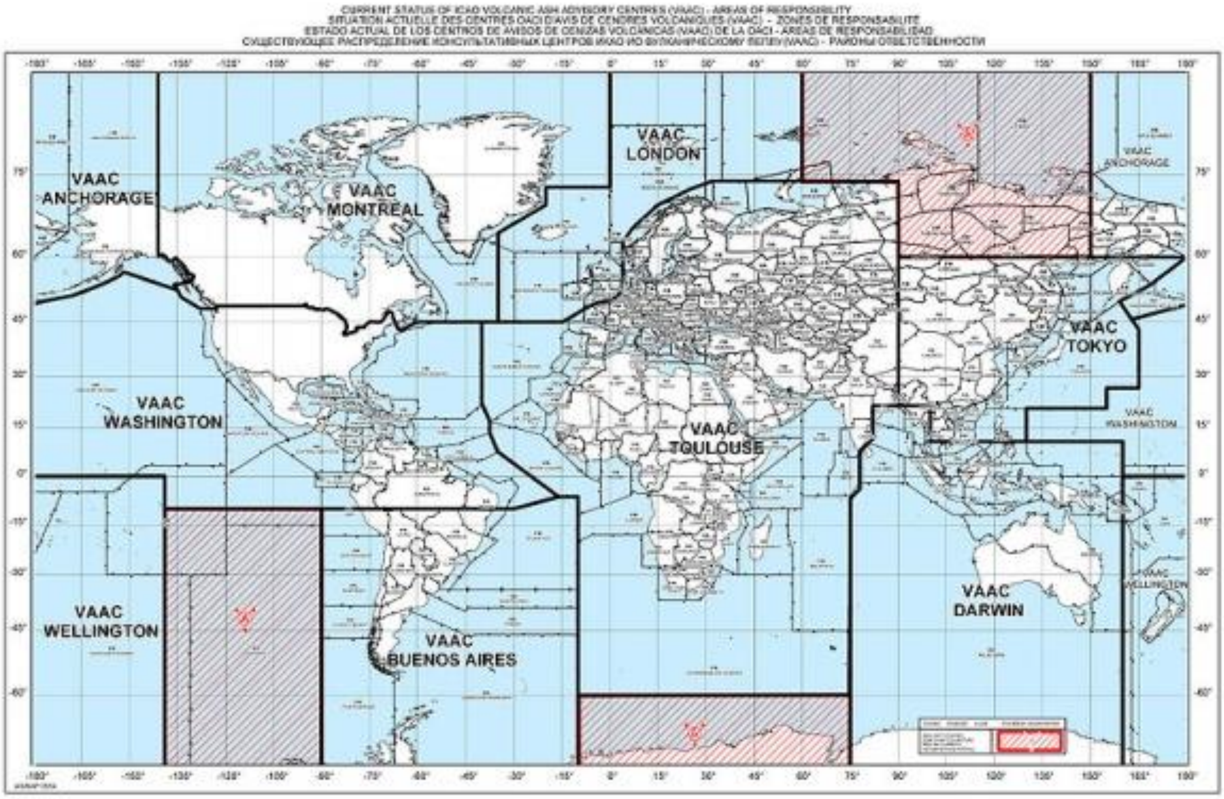
There have been no accurate estimates of the combined economic and airline effect of Eyjajalljokull but the figure of 1 Billion Euro per day for the duration of the airspace closure has been widely used.

6. Tracking of Volcanic Ash

A wealth of information about volcanic eruptions has been available for many years. However it was only in July 1991 that the broader aviation industry and the "Volcanological" community began a joint effort to find ways to avoid future encounters, (after the Mt. Redoubt eruption).

This was at an international conference in Seattle, Washington. Aviation industry members, meteorologists, and volcano scientists gathered to determine what volcano event information the aviation industry needed, how this information could be distributed, and who or which agencies should distribute it. The International Civil Aviation Organization (ICAO) had laid much of the foundation for the volcanic ash issue through its Volcanic Ash Warnings Study Group.

One of the outcomes of this initial meeting is the availability of today's Volcanic Ash Advisory Centers (VAAC). The VAACs provide an important link among volcano observatories, meteorological agencies, air traffic control centers, and operators. A total of nine VAACs observe and report on their respective region of the world.



(VAAC regions from the Wikipedia website)

The VAAC s provide a VAAS which is a Volcanic Ash Advisory Statement.

In addition to providing VAAS s directly to the airlines, the VAAC s also provide information to appropriate meteorological organizations that subsequently issue significant meteorological information (SIGMET) and other reports. The ICAO publication "International Airways Volcano Watch" (ICAO annex III) contains further information and contact names and numbers. Detailed information on the VAACs, including contacts for each of the nine centres, is available at http://www.ssd.noaa.gov/VAAC/.

Operators rely on the VAACs for information, and many operators maintain direct contact with volcano observatories within their flight domains. For instance, the Alaska Volcano Observatory (AVO) in Anchorage, with links to Fairbanks, issues a weekly bulletin by e-mail and fax detailing the activity of key volcanoes in Alaska. During periods of volcanic unrest and eruption, bulletins are issued more frequently as conditions change. Anyone can request to be placed on distribution lists for the bulletins.

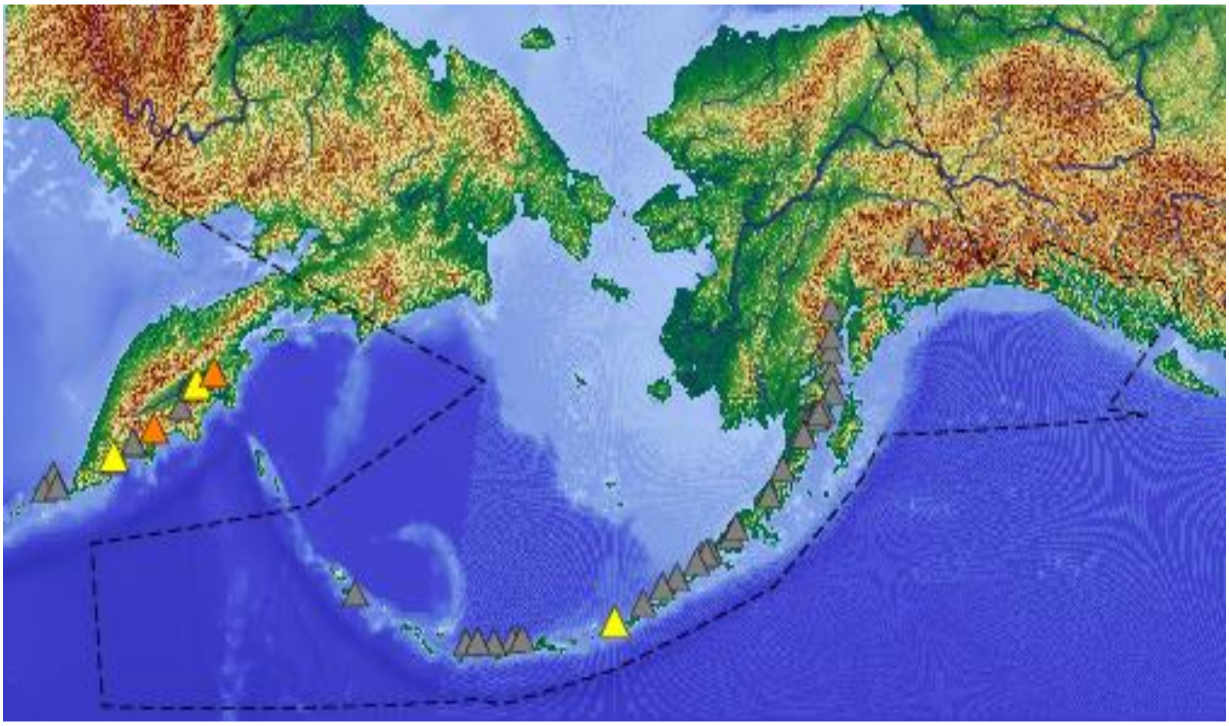
Many operators maintain personal relationships with individuals in the volcano observatories that monitor volcanoes within a particular flight domain. For instance, Alaska Airlines maintains contact with key individuals at the AVO because a significant portion of Alaska's flight domain could be affected by Alaskan volcanoes.

