United States Government Accountability Office

GAO

Report to Congressional Requesters

July 2010

AVIATION SAFETY

Improved Planning Could Help FAA Address Challenges Related to Winter Weather Operations

GAO

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GAO-10-678

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Highlights

Highlights of GAO-10-678, a report to congressional requesters

July 2010

AVIATION SAFETY

Improved Planning Could Help FAA Address Challenges Related to Winter Weather Operations

Why GAO Did This Study

Ice formation on aircraft can disrupt the smooth flow of air over the wings and prevent the aircraft from taking off or decrease the pilot's ability to maintain control of the aircraft. Takeoff and landing operations can also be risky in winter weather. Despite persistent efforts by the Federal Aviation Administration (FAA) and others to mitigate icing risks, icing remains a serious concern. GAO reviewed (1) the extent to which commercial airplanes have experienced accidents and incidents related to icing, (2) FAA's inspection and enforcement activities related to icing, (3) the efforts of FAA and others to improve safety in winter weather, and (4) the challenges that continue to affect aviation safety in winter weather. GAO analyzed data obtained from FAA, the National Transportation Safety Board (NTSB), the National Aeronautics and Space Administration (NASA), and others. Further, GAO obtained information from FAA and NTSB officials and representatives of key aviation industry stakeholders.

What GAO Recommends

To help facilitate FAA's efforts to address challenges to improving safety in winter weather conditions, GAO recommends that FAA develop a plan focused on winter operations holistically that includes detailed goals and milestones. In response, the Department of Transportation agreed to consider GAO's recommendation and provided technical comments, which were incorporated as appropriate.

View GAO-10-678 or key components. To view the e-supplement online, click on GAO-10-679SP. For more information, contact Gerald L. Dillingham, Ph.D. at (202) 512-2834 or dillinghamg@gao.gov.

What GAO Found

According to NTSB's aviation accident database, from 1998 to 2009 large commercial airplanes were involved in six nonfatal accidents related to icing (including in-flight and runway). However, FAA and others recognize that incidents are potential precursors to accidents. Although large commercial airplanes have experienced few icing-related accidents in the last decade, the several hundred icing-related incidents involving these airplanes contained in FAA and NASA databases suggest that they face ongoing risks from icing.

Based on multiple inspections, FAA assesses each large carrier's ground deicing program to ensure that it meets relevant safety regulations. For fiscal years 2005 to 2009, FAA largely met its own requirements for inspecting carriers' ground deicing programs. When a carrier violates a safety regulation, FAA can take enforcement action against the carrier. For fiscal years 2005 to 2009, FAA initiated enforcement actions against large commercial carriers in 274 cases for violations of icing-related regulations.

FAA and other aviation stakeholders have undertaken many efforts to improve safety in icing conditions. For example, in 1997, FAA issued a multiyear plan for improving the safety of aircraft operating in icing conditions and has since made progress on the objectives specified in its plan by issuing regulations, airworthiness directives, and voluntary guidance. However, FAA has not formally updated its 1997 in-flight icing plan, meaning the stakeholders do not have a consolidated and readily accessible source of information on the key in-flight icing actions FAA has under way or planned. NTSB has issued numerous recommendations as a result of its aviation accident investigations, and NASA has contributed to research related to icing. In addition, the private sector has deployed various FAA-required technologies on aircraft, such as wing deicers, and operated ground deicing and runway clearing programs at airports.

GAO's interviews with government and industry stakeholders identified challenges related to winter weather operations that, if addressed, could improve safety. Among others, these challenges include improving the timeliness of FAA's winter weather rulemaking efforts, ensuring the availability of resources for icing-related research, and developing a more integrated approach to effectively manage winter operations. With respect to an integrated approach, FAA said it needs to begin focusing on winter operations holistically because there are many vital elements to safe operations in winter weather, such as airport surface conditions, aircraft ground deicing, aircraft in-flight icing and icing certification, and air traffic handling of aircraft in icing conditions. A plan that addresses both in-flight and ground icing issues, as well as the challenges stakeholders identified for this report, would help FAA measure its ongoing and planned efforts against its goals for improving safety. Furthermore, a comprehensive plan could help identify gaps or other areas for improvement and assist FAA in developing an integrated approach to winter operations.

