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# Clearing the Air

Reconsidering how to respond to ash clouds.

BY THOMAS WITHINGTON

April 14, 2010, will be remembered in aviation history as the day that European airspace stood still. Not since the terrorist attacks of Sept. 11, 2001, had European and trans-Atlantic aviation witnessed so much disruption, triggered this time by the eruption of the Eyjafjallajökull volcano in

Iceland, which caused the progressive shutdown of airspace across the continent.

More than 20 nations emptied their skies and more than 300 airports closed, leading to the cancellation of around 100,000 flights and the grounding of up to 10 million passengers until Europe's airspace was reopened beginning April

20. Air travel was again disrupted, with delays and re-routing, during the weekend of May 8–9. Spanish air traffic control was forced to close seven airports on May 9, although they were reopened soon afterward, but as late as May 17, the U.K. Civil Aviation Authority imposed a no-fly zone comprising London Heathrow, London Gatwick and London City airports, among others.

No sooner had the skies been closed and aircraft grounded than the assignment of blame began to be discussed in the media. Seemingly oblivious to the danger that volcanic ash can present to airliners, angry passengers waiting in overcrowded terminals voiced their belief to television reporters that local air traffic control authorities, including Eurocontrol, had over-reacted.

### Contingency Planning

However, said Bo Redeborn, director of cooperative network design at Eurocontrol in Brussels, Belgium, “Our contingency planning was

not designed to cope with this kind of situation, where you have to close such a large section of airspace. We are ready to deal with crises, we are ready to deal with contingencies, but we were not ready to deal with the kind of situation that occurred in April.”

The airline industry also was quick to add its voice, noting the effect that the disruption was having on its bottom line. Giovanni Bisignani, director general and CEO of the International Air Transport Association (IATA), on April 19 said that the airline industry was losing \$250 million each day that the airspace remained closed — IATA later calculated that the industry had lost \$1.8 billion while airliners were grounded.

Was the decision to close almost all of Europe’s airspace that weekend an over-reaction? William R. Voss, president and CEO of Flight Safety Foundation, believes that, based on industry knowledge at the time, it was not. “We could have found ourselves in a situation, had appropriate action not been taken, of trawling the North Atlantic for flight recorders,” Voss said. “The fact remains that there was a major volcanic eruption in a high-density traffic area.”

The threat of ash to airliners is very real. On Dec. 15, 1989, the pilots of a Boeing 747-400 operated by KLM Royal Dutch Airlines made an emergency landing at Anchorage (Alaska, U.S.) International Airport when compressor stalls occurred in all four engines after ingesting volcanic ash from Mount Redoubt. During the 2010 Icelandic eruption, four Boeing F-18C/D aircraft of the *Ilmavoimat* (Finnish Air Force) experienced damage to their engines from ash ingestion.

### Clear Danger

As the event involving the KLM 747 illustrates, volcanic ash poses a clear and present danger to aircraft. It is almost impossible for a flight crew to see the ash because it is usually too fine to be observed by on-board weather radar, giving the crew no way of knowing if they are flying through a dust cloud. Once in the ash cloud, the aircraft’s engines ingest the fine particles, which melt into a sticky glass-like substance. This substance can disrupt compressor and turbine stator and blade

The fine ash went up and stayed up (above), spreading to the east and south over most of Europe (below).



**The eruption of Eyjafjallajökull has provided the European aviation community ... with a wealth of experience.**

aerodynamics, and block the blades' cooling holes, causing a corresponding rise in temperature and the risk that the engine will overheat. As if this were not serious enough, the ash particles can be abrasive, causing further damage to engine nozzles and fan blades. Could jet engines be designed to withstand the rigors of volcanic ash? Perhaps, but the design and manufacturing costs might become exorbitant. (See "Very Fine Ash.")

In Europe, eruptions of Eyjafjallajökull's magnitude are mercifully rare, with Italy and Iceland the only two nations on the continent that are home to regular major volcanic activity. But why was the disruption in Europe so acute compared with the effect on commercial air travel of eruptions in the Pacific region?