Many other web sites provide information and links to other sources of volcano information. A wealth of printed information, such as the *Bulletin of the Global Volcanism Network* through the Smithsonian National Museum of Natural History in Washington, D.C., is also available. However, the information about current volcanic activity in these printed sources is often two to three months old.

Aviation operations in volcanic ash situations rely on information based on detection and monitoring, alerting, modeling, and post event assessments. The U.S. Geological Survey (USGS) provides seismic monitoring for early detection and passes the information directly to the FAA to provide early warnings when an eruption is imminent or has occurred, which is especially important for en route aircraft. NOAA uses satellite monitoring as a core element in detection, tracking, and monitoring eruptions, and the resultant ash plume. Pilots also make observations, and the FAA disseminates pilot reports or PIREPS along with NOTAMs and Significant Meteorological Information (SIGMETs). SIGMETS originate from NOAA’s National Weather Service.

The challenge facing the industry is to detect and forecast the “ash cloud”. Various methods are used including “ash cloud modelling” which utilises advanced mathematical modelling processes. This process is still in its infancy and not yet robust enough for accurate forecasting but as more data is gathered, this process will improve.

Sources: Ifalpa Paper 2010 and Boeing Paper 2010



Example of current Volcanic Ash Status by the Volcanic Ash Advisory Center: Anchorage (a Green, Yellow, Red colour coded system is used)

7. International Federation of Airline Pilots' Associations(IFALPA) Position

Shortly after the Eyjafjallajökull eruption IFALPA produced an official Position Paper outlining its viewpoint. This Paper is readily available so I have not reproduced the entire paper here. I have however included the Executive summary and the seven Recommendations here. The following is taken directly from the paper:

Executive Summary

Dealing with hazards is inherent to aircraft operation. Like icing conditions, wake turbulence or microburst, volcanic ash introduces operational risks that can be identified and dealt with in order to achieve a safe flight.

Aircraft are not specifically designed nor certified for flight into volcanic ash simply because airworthiness requirements have not been specified with regard to volcanic ash. There is presently no clear threshold for the composition and concentration of ash that is hazardous to aviation, so the ICAO recommended practice is to avoid all volcanic ash (zero-tolerance).

Current regulations and guidance for volcanic ash operations (including measurement and certification), i.e. those that resulted in the widespread airspace closure in Europe in April and May 2010, do not fulfil all operational and safety needs. This has led to devastating economic consequences.

Under this pressure, the Council of European Union Transport Ministers adopted a value of 2 mg/m3 as acceptable provided that certain risk mitigating measures were implemented. IFALPA believes that such a value needs a scientific basis and this has not yet been demonstrated.

ICAO specifies that the position of the 'ash cloud mass' should be forecast, but does not define any threshold limits for ash concentration.
Threshold ash concentration values vary over the world with no clear relationship between threshold values and aviation hazards.

A continued zero-tolerance policy is probably not realistic therefore acceptable levels of exposure to defined ash-concentrations and appropriate risk mitigation measures must be established.

Volcanic Ash is first of all an operational problem as it affects the aircraft and its safe operation. The solution depends on new or revised specifications for acceptable tolerance levels from engine and airframe manufacturers which can be related to scientifically validated measurements. ICAO should establish or revise global Standards for refined threshold values for exposure to volcanic ash concentration which must be based on hazards to the aircraft and people; a so-called hazard threshold.

Furthermore flight operational and maintenance procedures must be adapted or developed and subsequently implemented. Taking into account scientifically proven aviation limits (hazard thresholds) the airlines/operators should be able to bear the responsibility for planning and executing safe flights.

The necessity of avoiding Volcanic Ash creates a problem for the Air Traffic Services (ATS). They play a significant role in the information distribution and have to prevent collisions between aircraft and to maintain an orderly flow of air traffic (ICAO Annex 11)

Objectives of the Air Traffic Services), even in situations where Volcanic Ash restricts operations in large portions of airspace. ATS Contingency Plans addressing all aspects of Air Traffic Management for Volcanic Ash
situations should be available for all regions of the world and be based on the needs of aircraft in flight.

Civil aviation has developed a ‘safety-first’ principle which should not be abandoned as a result of the economic pressures caused by the recent airspace closures. This means that the current principle of conservative avoidance should be maintained unless demonstrably safe hazard threshold criteria can be applied. These include accurate modelling or measurement of the hazard and certification criteria for flight in the hazard area that includes mitigation measures catering for longer term effects.

Finally, the ultimate responsibility for the safe conduct of a flight rests with the Pilot-In-Command. The Pilot-In-Command must therefore be given adequate tools, training information and guidelines to deal with volcanic ash.

Recommendation 1:

New SARPs and Guidance Materials are needed to ensure safety and minimize disruption to air travel in case of future eruptions. Revised procedures shall be based on data from scientific research; global volcanic ash standards (composition, concentration, etc.);

certified engine and airframe operations; reliable and fast (ideally real time) information on the hazards; etc.

Recommendation 2:

IFALPA strongly supports research to validate a safe and practicable boundary for acceptable ash concentration exposure. The introduction of standardised limitations must be based on a safety risk assessment.