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Abbreviations

AIP	Airport Improvement Program
AIRA	Aircraft Icing Research Alliance
APA	Administrative Procedure Act
ARAC	Aviation Rulemaking Advisory Committee
ASRS	Aviation Safety Reporting System
ATOS	Air Transportation Oversight System
CIP	Current Icing Product
EMAS	Engineered Materials Arresting System
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FIP	Forecast Icing Potential
IG	Inspector General
MTOW	Maximum Takeoff Weight
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NextGen	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NTSB	National Transportation Safety Board
PTRS	Program Tracking and Reporting Subsystems
R&D	research and development

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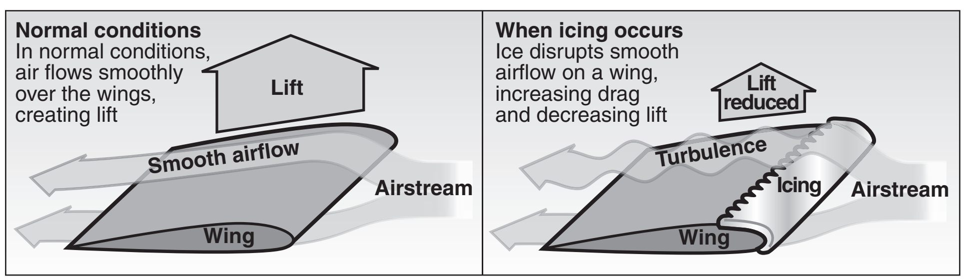
United States Government Accountability Office
Washington, DC 20548

July 29, 2010

Congressional Requesters

Icing can be a significant hazard for aviation operations of all types, including commercial flights.[1] As shown in figure 1, when there is ice on an aircraft's wings, it can disrupt the smooth flow of air over the wings and prevent the aircraft from safely taking off or decrease the pilot's ability to control the aircraft in flight. Depending on the location of the ice, the shape of the wing, and the phase of flight, even small, almost imperceptible amounts of ice can have a significant detrimental effect. Despite a variety of technologies designed to prevent ice from forming on wings or other critical surfaces or to remove ice that has formed, as well as persistent efforts by the Federal Aviation Administration (FAA) and other stakeholders to mitigate icing risks, icing remains a concern. Furthermore, runways that have not been cleared of snow or ice (referred to as contaminated runways) can be hazardously slick for planes during takeoff and landing.

Figure 1: Effect of Ice Build-up on Aircraft Wings



Sources: GAO and FAA.

This report describes the risks to aviation safety posed by icing and winter weather conditions and the steps taken and challenges faced by aviation stakeholders in their efforts to mitigate those risks. As such, we reviewed

[1]In this report we use the term "icing" to refer to icing of airplane surfaces. We use the term "contaminated runway" to refer to ice, snow, slush, frost, or standing water on the runway. Precipitation or the presence of fog at low temperatures may be defined as icing conditions for the airplane, which may require certain ground deicing procedures (e.g., checks or deicing of the critical surfaces). Runways that are contaminated with snow, slush, or ice are generally associated with operations in winter conditions.

(1) the extent to which large commercial airplanes have experienced accidents and incidents related to icing and contaminated runways, (2) FAA's inspection and enforcement activities related to icing, (3) the efforts of FAA and other aviation stakeholders to improve safety in icing and winter weather operating conditions, and (4) the challenges that continue to affect aviation safety in icing and winter weather operating conditions.

To review the extent to which large commercial airplanes have experienced accidents and incidents related to icing and contaminated runways, we analyzed data obtained from FAA, the National Transportation Safety Board (NTSB), and the National Aeronautics and Space Administration (NASA). To review FAA's inspection and enforcement activities related to icing we obtained FAA's inspection and enforcement policies and analyzed data from FAA's inspection and enforcement databases. For example, we obtained data from FAA's Air Transportation Oversight System to assess the timeliness of FAA's inspections of large commercial carriers' ground deicing programs. To review FAA's efforts to improve safety in icing and winter weather operating conditions and the challenges that remain, we obtained information from FAA, NTSB, NASA, the National Oceanic and Atmospheric Administration (NOAA), and the National Center for Atmospheric Research (NCAR). In addition, we interviewed representatives from the Flight Safety Foundation, an academic expert, and a diverse group of aviation industry stakeholders and associations.[2] We provided a draft of this report to the Department of Transportation (which contains FAA), the Department of Commerce (which contains NOAA), NTSB, NASA, and the National Science Foundation (which contains NCAR) for their review and incorporated their comments as appropriate.