The answer is that Europe's airspace is not only extremely crowded but is also a chokepoint in terms of the global route network. "So much was shut down by this volcano," said Geoffrey Lipman, special adviser to the United Nations World Tourism Organization secretary general, "and this volcano was on the heaviest air routes in the world. There have been volcano impacts before, but in markets with much thinner traffic, and where the distances between destinations have been huge. When you close Europe, you close for a certain time all the rest of the routes in the world."

### **A Lesson**

Nevertheless, the eruption of Eyjafjallajökull has provided the European aviation community — including airlines, aircraft manufacturers, air traffic service providers and regulatory authorities — with a wealth of experience about how to approach a similar, or even larger, disruption in the future.

"The aviation industry, and aviation authorities, were caught sleeping, as there was great uncertainty in how to deal with the issue at the scientific, political, business and consumer levels," said Icelandair's CEO Birkir Holm Gudnason.

Gudnason noted that it is important for airlines to be prepared for such an eventuality.

"We were aware of the possibility that an eruption could cause a great disruption in aviation, and we had studied models showing

probable distribution of an ash cloud," he said. "We also had plans in place to deal with a crisis, and we found our staff very quick to respond to this situation."

This planning enabled Icelandair to continue operations despite the disruption caused by the airspace closure.

"We made the decision to maintain our scheduled operation through the eruption and, as airspace closed down, we made regular schedule changes," Gudnason said. "For 10 days, we moved our hub from Iceland to Glasgow, Scotland. Throughout the days of disruption, we were able to operate 80 percent of our schedule and were never grounded."

One way to determine where the ash is positioned, and its density, could be found through increasingly sophisticated air sampling equipment that can provide an accurate gauge of the extent of dust contamination in a section of airspace. The Climate and Atmosphere Department of the Norwegian Institute for Air Research has developed a system called the Aircraft-Mounted Passive Infrared Volcanic Ash Detector, or Avoid. Avoid detects areas of particularly heavy ash concentration to allow aircraft to fly around them. However, the ability to see the ash is not the only capability that may make it safer and easier to continue operations during a future eruption of a similar magnitude.

### **Engine Ash Tolerance**

Obtaining more detailed information from engine manufacturers about the ash tolerance of their powerplants could enable air traffic authorities to draft more accurate regulations to specify which sectors of airspace are safe to fly through, based on their ash density. While some sections may be too ash-saturated, other less-affected sectors could remain open. This would help to move away from a blanket grounding of all flights and to a more targeted closure of airspace in the most seriously affected areas.

Moreover, the ability to predict volcanic eruptions is improving thanks to advances in volcanology and the global seismic monitoring network. "To predict future eruptions is not so

## Very Fine Ash

The root of the troubles produced by the eruption of the *Eyjafjallajökull* volcano in Iceland was the very fine ash that persisted in the atmosphere and drifted in an unusual direction, according to Ed Pooley, principal consultant for The Air Safety Consultancy.

Speaking at Flight Safety Foundation's International Air Safety Seminar in Milan, Italy, in November, Pooley said the consequences of the ash dispersal were exacerbated by an International Civil Aviation Organization (ICAO) standard created for the much larger ash particles and higher ash densities associated with eruptions around the Pacific Rim, conditions unlike those that were experienced over European air routes this past spring.

From a volcanology point of view, the Icelandic eruption was a modest affair: "One-tenth of Mount St. Helens and one-100th of Mount Pinatubo," Pooley said, "not powerful enough to break through the tropopause," the upper boundary of the troposphere, the lowest region of Earth's atmosphere. "It was not going to circle the world like Mount Pinatubo. ... With the prevailing weather we have in this part of the world, normally that ash is going off to the east-northeast and maybe the northeast." This time the drift was southeast.

The combination of weather and ash size meant that the ash stayed around: "Gravity will make sure the big stuff comes to earth. What you're left with is much smaller stuff," Pooley said, "and if the weather situation is stable, you're going to get the ash in layers and it's going to persist ... There [also] was no rain to wash it out."