Recommendation 3:

IFALPA believes that additional refinement of the model(s) will indicate more reliable and precise defined airspace volumes (3D) of ash hazards. Furthermore, whenever the dispersion of volcanic ash is forecast the extent of the airspace volume(s) estimated to be above the acceptable threshold concentration should be verified and validated by in-flight measurements otherwise a conservative safety buffer should be applied.

Recommendation 4:

IFALPA believes that a global approach is needed that allows for a tailor-made solution for any airspace concerned. Operators and flight crews are primarily responsible for safe flight operations and thus general no-fly restrictions should be minimised. Operations should be left subject to the operators' safety risk assessment that is acceptable to the overseeing national regulator (safety oversight authority). ANSPs should have contingency plans available, based on Regional Air Navigation Agreement.

Recommendation 5:

Regional contingency plans should also consider potential effects of volcanic ash on aerodromes in the region.

Recommendation 6:

The Aircraft Operations Certificate (AOC) holder must conduct a safety risk assessments prior to planned operations within or in the vicinity of volcanic ash. The risk assessment must include all affected stakeholders and must satisfy the acceptable level of safety prescribed by the safety oversight authority. The risk assessment must include clearly definable threat scenarios, actions, training and other mitigations.

Recommendation 7:

IFALPA strongly believes that several issues must be resolved to guarantee safe flight in a volcanic ash environment with maximum flexible use of the available airspace. The underlying goal should always be to plan a flight path that will be free from significant ash hazards. To achieve this goal the following requirements shall be accomplished:

1. Identify the hazards.

a. Perform adequate research on the short and long term effects of volcanic ash on the entire aircraft and their occupants.

b. Conduct an in-depth risk analysis for the hazards of aircraft operation in VA.

c. Establish generic engine ash tolerance levels based on actual data and research for relevant ash parameters: content concentration, particle size/type/properties and acidity.

2. Identify the contaminated airspace.

a. Improve modelling, measurement and/or sensing accuracy of ash particle size and density in volcanic ash clouds. Compile experience and data from present and past encounters and test flights.

b. VAAC must deliver relevant data in an accurate, timely and robust way by means of measurement, imaging, modelling and validation.

c. The appropriate safety oversight authority shall establish a danger area, where necessary.

d. Uniform global criteria for closure of (parts of) airspace should be applied in case of unacceptable hazardous ash concentrations (the no-fly black zone). Closure should be based on unambiguous validated data and executed in accordance with global 'closure criteria'.

e. Implementation of one or more intermediate levels of ash hazard/concentration with restrictive use and additional operating rules and maintenance requirements (e.g. red, orange zone) needs further study and validation.

3. Flight Operation.

a. Responsibility for flight operations should remain with the operators, except for hazardous high-density ash levels exceeding aircraft and engine tolerance limitations (black zone). The black zone should be defined by the National Safety Oversight Authorities responsible for regulating flight operations, not by Air Traffic Management authorities or Air Navigation Service Providers.

b. The operator must fulfil this responsibility for a safe flight and conduct a safety risk assessment prior to any operation in low-concentration ash (grey, red, orange zones) and get approval from his Safety Oversight Authority. The operators should effectively train crews for operation in these zones.

c. The Pilot-In-Command is ultimately responsible for safe flight and must therefore have insight in all relevant ash data and specific aircraft procedures. As the person ultimately responsible, the Pilot-In-Command must retain the final decision whether a flight can be conducted safely.

d. Operators should refrain from any disciplinary actions when flight crews exercise their flight safety responsibility not to fly in ash (i.e. delay departure or diversion).

e. VFR operations ("See and avoid") shall not be considered as a suitable method of conducting commercial air transport operations in, or near, ash. A restriction to fly in potentially or actually contaminated areas only under daylight VMC might be an adequate mitigation measure to avoid high ash concentration, but does not necessarily protect from low ash concentration that might still be hazardous.

Source: The IFALPA Position Paper on Volcanic Operations (June 2010)

8. Boeing Volcanic Ash Advice

Boeing published a Volcanic Ash Advice Paper in May 2010. This Paper is readily available so I have not reproduced the entire document here.

This briefing leaflet comprised two parts.

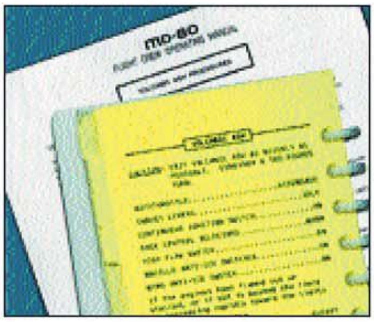
The first is a selection of pages from the Boeing Commercial Airplanes publication Aero and dealt with advances in volcanic ash avoidance and recovery and the second part is based on the Flight Operations Technical Bulletin issued by the company on 21 April 2010.

The "Specific Flight Crew Actions Required in Response to Encounters" is particularly interesting as it accepts that there will be encounters and thus offers specific advice (it does acknowledge that the aircraft/company manuals will take preference).

It also publishes Alaska Airlines Procedures for operating in volcanic ash as they have extensive experience in this regard due to the extensive of active volcanoes in their route structure.

Lastly I have also reproduced their "Volcano Eruption Warning Color Codes" table and their list of Volcanic Ash Resources.

3 SPECIFIC FLIGHT CREW ACTIONS REQUIRED IN RESPONSE TO ENCOUNTERS



Despite ongoing avoidance efforts, operators can still experience volcanic ash encounters. Guidance on the operational issues surrounding volcanic ash is divided into three aspects: avoidance, recognition, and procedures. The following information is general; flight crews should refer to their respective company's operating manuals for details.

Avoidance.

Preventing flight into potential ash environments requires planning in these areas:

- Dispatch needs to provide flight crews with information about volcanic events, such as potentially eruptive volcanoes and known ash sightings, that could affect a particular route (see sidebar at bottom of p. 26).
- Dispatch also needs to identify alternate routes to help flight crews avoid airspace containing volcanic ash.
- Flight crews should stay upwind of volcanic ash and dust.
- Flight crews should note that airborne weather radar is ineffective for distinguishing ash and small dust particles.

Recognition.

Indicators that an airplane is penetrating volcanic ash are related to odor, haze, changing engine conditions, airspeed, pressurization, and static discharges.

- **Odor.** When encountering a volcanic ash cloud, flight crews usually notice a smoky or acrid odor that can smell like electrical smoke, burned dust, or sulfur.
- **Haze.** Most flight crews, as well as cabin crew or passengers, see a haze develop within the airplane. Dust can settle on surfaces.
- **Changing engine conditions.** Surging, torching from the tailpipe, and flameouts can occur. Engine temperatures can change unexpectedly, and a white glow can appear at the engine inlet.
- **Airspeed.** If volcanic ash fouls the pitot tube, the indicated airspeed can decrease or fluctuate erratically.
- **Pressurization.** Cabin pressure can change, including possible loss of cabin pressurization.
- **Static discharges.** A phenomenon similar to St. Elmo's fire or glow can occur. In these instances, blue-colored sparks can appear to flow up the outside of the windshield or a white glow can appear at the leading edges of the wings or at the front of the engine inlets.