We performed this work from August 2009 to July 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. Further, we assessed the reliability of the data used in

[2]The Flight Safety Foundation is an independent, nonprofit, international organization engaged in research, auditing, education, advocacy, and publishing to improve aviation safety.

this report and determined that the data were sufficiently reliable for our purposes. To assess the reliability of the inspection and enforcement data that we received from FAA, we performed electronic testing of the data elements that we used, obtained and reviewed documentation about the data and the systems that produced them, and interviewed knowledgeable FAA officials. To assess the reliability of the accident data we received from NTSB and the incident data we received from FAA and NASA, we obtained and reviewed documentation about the data and the systems that produced them. Appendix I contains a more detailed discussion of our objectives, scope, and methodology, including a complete list of industry stakeholders we interviewed.

Background

Deicing operations include removing ice from aircraft, applying chemicals to prevent initial icing or further icing (anti-icing), and removing (and preventing) ice from airfield pavement (runways, taxiways, aprons, and ramps). Prior to departure, the removal of ice, snow, slush, or frost from an aircraft's critical surfaces can be accomplished by mechanical means, using heat, using a heated fluid, using forced air, or a combination thereof. When frost, snow, or ice adheres to an aircraft surface, the surface must be heated or sprayed with pressurized fluid to remove the contaminant. Anti-icing on the ground is accomplished by applying a freezing point depressant to a surface either following deicing or in anticipation of subsequent winter precipitation; it is intended to protect the critical surfaces from ice adherence for a limited period of time. The fluid is capable of absorbing freezing or frozen precipitation until the fluid freezing point coincides with the ambient temperature. Once this fluid freezing point has been reached, the fluid can no longer protect the aircraft from ground icing conditions. During in-flight operations, an anti-icing system is expected to keep ice from forming in all but severe icing conditions and is accomplished with the use of engine bleed air, electro-thermal heaters, or fluid freezing point depressants. Table 1 describes the tools and processes used for ground deicing and anti-icing procedures on aircraft; table 2 describes systems found on aircraft for in-flight ice protection.

Table 1: Description of Tools and Processes Used for Ground Deicing and Anti-Icing

Anti-ice and deicing fluid application	Prior to takeoff, deicing and anti-icing fluids are used to remove ice from the aircraft and to prevent future ice formation. Once anti-icing fluids are applied to an aircraft, the aircraft has a finite amount of time—known as a holdover time—that the fluid will remain effective. These holdover times are established as a guide for the amount of time anti-icing fluid will provide protection. Deicing facilities can be located at the terminal area or at "centralized deicing pads" which restrict aircraft deicing to a specific area, minimizing the volume of deicing waste water and allowing for the capture of deicing waste.
Infrared heat deicing	A method of deicing using infrared thermal energy. Aircraft using this method enter a drive-through structure designed to rapidly melt the accumulated ice, frost and snow off all critical surfaces of the aircraft. As a result, the aircraft come out of the system clean and dry. Currently, such systems are in place at two airports: Rhinelander, Wisconsin, and John F. Kennedy Airport in New York. The infrared system is powered by natural gas and thought to be less harmful to the environment than the use of deicing fluid. These systems can handle any size aircraft and are fully automated. After the aircraft goes through the infrared deicing process, a small amount of anti-icing fluid is applied to the plane so that new ice does not develop prior to takeoff.
Forced air deicing	A method of deicing using forced air to blow frozen contaminants off an aircraft surface. Some forced air deicing systems use high-pressure air or a mix of air and deicing fluid, while others are based on delivering large air volumes at low pressure.
Critical surface inspection	A critical surface inspection is a preflight external inspection of critical surfaces conducted by a qualified person, to determine if they are contaminated by frost, ice, snow or slush. This inspection is mandatory whenever ground icing conditions exist and, if the aircraft is deiced with fluid, must take place immediately after the final application of fluid, or when an approved alternative method of deicing is used, upon completion of this process. After the inspection, a report completed by a qualified individual must be submitted to the pilot-in-command.

Source: GAO analysis of NASA and industry information.

Table 2: Description of Aircraft Systems for In-flight Ice Protection

Pneumatic deicers	A common deicing system uses pneumatically inflated rubber boots on the leading edges of airfoil surfaces, typically including the leading edges of the wings and tail surfaces. The system uses relatively low pressure air to rapidly inflate and deflate the boot. This is usually done in a sequence of segments— for example, the outer wings followed by the inner wings followed by the horizontal stabilizer. Depending on the manufacturer's specifications, the system may be operated either automatically, through a timing circuit, or manually, using a cockpit control to initiate the boot cycle sequence.
Weeping wing	An anti-icing system that pumps fluid from a reservoir through a porous panel embedded in the leading edges of the wings and tail. Activated by a switch in the cockpit, the liquid flows all over the wing and tail surfaces, anti-icing as it flows. It can also be applied to the prop and the windshield.
Thermal systems	Some aircraft use electronically heated surfaces on critical components of the aircraft (e.g., windshield, pitot/static tubes, and propeller blades). These systems operate in-flight to rid the aircraft of ice buildup and to prevent ice accumulation. Large aircraft may use a hot "bleed air system" from the compressor stages of a turbine engine to periodically break the bond between accreted ice and the surface of the airframe.[a]

Source: GAO analysis of NASA, the Aircraft Owners and Pilots Association, and industry information.