Responding to ash encounters in the Pacific Rim, the civil aviation community studied the threat, and "in 2001, we had the issue of the ICAO Document 9691 [*Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds*], which is a very good manual with a lot of the solid detail," Pooley said.

"ICAO [saw] ash as an air traffic management problem. When this happened in Europe, everybody was told it was a rule from ICAO that you had to stay clear of all volcanic ash. Actually, it was a recommendation," similar to the recommendation to

avoid low-level wind shear.

Another shortcoming of the ICAO guidance is its failure to specify what level of ash is dangerous. "That was never addressed by ICAO, even though the expert groups that have been meeting for the last decade have been saying we need to define what is the limit of volcanic ash," he said. And

while the advice was to avoid ash clouds, "frankly, nobody really knows what an ash cloud is; nobody has actually defined it."

Ash densities encountered also were not on a scale previously experienced: "The ash density in the 1980s events — where engines were compromised [over] Alaska and Indonesia — was 2 million micrograms per cubic meter," he said. In ash clouds over Europe this past spring, "there never was more than about 300 [micrograms per cubic meter]."

And the particles were quite fine. "Volcanic ash is pretty large," starting in size at 2,000 microns — a micron is 1 millionth of a meter — and smaller. Fine ash is defined as less than 50 microns, Pooley said, "but even that [size] is going to start dropping out pretty quickly... The majority of the [particle sizes] recorded [in the Icelandic event] was around about 3 microns.

"Most of what comes out of most volcanoes ... is silicates, volcanic glass ... with melting temperatures lower than the temperatures reached in the hottest parts of modern high-bypass turbine engines ... probably about 800 to 1,200 degrees C (about 1,470 to 2,200 degrees F)," Pooley said. "At cruise thrust, the temperature in the turbine is about 1,650 degrees C (about 3,000 degrees F), well above the melting range. As this stuff passes through [the engine], it is quite likely to melt. It depends on the quantity and a lot of other things, but [when it melts] it's going to cool onto some of the surfaces that are critical to the function of the engine.

"But eventually, if that part of the engine is cooled, it's going to largely drop off. That's because it's settling on the surface in a crystalline form, which is less likely to adhere to the surface at a cooler temperature. So this is why the crew responses are important — if they're quick enough to get back to idle thrust or if the engine is run down, then the effect will be very similar." The severe damage incurred by a KLM Royal Dutch Airlines Boeing 747-400 after ingesting ash from Mount Redoubt in Alaska in 1989 happened when the crew "tried to power out of an ash cloud — which is the very last thing you want to do," he said.

The nature of the threat presented by this ash chemistry remains unknown. "There is some work to be done by the scientists, and there's a recognition that we have to have a system which can cope with the amount of hazard that very fine ash represents when it is up to almost a week old ... still there in densities which are measurable," he said. "Whether those measurable densities matter is something that we have to resolve."

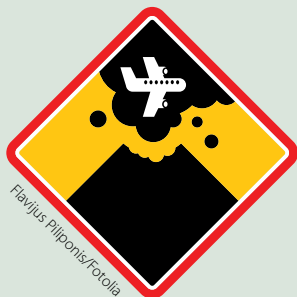
In the end, Pooley said, "it's very important to recognize that the ICAO system we had to guide us did not take account of the nature of the risk that we faced in Europe." Further, "I think it's very important to recognize the quite ridiculous burden placed on the air navigation service providers, to ensure that aircraft avoid this sort of ash hazard. That is unrealistic."

— J.A. Donoghue

Pooley



Wayne Rosenkrans



difficult now because observation installations exist on many volcanoes,” said Evgeny Gordeev, director of the Institute of Volcanology and Seismology at the Russian Academy of Sciences. However, he cautioned, “estimates of the duration, maximum power and the size of the volcano eruption are not so easy.”

Anticipating a volcano’s behavior is a particularly challenging exercise and contributed to the uncertainty about how long the flight bans would remain in place in Europe after the airspace closures began on April 14.

