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Statement of
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Subcommittee on Space and Aeronautics
House Committee on Science and Technology

Madam Chair Giffords, Ranking member Olson, and Members of the Subcommittee, thank you for the opportunity to appear before you today. I am here to discuss NASA's past experiences related to the impact of volcanic ash on aircraft systems and operations, and some past and current research activities conducted by NASA and the aviation community which could be relevant to this issue.

Airlines thrive on reliability and predictability, as witnessed by their published "on-time departure" metrics. As we have recently learned, volcanic eruptions, and specifically, the dispersal ash clouds are beyond today's predictive capabilities, thus upsetting the reliability of airplane operations. In light of the great uncertainty of the location of volcanic ash, and the extreme hazard it presents to jet aircraft, airlines and air traffic managers take extraordinary precautions to avoid flying into these danger zones. In the case of the recent eruption of Iceland's Eyjafjallajokull volcano, the risk was deemed so great that the only prudent response was to ground all aircraft within the danger zone, which encompassed the United Kingdom and most of northern Europe. The problems associated with the eruption in Iceland were compounded by the fact that many of the impacted flights were the trans-Atlantic oceanic routes, where there is no continuous surveillance (such as radar) and the requirement for proximity to contingency landing sites presents a significant constraint to alternate routes.

The International Air Transport Association reported that the volcanic eruption cost the world's airlines at least $1.7 billion and affected as many as 1.2 million passengers a day. Many Americans were directly or indirectly impacted by this stoppage. Certainly there will be a significant assessment of this issue by the global aviation community in the coming months and years.

Detecting, monitoring and understanding volcanic ash clouds and their composition are critical first steps in addressing this issue. My colleague, Jack Kaye, from the NASA's Science Mission Directorate is discussing this issue with the Subcommittee at this hearing today.

Volcanic Ash and Aircraft

Encounters with volcanic ash are known to have detrimental effects on modern turbine engines. Particulate erosion testing is a part of some engine testing, but these tests are generally focused on abrasive materials such as sand, which have some material properties that have a different impact compared to volcanic ash. Therefore, today's engines are not certified for volcanic ash ingestion.

There has been some notable research on the impact on gas turbine engines of ingesting dust-laden air that was conducted by the Calspan Advanced Technology Center in the late 1980's and early 1990's under sponsorship of the Defense Nuclear Agency. The Calspan team tested several military gas turbine engines using volcanic ash to better understand the impacts of dust-laden air on engine operation. An important research result is that there are a number of factors that significantly impact the effect of a volcanic ash encounter, including engine type, operating conditions, constituents of the ash cloud, and ash concentrations. This research also identified several ways that ash can damage an engine including: melting of ash on components in the engine hot sections, erosion of components, blockage of cooling passages in turbines, and contamination of the oil or bleed air systems. This research also developed and validated various potential recovery strategies for addressing in-flight operational problems, depending upon the engine and conditions encountered.

The signs that an aircraft is in a volcanic ash condition are not always clear. Previous ground tests of engines by Calspan indicate that the warning signs of ash damage vary with engine type and that an ash encounter is often very difficult to discern from existing instrumentation until a serious problem like an engine surge or flame-out occurs.

Engine manufacturers currently are the best source of information regarding the impact of volcanic ash on their engines in various conditions. The Subcommittee will be hearing directly from industry sources about this subject at this hearing, including their experiences recently in facilitating the resumption of commercial operations in European airspace.

To be safe, the current established practice is to avoid flight operations in the vicinity of known volcanic airborne debris. As a result, volcanic ash ingestion is not a leading cause of aircraft safety accidents or issues—in fact they are quite rare. There have been no known or reported aircraft fatalities a result of flying through a volcanic ash cloud. Nonetheless, there are several documented cases of aircraft experiencing engine shutdowns and/or costly damage as a result of an unintended encounter.

NASA DC-8 Volcanic Ash Incident

NASA's understanding of the effects of aircraft flying through volcanic ash clouds comes from its evaluation of one unplanned in-flight encounter. This evaluation was enabled by the presence of an onboard science team and specialized instrumentation for unrelated airborne chemistry research. These findings and lessons were developed from volcanic ash plume and satellite trajectory analysis, analysis of ash particles collected in cabin air heat exchanger filters and removed from engines, and data from onboard instruments and engine conditions.

Early on the morning of February 28, 2000, the NASA DC-8 airplane, a highly instrumented research platform for conducting atmospheric science research, inadvertently flew through the fringe of a diffuse volcanic ash cloud produced by the Mt. Hekla volcano in Iceland. This encounter, which lasted approximately seven minutes, occurred in total darkness (no moonlight) during a ferry flight from Edwards, California to Kiruna, Sweden.

This particular encounter demonstrated the difficulty of predicting the location of the ash plume produced by a volcanic eruption. Thirty five hours after the eruption, the London Volcanic Ash Advisory Center (VAAC), using observatory inputs, satellite pictures, radar imagery and pilot reports, predicted the ash plume would be south of the proposed DC-8 track. However, to provide an additional margin of safety, the DC-8 flight path was adjusted an additional 200 miles north, with the expectation of totally avoiding any possibility of encountering the ash plume.

From this research mission, we have learned that a damaging encounter with volcanic ash can be undetectable, even to an alerted flight crew. During this flight, scientists onboard the DC-8 monitoring sensitive research instruments reported a sudden increase in sulfur dioxide (SO2) measurements that indicated the presence of a volcanic ash cloud. Except for the reports from the on-board science team, the DC-8 crew had no indication they were flying through the plume from Mt. Hekla. In previous ash plume encounters by aircraft, the events were frequently accompanied by an odor in the cabin air, by changes in engine readings, by the frosting of windows, and at night, by the presence of St. Elmo's fire on forward-facing parts of the aircraft. NASA's DC-8 flight crew noted no change in cockpit readings, no St. Elmo's fire, no odor or smoke, and no change in engine instruments. They did notice that no stars were visible, but this is typical of flight through high cirrus clouds.