Procedures.

The following nine procedures are general recommendations. Each operator's flight operations manuals will include more specific directions.

1. **Reduce thrust to idle immediately.** By reducing thrust,engines may suffer less buildup of molten debris on turbine blades and hot-section components. Idle thrust allowsengines to continue producing electrical power, bleed air for pressurization, and hydraulic power for airplane control.
2. **Turn the autothrottles off.** This prevents the engines from increasing thrust above idle. Ash debris in the engine can result in reduced surge margins, and limiting the number of thrust adjustments improves the chances of engine recovery.
3. **Exit the ash cloud as quickly as possible.** A 180-deg turn out of the ash cloud using a descending turn is the quickest exit strategy. Many ash clouds extend for hundreds of miles, so assuming that the encounter will end shortly can be false. Climbing out of the ash could result in increased engine debris buildup as the result of increased temperatures. The increased engine buildup can cause total thrust loss.
4. **Turn on engine and wing anti-ice devices and all air-conditioning packs.** These actions improve the engine stall margins by increasing the flow of bleed air.
5. **If possible, start the auxiliary power unit (APU).** The APU can power systems in the event of a multiple-engine power loss. It can also be used to restart engines through the use of APU bleed air.
6. **If volcanic dust fills the flight deck, the crew may need to use oxygen.** Use flight deck oxygen at the 100 percent setting. Manual deployment of the passenger oxygen system is not required because it will deploy automatically if the cabin altitude exceeds 14,000 ft.
7. **Turn on the continuous ignition.** Confirm that autostart is on, if available. In the event that the engines flame out or stall, use appropriate procedures to restart the engines. During restart, the engines may take longer than normal to reach idle thrust due to the combined effects of high altitude and volcanic ash ingestion. If an engine fails to start, try restarting it again immediately. Flight crews should remember that the airplane may be out of the airstart envelope if the encounter occurs during cruise.
8. **Monitor engine exhaust gas temperature (EGT).** Because of potential engine debris buildup, the EGT can climb excessively. The flight crew should prevent EGT exceedances. Shut down the engine and restart it if the EGT is approaching limits similar to a hung start.
9. **Fly the airplane by monitoring airspeed and pitch attitude.** If necessary, follow the procedure for flight with unreliable airspeed.

SUMMARY Though the number of commercial airplane encounters with volcanic ash clouds has decreased significantly over the past several years, the potential for this type of event still exists. Efforts to advance knowledge about how to avoid and recover from these encounters have resulted in improved capability in these areas. By working with members of the volcanological community, the aviation industry has developed procedures to share information about events with flight crews, dispatchers, volcano scientists, and others. Volcano observatories that provide daily updates through e-mail messages or phone recordings have been established. In addition, a variety of Internet sources provide information that operators can tailor to their specific flight domains. Finally, flight operations procedures are documented and available to flight crews to help them respond immediately and appropriately to maintain the highest possible level of flight safety.

ALASKA AIRLINES PROCEDURES FOR

OPERATING IN VOLCANIC ASH CONDITIONS

Alaska Airlines has many active volcanoes within its flight domain. To prepare for an eruption and resulting encounter with volcanic ash, the airline has developed focused guidelines for flight operations when eruptions interfere with its route structures:

1. When in doubt, don't fly.
2. Use facts and data.
3. Identify the location of both the ash and clear areas.
4. Stay focused.

1 WHEN IN DOUBT, DON'T FLY

The fundamental principle by which Alaska Airlines operates is knowing where to find the ash after a volcanic eruption. If unsure of the ash location, it will not allow its flight crews to fly through the eruption area. Though this approach is conservative, Alaska Airlines successfully and safely operated after the 1989 Mt. Redoubt eruption and other volcanic eruptions.

2 USE FACTS AND DATA

Alaska Airlines has selected several information sources, uses Volcanic Ash Advisory Statements from the Volcanic Ash Advisory Centers, and is in direct communication with the Alaska Volcano Observatory. During a major eruption, Alaska Airlines will interview its own pilots as well as other operators' pilots about their observations on ash location. It has also established contacts on the ground that it can call for additional intelligence. These individuals include mayors and police officers in villages and towns near the airline's flight paths. If Alaska Airlines receives inconsistent information, it double-checks and continually validates what appears to be correct.

3 IDENTIFY THE LOCATION OF BOTH THE ASH AND CLEAR AREAS

Alaska Airlines tracks the ash by asking a number of questions:

- Where is the ash itself?
- Where is the volcanic source of the ash?
- What are the winds doing?
- What information is available from the volcanological community?
- What information do the reports from the pilots, selected contacts, and others contain?

Alaska Airlines then provides its pilots with information on where to fly and the reasons for not flying in certain areas.

4 STAY FOCUSED

Ed Haeseker, manager of air traffic control for Alaska Airlines, worked during the Mt. Redoubt event with Tom Cufley, then chief pilot at Alaska Airlines. They found that a small team worked better than a large team, especially if the chief pilot provided information directly to the flight crew in the early days of the event. In addition, a small team can travel more quickly to the site where the greatest assistance is needed and remain focused on the key task: identifying where the ash is.

ICAO ACTIVITIES ON VOLCANIC ASH

The International Civil Aviation Organization (ICAO) initiated a volcanic ash effort in 1982 after multiple volcanic ash encounters by 747 airplanes near Jakarta, Indonesia. The resulting organization, the Volcanic Ash Warnings Study Group, has worked since then to standardize the information provided to flight crews about volcanic eruptions.

In addition, ICAO formed the International Airways Volcano Watch (IAVW) in 1987. This effort formalized the international arrangements for monitoring and providing warnings to airplanes about volcanic ash in the atmosphere. ICAO annex III and the World Meteorological Organization (WMO) Technical Regulation C.3.1 introduced a requirement to disseminate information about volcanic ash to airplanes in the form of significant meteorological information (SIGMET) and notice to airmen (NOTAM).

The first WMO/ICAO workshop on volcanic ash hazards was held in Darwin, Australia, in 1995. Since then, a number of the designated Volcanic Ash Advisory Centers (VAAC) have come into full operation. A second workshop in Toulouse, France, in 1998 focused primarily on VAAC responsibilities and procedures

More information about ICAO activities related to volcanic ash avoidance and encounters is available in the organization's document titled "Operational Procedures And List Of Operational Contact Points Between Vulcanological Agencies, Meteorological Watch Offices And Area Control Centres," or from the address to the right.