“The biggest challenge is in modeling the level of volcanic activity in Iceland, as this

was largely reliant on the very difficult task of compiling accurate and continuous observations of the volcanic eruption by the Iceland Meteorological Office,” said Ian Lisk, volcanic ash coordination program manager at the U.K. Meteorological Office. “The other two major challenges relate to how the information being provided is interpreted and then used by a variety of stakeholders with differing levels of understanding, and availability of standardized, real-time, high-quality volcanic ash observational data.”

Lisk emphasized the importance of ascertaining what levels of ash are safe to fly through



as one of the important lessons resulting from the eruption in Iceland.

“The U.K. Meteorological Office is heavily involved in initiatives to better define international volcanic ash requirements,” Lisk said, adding that efforts to improve the clarity of information are moving forward. “There has been an enhancement of volcano-observing capabilities [following the eruption] in Iceland in collaboration with the Icelandic Meteorological Office, British Geological Survey and the U.K. National Centre of Atmospheric Science.”

### Density Standards

“If ever you wanted a lesson on how important standards are, even if they are not always precise, I think we have it here,” said Flight Safety Foundation’s Voss. “The absence of any standard levels of ash concentration in which it was safe or unsafe to fly left everyone in confusion. It’s not as if that density has to be worked out to the third or fourth decimal point. If we had just been able to work out a rough figure, there could have been spectacular decreases in the size of the no-fly zones.”

Eurocontrol is also looking at its own processes for coping with a similar future situation. “Everybody needs to deal with this in a more harmonious way,” Redeborn said. “The fact that each state takes a decision on how they deal with such a situation, how they close airspace, how they transmit information, makes it absolutely impossible for airlines and the public to deal with. Everybody should use information from the same source, and apply an agreed-on set of harmonized criteria.”

Problems with information flow also were noted by the airport operators. Henrik Littorin, head of public affairs at Swedavia, Sweden’s airport operator, recalls that “the information provided to air traffic control authorities, and to airlines, about which airspace was open and which was closed seems to have been adequate, but the information provided to passengers was lacking a bit in the first days of the eruption.”

Redeborn noted that Eurocontrol’s plans for dealing with volcanic ash clouds have been revised and continue to be revised, along with

the guidelines used by the International Civil Aviation Organization. Moreover, Redeborn believes that it is vital to have “detailed information regarding every engine in the air and the level of ash that engine can cope with. It also would have been useful to know a limit in terms of ash concentration that it is safe to fly in.”

### Coordinated Messages

“It’s easy to say that airspace should have been opened up quicker,” said Lipman of the World Tourism Organization, “but if you are the person with the finger on the button, and the consequence of error could be a plane crash, you would want to take every precaution possible.” Similarly, Swedavia’s Littorin cautioned against adopting a “one size fits all” approach to dealing with future eruptions of this scale in Europe: “All crises are unique. We’ve been very focused on plane crashes, terrorism and strikes. The lesson learned was that other crises tend to be very short, and then you have to cope with what happens afterward to get operations running. Furthermore, there is an absolute need for coordinated messages from different stakeholders.”

As a *force majeure*, volcanoes remind humans that there are natural forces more powerful than themselves. Whether the closure of Europe’s airspace was an overreaction seems to be a matter for the general media to fight out. However, the decision to close the airspace to prevent the loss of an aircraft, based on insufficient data and standards, defaulted to conservative standards. As Eurocontrol’s Redeborn noted, “There have been a number of situations involving aviation and ash, but no one has been killed, yet.”

*Thomas Withington is an aviation journalist in the United Kingdom. On the day that Europe’s airspace closed, he was on assignment at Freidrikshavn, Denmark, waiting to board a German naval helicopter to visit a French aircraft carrier. He recalls the helicopter crew’s difficulty in obtaining accurate and non-conflicting information about which national airspace around Denmark was closed, the severity of the ash cloud and how long flight restrictions were likely to remain in place.*

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