[a]Ice accretion is the process by which a layer of ice builds up on solid objects that are exposed to weather conditions such as freezing precipitation.

FAA issues regulations, airworthiness directives, and other guidance and monitors industry compliance as part of its mission to ensure safe, orderly, and efficient air travel in the national airspace system. FAA regulations contain a number of parts, and different parts apply to aircraft based on their size and type and the activities they are used for. In this report we use the term "large commercial airplanes" to refer to those airplanes operating under part 121 of title 14 of the United States Code of Federal Regulations. Among other things, part 121 applies to air carrier operations involving turbojet airplanes or any airplane with a seating capacity of more than nine passenger seats or a maximum payload capacity of more than 7,500 pounds. We use the term "small commercial airplanes" to refer to those airplanes operating under part 135 of title 14. Among other things, part 135 covers certain commuter and on-demand operations on airplanes, other than turbojet powered airplanes, with nine passenger seats or less, and a payload capacity of 7,500 pounds or less. Some commuter and most air tour operators and medical services (when a patient is on board) fall under the purview of part 135. By "noncommercial airplanes," we mean airplanes that are privately operated under part 91 of title 14. These types of operations are often referred to as "general aviation" and include, among other things, flights for recreation and training and certain business flights. Although noncommercial flights usually involve small aircraft, the definition we are using depends on the nature of the operation, not the size of the aircraft.

In developing regulations, FAA follows the rulemaking process used by all federal agencies, which is established in the Administrative Procedure Act (APA).[3] This act establishes procedures and broadly applicable federal requirements for informal rulemaking, also known as notice and comment rulemaking. This process is designed to provide the opportunity for public participation in rulemakings by submission of written comments and to ensure that all aspects of any regulatory change are fully analyzed before the change goes into effect. Starting early in a rulemaking, FAA may seek input from its Aviation Rulemaking Advisory Committee (ARAC), and during the course of a rulemaking it may conduct research related to the rulemaking. In addition, the APA generally requires agencies to publish a notice of proposed rulemaking in the *Federal Register*. During the public comment period that follows the publication of the proposed rule,

[3]APA describes two types of rulemaking, formal and informal. Formal rulemaking includes a trial-type on-the record proceeding. Most federal agencies use the informal rulemaking procedures outlined in 5 U.S.C. §553.

interested parties may submit written comments, which FAA examines and may consider when making any changes before publishing the final rule. The final rule is then incorporated into the United States Code of Federal Regulations, but it may not take effect immediately. For example, FAA may phase in requirements over time or it may give industry time—sometimes several years—to implement changes.

FAA can also issue airworthiness directives.[4] An airworthiness directive is a legally enforceable rule that may apply to an aircraft or its parts, such as engines and propellers. FAA issues an airworthiness directive when it determines that (1) an unsafe condition exists in the product and (2) the condition is likely to exist or develop in other products of the same type design.

NTSB investigates and reports on civil aviation accidents, which it defines as occurrences whereby a person suffers death or serious injury, or in which the aircraft receives substantial damage. FAA and NTSB also investigate aviation incidents, which NTSB defines as occurrences other than an accident associated with the operation of an aircraft that affects or could affect the safety of operations. FAA maintains an incident database generated by its investigations. NASA also administers a voluntary reporting system on aviation incidents, called the Aviation Safety Reporting System (ASRS). It contains voluntary reports, which are later de-identified, from pilots, controllers, maintenance technicians, and other operating personnel about human behavior that resulted in unsafe occurrences or hazardous situations. NASA seeks to avoid double counting of incidents by ensuring that multiple reports for a single incident are grouped together under that incident. Because ASRS reporting is voluntary, it is unlikely to cover the universe of safety events. It is also possible that ASRS incident data may overlap with FAA incident data because a single incident may be entered into FAA's incident database by an FAA inspector and reported to ASRS by a pilot or bystander. However, the extent to which overlap occurs is unknown.