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VOLCANO ERUPTION WARNING COLOR CODES

Eruption warnings are issued in the form of color-coded information releases. Over the past 10 years, this method has proved to be effective for alerting the aviation community to potential volcanic ash.

ALERT COLOR CODE	VOLCANO ACTIVITY STATUS
Red	Volcanic eruption in progress. Ash plume or cloud reported above FL 250.
	Volcano dangerous, eruption likely, with ash plume or cloud expected to rise above FL 250.
Orange	Volcanic eruption in progress but ash plume or cloud not reaching nor expected to reach FL 250.
	Volcano dangerous, eruption likely, but ash plume or cloud not expected to reach FL 250.
Yellow	Volcano known to be active from time to time and volcanic activity has recently increased significantly, volcano not currently considered dangerous but caution should be exercised.
	After an eruption, i.e., change in alert to yellow from red or orange, volcanic activity has decreased significantly, volcano not currently considered dangerous but caution should be exercised.
Green	Volcanic activity considered to have ceased and volcano reverted to its normal state.

The responsible volcanological agency in the region where the volcano erupts should provide the area control center with (1) the color code for the level of alert indicating the status of activity of the volcano and (2) any change from a previous status of activity (e.g., "Red alert following yellow" or "Green alert following orange"). Source: ICAO—International Airways Volcano Watch.

VOLCANIC ASH RESOURCES

Volcanic ash resources are available worldwide and in many forms accessible to operators. Volcano observatories are located throughout the world, including the Alaska Volcano Observatory for information about North Pacific volcanoes and the Nordic Volcanological Institute for information about volcanic activity that could affect North Atlantic routes. Many of these observatories provide immediate eruption and volcanic ash updates to operators by fax, e-mail, telephone, or teletype. Information is also available on the World Wide Web at the following sites:

The Smithsonian National Museum of Natural History Global Volcanism Program: http://www.volcano.si.edu/gvp/

The U.S. Geological Survey: http://www.usgs.gov/themes/volcano.html

The Airline Dispatcher Federation (a detailed paper about volcanic ash written by Leonard J. Salinas of United Airlines, Chicago, Illinois): http://www.dispatcher.org/library/VolcanicAsh.htm

The Committee on Earth Observation Satellites Disaster Management Support Project/Volcanic Hazards Management (an effort by the U.S. National Oceanic and Atmospheric Administration; information on tracking ash clouds):

The Istituto Internazionale di Vulcanologia (a summary of volcanoes in Italy): http://www.iiv.ct.cnr.it/

The Nordic Volcanological Institute (information about volcanoes in and around Iceland): http://www.norvol.hi.is/index.html

The Volcanological Society of Japan (eruption information, live images of Japanese volcanoes, and other information): http://hakone.eri.u-tokyo.ac.jp/kazan/VSJ1E.html

Current Eruptions in Japan (additional current information): http://hakone.eri.u-tokyo.ac.jp/vrc/erup/erup.html

Other sources of information include the following:

The Boeing Company, *Airliner* magazine ("Vulcan's Blast," April-June 1990, and "Vulcan Returns: Volcanic Ash Effects on Airplanes Revisited," October-December 1991) and video ("Volcanic Ash Avoidance: Flight Crew Briefing").

U.S. Federal Aviation Administration, *Aviation Safety Journal* reprint ("The Volcano Threat to Aviation Safety").

Casadevall, T. J., ed. 1994. The First International Symposium on Volcanic Ash and Aviation Safety: Proceedings Volume: U.S. Geological Survey Bulletin 2047.

Casadevall, T. J., T. B. Thompson, and T. Fox. 1999. World map of volcanoes and principal air navigation features. U.S. Geological Survey Map I-2700.

THE PRIMARY SOURCE FOR ANY VOLCANIC ERUPTION AND ASH INFORMATION IS A VOLCANIC ASH ADVISORY CENTER. THE OTHER SOURCES LISTED HERE MAY OFFER MORE DETAILED INFORMATION ON A PARTICULAR ERUPTION. – ED.

Source: Boeing Volcanic Ash Advice (May 2010)

9. Airbus Volcanic Ash Advice

Airbus also published a similar paper to Boeing. Once again I have not reproduced the entire document but have selected appropriate sections.

There are some interesting points such as the recommendation that if forced to take off from an ash covered runway it should be treated in the same way as a contaminated runway in terms of aircraft performance

The following is taken directly from the paper:

In its Flight Operations Briefing Notes (FOBN) Airbus addresses the issue of operations in or near airspace contaminated with volcanic ash as follows.

This FOBN is part of a set of notes that provide an overview of the applicable standards, flying techniques and best practices, operational and human factors, suggested company prevention strategies and personal lines-of-defence related to major threats and hazards to flight operations safety. In addition this Briefing Leaflet contains the procedures revisions sent by Airbus in its Operators Information Telex (OIT) of 22 April 2010 following the eruption of Mt Eyjafjallajökull and subsequent closure of parts of European airspace.

<u>Introduction</u>

Flying through an ash cloud should be avoided by all means due to the extreme hazard for the aircraft. Experience has shown that damage can occur to aircraft surfaces, windshields and power plants. Aircraft ventilation, hydraulic, electronic and air data systems can also be contaminated. Partial or total engine power loss events caused by volcanic ash ingestion, while not frequent,
are major safety concerns. Simultaneous power loss in all engines has occurred, where the crew succeeded in restarting the engines, after application of operational procedures. As weather radar is not effective in detecting volcanic ash clouds, crews must be informed by other means of the potential or
effective presence of ash clouds on air routes. The aim of this Flight Operational Briefing Note is to provide information about volcanic ash effects on aircraft, and operational guidelines, in order to help preventing a volcanic ash cloud encounter.

Detection

Night and IMC flights are more favourable to ash cloud encounter, as dust clouds cannot be detected by airborne weather radars
(see Flight Operations Briefing Note Optimum Use of the Weather Radar).
Low concentration of volcanic ash may not be detected by the crew.

Presence of the following elements can help recognize a volcanic ash cloud encounter:

Acrid odour similar to electrical smoke

Rapid onset of engine problems

St. Elmo’s fire

Bright white/orange glow appearing in the engine inlets

Dust and smell in the cockpit

Outside darkness

Airspeed fluctuation

Landing lights casting sharp, distinct, shadows.

Consequences

Recent (within hours of eruption) volcanic clouds contain concentration of ash that can cause complete loss of engine power within one minute.

Engines operating at high thrust setting are more prone to suffer from ash deposit build up in the turbine chamber, as internal engine temperature may exceed volcanic-glass material melting point.

In service events show that even low concentration of volcanic ash can cause expensive damage.