Since in-flight performance checks and detailed visual inspections after landing in Sweden revealed no damage to the airplane or engine first-stage fan blades, the research campaign was completed, and the airplane was ferried back to Edwards Air Force Base in California. More complex engine borescope inspections revealed clogged cooling passages and some heat distress in the high temperature section of the engines. One engine appeared to be more heavily damaged.

The DC-8 is powered by four General Electric CFM56-2 high bypass turbofan engines. All four engines were sent to the manufacturer's General Electric Strouther overhaul facility near Arkansas City, Kansas, where they were disassembled and refurbished. Their detailed engine inspection revealed that even though this was a brief flight through a diffuse ash cloud, the exposure was long enough and engine temperatures were high enough that engine hot section blades and vanes were coated and cooling air passages were partially or completely blocked. All engines exhibited a fine white powder coating throughout, leading edge erosion on high-pressure turbine vanes and blades, blocked cooling air holes, blistered coatings, and a buildup of fine ash inside passages. A blade with blocked cooling operates at a sufficiently higher temperature, significantly impacting blade life. Although engine trending did not reveal a problem, hot section parts may have begun to fail (through blade erosion) if flown another 100 hours, in contrast to the normal service life of thousands of hours. The engines were overhauled, at a total cost of $3.2 million.

Research That Could Benefit Future Situations

NASA does not have any ongoing research efforts that are focused on understanding the impact of volcanic ash on aircraft engines, mainly because the volcanic ash encounters are very rare events and have been consistently placed at a very low priority for research needs by the aviation community.

While NASA aeronautics research has not directly addressed impacts of volcanic ash on aviation, it is possible that some past and current research activities conducted by NASA and the aviation community could be of value to industry and airspace regulators as they seek to better understand the impact of volcanic ash and devise strategies for addressing similar situations in the future.

Operational procedures

Making the best possible use of available airports and airspace is critical to sustaining limited service during, and recovering from, a major disruption such as Eyjafjallajokull. NASA-developed analysis tools can simulate air traffic scenarios, evaluate outcomes, and support decisions made by air traffic managers and airline operators. There could be some applicability of these analysis tools to decision support tools for the oceanic flight realm, benefitting routine daily operations as well as recovering from system disruptions such as ash plumes.

Parallels exist between the problems presented by an ash plume and by severe convective weather: both form in an unpredictable manner, present a dynamically changing hazard to aviation, and require coordinated modification of flight routes. The aviation community has made a large, sustained investment in technology development to address convective weather, resulting in sensors, models, and tools that have significantly improved the ability to keep people and aircraft safely moving when subjected to adverse weather conditions. Past research in dealing with severe weather has shown that even the most daunting scenarios provide limited yet workable operational solutions.

Better plume measurements and propagation forecasts and operational procedures together could contribute to air traffic management solutions to the problem of volcanic ash. Tracts of useable airspace could be identified to build routes that can be used to maximize traffic throughput in constrained airspace. Fleet management options could be assessed to quantify the advantages and impacts of different strategies. For example, corridors-in-the-sky that use the available airspace could be developed and dynamically updated based on the prevailing wind and plume conditions. Based on the traffic demands, additional reroutes could be developed as appropriate.

Sharing information about hazards

NASA is developing new display concepts to intuitively convey new information sets available to pilots. One such concept could improve the current Notices to Airmen (NOTAM) system. Current NOTAMs of changes to flight conditions are not instantaneous. Expeditious datalink of NOTAMs with an appropriate display and notification could shorten this to seconds to minutes of when such events occur. NOTAMs related to volcanic ash activity are called ASHTAMs by the International Civil Aviation Organization (ICAO), and are regularly released when such events occur across the globe. However, such information today is very coarse and delayed, and is therefore open to misinterpretation. Improvements in display concepts, while not developed to specifically address the issue of hazardous ash conditions, could enable the provision much more detailed ash information along with real-time updates as they become available through air traffic service providers.

NASA also has available data mining tools that might be of use to industry and regulators to make sense of data resulting from recent operational experiences or future tests.

Engine technologies

Since there are so many factors that contribute to the severity of damage from volcanic ash, it is unlikely that even a robust research effort will lead to engines that are tolerant of significant amounts of ash ingestion. However, some NASA research in novel materials may have an effect of mitigating some of the negative effects from ash ingestion. For example, ceramic matrix composite turbine blades may need fewer cooling channels which would make them less susceptible to degraded cooling performance due to clogging. These materials may also have better damage tolerance qualities. Similarly, research in engine monitoring and instrumentation might also have applicability in this circumstance.

In the 1990's, NASA conducted flight research to examine deteriorated engine operation and performance (the Dryden Performance Seeking Control research project). Extrapolating from that experience, NASA research on integrated propulsion and control systems and robust engine control (i.e. controller design and possible modification of actuators to extend engine operating life) could have some potential applicability in mitigating the hazards associated with volcanic ash. Current research regarding effective interaction or monitoring methods for the crew under degraded engine operating conditions could be applied in instances where those circumstances are due to volcanic ash.

Conclusion

NASA Aeronautics will continue to make available our expertise and knowledge in these areas to other federal agencies and the broader aviation community as they assess plans for national and global flight operations in these conditions.