Prevention Strategies and Operational Recommendations

Prevention strategies and lines-of-defence should be developed to address the risk of volcanic ash encounter.

<u>Flight Crew Awareness</u>

The following communication links can be used to obtain timely up-dated information on the volcano eruptive activity:

Volcanic Watch Function The Volcanic Watch Function consists in collecting, compiling, processing and up-dating detailed information regarding the
active and pre-eruptive volcanoes likely to affect the company area of operation.
This function can be assigned to the following departments, as applicable:
Flight Operations

Flight Safety Office. So as to assess the volcanic threat for each company route the following information sources and communication links can be used:

Air Information Service (AIS), for active NOTAM's Meteorological Watch Offices, Airport Offices and Regional Area Forecast Centers for active SIGMET's
On-site Aviation Authorities for additional information, such as data and maps related to the ash cloud observed and forecasted extension.
International organisations such as ICAO, IATA, IFALPA Inter-airlines agreements

Company outside stations.
The Volcanic Watch Function provides synthesized and up-dated information to all operational departments (Flight Operations,
Dispatch, Outside Stations etc) as follows:
Map(s) of active volcanoes and hazard areas
Relevant data to be included in the Pre-departure Area Briefing and Route Forecast

Specific procedures for en-route information up-dating (e.g. HF company frequency, ACARS, en route FIS and ATC).

Flight Crews Pre-flight Briefing and Documentation

All flight crews, operating a flight to/from/through an area likely to be affected by volcanic activity, should be provided with the following information and documents on a systematic basis

I. F .A . L .P .A
The Global Voice of Pilots Briefing Leaflet
Aircraft Design & Operation

Map(s) of active volcanoes and hazards area
ICAO special air-report of volcanic activity form (model VAR).
As dictated by current volcanic eruptive activity:
Last active NOTAM's,
Last active SIGMET's
Data or map(s) reflecting the observed ash cloud location, extension and/or trajectory forecast
Upper wind analysis and forecast at selected flight levels
Satellite images.
En-route Information Up-dating
The activity of an erupting volcano usually features series of eruptions sometimes separated by only a few hours. En-route updating
of the pre-flight briefing information is therefore of paramount importance to minimize the potential for volcanic ash cloud
encounter. The following communication links can be used to obtain timely up-dated information on the volcano eruptive activity:
Company FLIGHT WATCH frequency
ACARS
VOLMET broadcasts (SIGMETs)
FLIGHT information Service (SIGMET's).
Detailed update should be solicited and obtained regarding the following aspects:
Notification of new eruption(s)
Location, height, extension and forecasted trajectory of volcanic ash cloud.
Notification of airspace restrictions (closure of air routes, activation of contingency routes).

Flight Crew Training

So as to build-up a flight crew mind-set regarding the volcanic ash threat, volcanic ash awareness should be addressed as part of the flight crew initial and recurrent training, as follows:
Understanding volcanic ash and volcanic ash clouds, as any other weather systems, and their threat to jet aircraft operation
Highlighting the published procedures related to volcanic ash cloud avoidance, recognition of encounter and encounter recovery.

Placing a particular attention, during the simulator session related to the ALL ENGINE FLAME OUT procedure, to the slow engine acceleration characteristics to be expected upon engine restart after volcanic ash ingestion
Stressing the instrumental contribution of flight crew air reports and the use of the ICAO special air-report of volcanic activity form (model VAR).

Operational Recommendations

Flight crew operational procedures are published in respective aircraft manufacturers' documentation. Nevertheless, the following actions have been identified as being typical recommendations in case of volcanic ash encounter.

On the Ground

Operation from or to airports contaminated with volcanic ash should be avoided, if possible. Should volcanic ash exposure be unavoidable, the following recommendations and procedures should be applied:

Whenever an aircraft is planned to stay over at an airport contaminated with volcanic ash, engine inlet covers as well as other protective covers and plugs should be installed

Have the aircraft cleaned before departure
− Ash may contaminate the lubricated parts, penetrate the seals or enter the engines gas path, air conditioning system, air data probes and other aircraft orifices.

Dry crank the engines
− Before starting the engines, ventilate them by dry cranking at maximum motoring speed for two minutes.

Do not use windshield wipers for ash dust removal.

Restrict ground use of APU to engine starts

− Do not use APU for air conditioning and electrical power supply. Use external pneumatic supply for starting the engines, if it is available.

Keep bleed valves closed for taxiing

Aircraft Design & Operation

Taxi with minimum thrust

− Advance the levers smoothly to the minimum required for breakaway. Avoid making sharp or high-speed turns. All engines taxi should be preferred, to minimize thrust level on each engine.
Allow ash and dust (if present) to settle on runway before starting the takeoff roll
Use the rolling takeoff technique if possible
Consider the runway as wet (for dry ash) or contaminated with slush (wet ash) for takeoff/landing perf calculation
− Braking efficiency may be degraded by the layer of ash on the runway.

In Flight

If a volcanic eruption is reported while in flight, the flight should remain well clear of the affected area and, if possible stay on the upwind side of the volcanic dust (typically 20 NM upwind of the erupting volcano).
Should the volcanic ash encounter be unavoidable, the following general recommendations apply:

Make a 180deg turn
− Pilots should exit the cloud as quick as possible. Generally, a 180deg turn will result in the fastest cloud exit, due to the possible extension of such clouds over hundreds of nautical miles

Decrease thrust
− High thrust settings increase the risk of glass particles melting and associated ash deposit build-up in the turbine chamber. Thrust should therefore be decreased, if conditions permit.

Don the crew oxygen masks (100%)

Report to ATC
− Any observation of volcanic activity or any encounter with a volcanic ash cloud should be reported by immediate radio transmission or/and by filling the ICAO special air-report of volcanic activity form (model VAR).

Increase bleed demand (wing and engine anti-ice ON)
− Increasing the bleed demand aims at increasing the fuel/air ratio in the engine combustor to limit the possibility of an engine surge and/or flameout.

Start the APU

− The APU GEN will be available to supply the electrical network in case of engine flameout.

Monitor engine parameters and airspeed indications
− The crew should be aware that volcanic ash may render airspeed indications unreliable.

Summary of Key Points

It is important to note the following key points:

Airlines should provide exhaustive and updated information to crews flying in regions likely to be affected by volcano activity

Flight crews should get updates of pre-flight information when en route

Flight Crews should report to the ATC any observation of volcanic activity or any encounter with a volcanic ash cloud

If encounter with volcanic ash cannot be avoided, the flight crew should immediately apply the procedure recommended by the aircraft manufacturers' documentation.

Source: Airbus Volcanic Ash Advice (May2010

10. Worldwide aviation response and the difference between the USA and European responses

It is clear that the Eyjafjallajökull volcanic eruptions in April 2010 highlighted the effect of Volcanic Ash on Aviation in an unprecedented way. The dramatic effect of closing the airspace and the huge cost implications brought to the fore the current inadequacies of the European authorities.

Below is a short excerpt from an article in Flight International dated 5 Oct 2011 by the respected aviation journalist David Learmount.

European volcanic upset could have been avoided
By ***David Learmount***

European air transport need not have been immobilised by the Eyjafjallajökull volcanic eruptions in April because the knowledge of how to deal safely with the conditions existed, a conference on the subject at the Keilir Aviation Academy, Keflavik, Iceland has heard.

Volcanologist Dr Haraldur Sigurdsson revealed that the Eyjafjallajökull eruption was minuscule on a historic scale, even in the past 100 years, and that much more powerful events were just a matter of time.
The Conference on Eyjafjallajökull and Aviation learned that existing knowledge, properly employed, could have prevented the massive losses that airlines and the European economy suffered as a result of the grounding.

At the time of the eruptions the necessary knowledge and expertise was dispersed all over the world among individual volcanologists, meteorologists, engine and airframe manufacturers, and airlines. It had not been assembled, by the International Civil Aviation Organisation - nor any other organisation - with a view to creating a volcanic ash contingency plan for an eruption such as Eyjafjallajökull's.

Certainly no-one had shared this dispersed expertise with regulators or national aviation authorities, except on a local basis by countries with regular volcanic activity within their sovereign airspace.
But none of the latter had reason to anticipate an ash cloud that would affect a large, high-density traffic area comparable with that of northern and central Europe. Their experiences had resulted in the ICAO advice prevailing at the time of the Eyjafjallajökull eruption, which was to avoid all volcanic ash on the grounds that it was almost always possible to re-route aircraft around it, under it or over it.

The International Air Transport Association's director for safety and operations Gunther Matschnigg characterised Europe's April reaction to Eyjafjallajökull as "risk-averse, not risk management". He advised learning from airline standard operating procedures that had been tested over time.

Essentially this is the major difference between the European and US approaches to Volcanic Ash (from an aviation point of view)

The US uses a “Risk Management” approach. Alaskan Airways are the leaders in this field having had years of experience of operating with the Volcanic Ash risk in their route structure. This has not led to complacency but rather to an approach comprising a strict set of guidelines for air and ground crews as well as regular training.

The European approach (certainly prior to Eyjafjallajökull) was one of “Risk Aversion”. Whilst the basic approach will always be that of avoidance it may well be possible to have a safe approach without the blanket shutdown of a huge section of European Airspace.

A lot of progress has been made and there is now a strong movement towards shifting the responsibility to the Operator. This will allow the Airlines themselves to make the decision (in conjunction with the best available worldwide information.)

11. Future Developments

There are some exciting developments in the pipeline.

Some years ago a scientist Dr Fred Prata developed the technology to detect volcanic ash whilst airborne. The idea never came to fruition due to lack of funding but after Ejyafjallajokull this has changed.

Below is an article explaining the developmental plans:

EasyJet is to test a gadget identifying the location and density of volcanic ash clouds. Will it mean an end to travel chaos caused by volcanic eruptions?

Following the travel chaos which enveloped Europe in April as the eruption of Icelandic volcano Ejyafjallajokull caused widespread closure of airspace, it's hoped that a new gadget may be able to prevent a repetition of the disruption. The budget airline easyJet announced on 4 June 2010 that it would be trialling the new technology and that the first test flights will take place within two months (easyJet Press Release, corporate.easyjet.com, 4 June 2010).

The fact that volcanic ash causes potentially catastrophic damage to aircraft engines at certain densities in not in dispute. The decision to close airspace in April has, however, been widely criticised by airline operators as being an over-reaction – an assertion supported by the subsequent revision of guidelines for flying as further pulses of volcanic ash reached European airspace later in April and May (*Telegraph*, "Volcanic Ash: Ryanair Boss Michael O'Leary in Withering Attack on Met Office, 1 June 2010).

The Airborne Volcanic Object Identifier and Detector (AVOID)

The technology being piloted by easyJet is known as the Airborne Volcanic Object Identifier and Detector, or AVOID. In essence it is a radar system but one designed to identify volcanic ash rather than weather patterns. Infrared technology will be used to identify areas where volcanic (or other) ash is present and to measure its density, allowing the pilots to alter their flight path of the cloud is determined to be too dense for safety.

The infrared cameras which record the data will locate ash hazards at up to 100km ahead of a plane, and over a significant range of altitude (easyJet press release). In addition to ash detection, the so-called ‘ashcam’ can identify atmospheric hazards such as sarin gas, giving it a potentially wider defensive application (*The Age*, “Discarded Scientists Fail to Grasp CSIRO Logic” by Jo Chandler, 11 February 2006, theage.com.au).

Although this will be its first commercial outing, the AVOID technology has not been developed as a response to this year’s travel problems. The brainchild of Dr Fred Prata, the idea was first floated some years ago while Dr Prata was working in Australia, but was not developed until he took it with him to the Norwegian Institute for Air Research in 2006.

The adoption of the ashcam was described by easyJet’s Chief Executive Andy Harrison as ‘the silver bullet that will make ash disruption history’. The technology was also welcomed by the Civil Aviation Authority, whose Chief Executive said that the CAA would do all that was possible to facilitate the development of such innovations (easyJet press release).

Source: New Technology May Prevent Future Ash Cloud Air Travel Chaos
http://www.suite101.com/content/new-technology-may-prevent-future-ash-cloud-air-travel-chaos-a245303#ixzz19aP5KlEw

This “ashcam” technology has been described by airline bosses as “the silver bullet”. However in reality a more comprehensive approach will be needed using all the available knowledge to forecast volcanic eruptions and then to use all the principles that have been developed to avoid ash encounters. The “ashcam” will in all likelihood be used as a last resort for the foreseeable future.

There have also been advances in satellite imaging which will make it easier to determine the areas of “less dense” ash cloud.

There have also been advances in the use of mathematical modelling using the latest technological advances.

A combination of all these methods along with efficient actions by the relevant CAA’s, well-informed operators and well trained crews will in all reality be the way forward.

12. Volcanoes in Africa

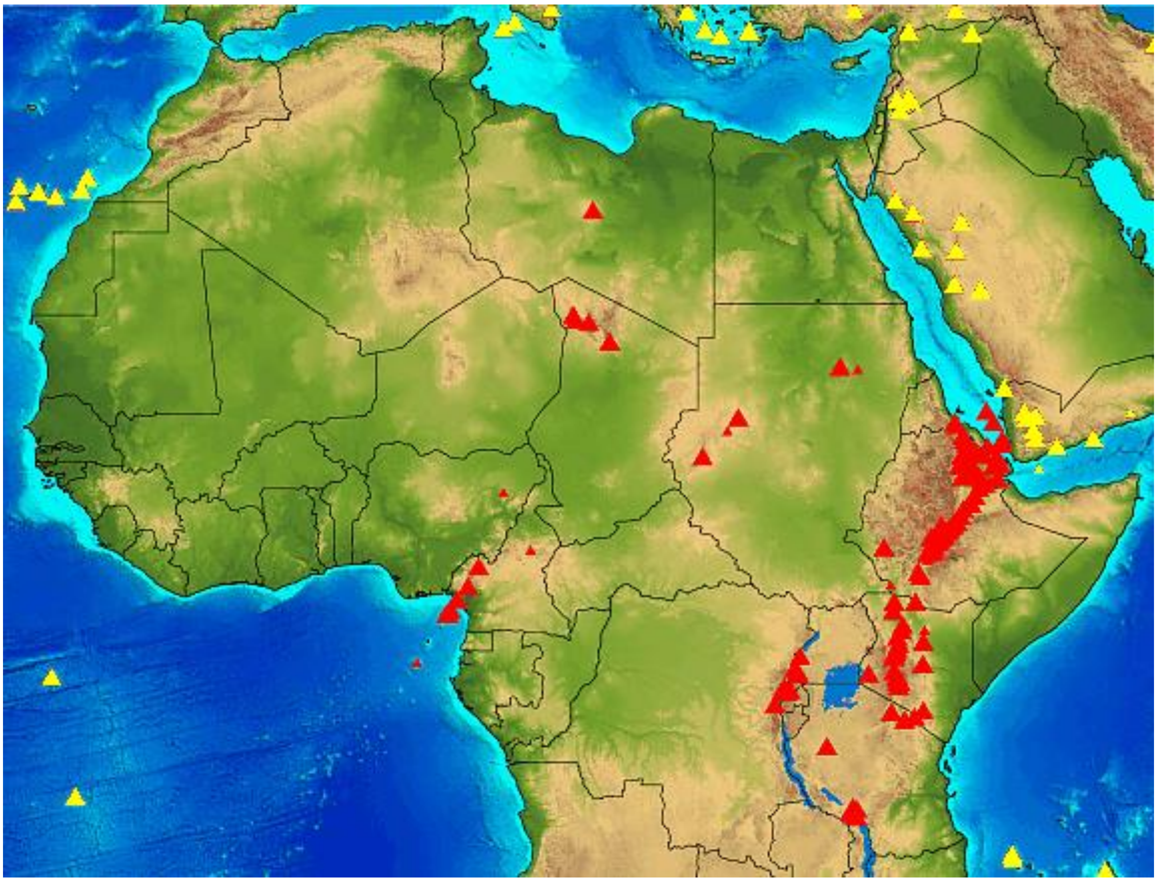
It may come as a surprise to some crews that there many volcanoes in Africa.

According to The Global Volcanism Program database for Volcanoes of Africa and the Red Sea currently contains 141 Holocene volcanoes and 3 Pleistocene volcanoes with thermal activity,. "Volcano Type" and "Volcano Status" designations can be found on the Volcano Data Criteria page on the website:

www.volcano.si.edu

(Source: The Smithsonian National Museum for Natural History.)

A volcano is considered active if it has erupted in Holocene times i.e. from 12000 years ago to the present day. It is considered Pleistocene if it has erupted from 2,588,000 to 12,000 years ago.



Large red triangles show volcanoes with known or inferred Holocene eruptions; small red triangles mark volcanoes with possible, but uncertain Holocene eruptions or Pleistocene volcanoes with major thermal activity. Yellow triangles distinguish volcanoes of other regions

Most African volcanoes result from hotspots, the rifting in East Africa, or a combination of the two. The East African rift, one of the world's most dramatic extensional structures, has produced the continent's highest and lowest volcanoes, ranging from the massive Kilimanjaro to vents in Ethiopia's Danakil Depression that lie below sea level. Two neighbouring volcanoes in Zaire's (today's Democratic Republic of the Congo) Virunga National Park, Nyamuragira and Nyiragongo, are responsible for nearly two-fifths of Africa's historical eruptions.

Mount Cameroon, one of Africa's largest volcanoes, rises above the coast of west Cameroon. Historical activity, the most frequent of west African volcanoes, was first observed in the 5th century BC by the Carthaginian navigator Hannon. During historical time, moderate explosive and effusive eruptions have occurred from both summit and flank vents.

Nyiragongo as seen from Goma, Congo (DRC)in 2002.
Photo: http://scienceblogs.com/eruptions/

Ol Doinyo Lengai is a volcano located in the north of Tanzania – March 2008
Photo: http://www.flickr.com/

It is unlikely that the monitoring of volcanic activity in Africa will be up to the same standard of that of the rest of the world

According to the VAAC (Volcanic Ash Advisory Center) Map the whole of Africa falls under Toulouse area of responsibility

Website : http://meteo.fr/vaac/eliens.html

Some of the more active volcanoes are monitored visually but there is still some doubt as to whether this information is transmitted quickly and efficiently to aircrews in the form of NOTAMS or ASHTAM S (each country is responsible for its own NOTAMS)

It must thus be considered as a threat for crews flying on these routes especially at night. They must therefore be well informed and well trained in all aspects of volcanic ash in order to minimize this threat.

This is the responsibility of the Operator.

13. Conclusion

There can be no doubt that the Eyjafjallajökull eruption was a watershed in the history of volcanic ash. There had been major incidents of volcanic ash encounters in aviation before but the massive closure of airspace was certainly unprecedented. The enormous costs incurred (both directly and indirectly) as well as the huge inconvenience caused to the broader public resulted in a massive media event. The fact that the European authorities acted in a heavy handed manner by enforcing a blanket airspace closure attracted huge criticism.

In the year following the event much has been written about how things could have been better managed. There have been conferences and paper's presented recommending better measurement techniques and management systems. Engine manufacturers are looking at the possibility of certifying their engines for acceptable levels of volcanic ash.

The International Volcanic Ash Task Force established after the ash cloud event by the International Civil Aviation Organization is scheduled to report in May 2011.

It is too early to predict what their recommendation will be but it seems likely that there will be a shift to the "risk management" style whereby the best information is made readily available to the operator or airline and the choice to fly is left up to them. If this is the case then the responsibility will become that of the operator or airline to have training programs in place. SA Airways was affected by the Eyjafjallajökull eruption and the recurrent training program which followed incorporated volcanic ash training for their crews. Short/regional range crews were also trained as many African routes overfly volcanic regions.

As further developments take place the training programs will also need to be adjusted accordingly to counteract the threat of volcanic ash.

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