When airlines and airports conduct deicing operations on aircraft and airfield pavement, the large amounts of chemicals used for deicing operations may drain off airport facilities to nearby rivers, lakes, streams, and bays and can have major impacts on water quality. In August 2009, the Environmental Protection Agency (EPA) issued a proposed rule on the use

[4] 14 C.F.R. part 39.

of deicing fluids at airports.[5] According to EPA, the proposed rule would require 218 airports to collect spent deicing fluid and treat the associated wastewater, and 6 major airports would likely need to install centralized deicing pads to comply with the rule. Additionally, some airports would be required to reduce the amount of ammonia discharged from urea-based airfield pavement deicers or use more environmentally friendly airfield deicers that do not contain urea.[6] EPA plans to issue a final rule in December 2010.

Although Large Commercial Airplanes Have Experienced Few Icing-Related Accidents Since 1998, the Many Reported Icing Incidents Suggest That Icing Is an Ongoing Risk to Aviation Safety

According to NTSB's aviation accident database, from 1998 to 2009 one large commercial airplane was involved in a nonfatal accident after encountering icing conditions during flight and five large commercial airplanes were involved in nonfatal accidents related to snow or ice on runways. Although there have been few accidents, FAA and others recognize that *incidents* are potential precursors to accidents. Data on hundreds of incidents that occurred during this period reveal that icing, contaminated runways, and other winter weather conditions pose substantial risk to aviation safety. FAA's database of incidents includes 120 incidents related to icing, contaminated runways, taxiways, or ramps, or other winter weather conditions involving large commercial airplanes that occurred from 1998 through 2007.[7] These data covered a broad set of events, such as the collision of two airplanes at an ice-covered gate, and an airplane that hit the right main gear against the runway and scraped the left wing down the runway for about 63 feet while attempting to land with ice accumulation on the airplane. During this same time period, NASA's ASRS received over 600 icing and winter weather-related incident reports involving large commercial airplanes. These incidents reveal a variety of safety issues such as runways contaminated by snow or ice, ground deicing problems, and in-flight icing encounters. These incidents thus also suggest that risks from icing and other winter weather operating conditions may be greater than indicated by NTSB's accident database and by FAA's incident database. FAA officials point out that there is no defined reporting threshold for ASRS reports and because they are developed from personal narrative, they can be subjective. However, these officials agree

[5] 74 Fed. Reg. 44676, Aug. 28, 2009.

[6] Urea is a chemical compound commonly used to deice runways and other airfield surfaces at commercial airports in the United States.

[7] We did not analyze trends because, according to incident data experts, not all incidents are reported and therefore trends are not meaningful.

that the ASRS events must be thoroughly reviewed and evaluated for content to determine the relevancy to icing and the extent and severity of the safety issue. The contents of the ASRS data system also demonstrate the importance of aggregating data from all available sources to understand a safety concern. See table 3 for the number of icing and winter weather-related incident reports from ASRS for large commercial airplanes.

Table 3: Icing and Winter Weather-Related Incident Reports for Large Commercial Airplanes by Category of Incident, 1998 to 2007

Category	Number of reports
Anti-icing or deicing incident/procedure[a]	179
Controllability issue—ground	72
In-flight encounter—aircraft equipment problems	72
In-flight encounter—airframe and/or flight control icing	69
Other winter weather incident	42
Surface marking and signage obstruction	41
Runway, ramp, or taxiway excursion[b]	36
Runway, ramp, or taxiway incursion[c]	34
Controllability issue—air	32
Maintenance incident	19
Ramp safety—personnel risk or injury	17
In-flight encounter—sensor type incident	15
Total	**628**

Source: GAO analysis of NASA ASRS data on incidents due to winter weather conditions.

[a]An anti-icing or deicing incident/procedure is an event involving the process of preventing or removing accumulations of ice, snow, frost, etc., on aircraft critical surfaces by means of aircraft equipment deployment or application of specified fluids. Anti-icing means that ice, snow, or frost formation was prevented, either by on-ground means or by aircraft equipment in flight. Deicing means that ice, snow, or frost was removed, either by on-ground means or by aircraft equipment in flight.

[b]An excursion occurs when an aircraft unintentionally exits a runway, ramp, or taxiway.

[c]An incursion occurs when an aircraft enters a runway, ramp, or taxiway without authorization.

While our review focused on large commercial airplanes, small commercial airplanes and noncommercial airplanes experienced more icing-related accidents and fatalities than did large commercial airplanes from 1998 to 2007, as shown in table 4. They did so largely because, compared to large commercial airplanes, small commercial airplanes and noncommercial airplanes (1) may be performance-limited and therefore operate for longer periods at lower altitudes that more frequently have icing conditions, (2) have a higher icing collection efficiency due to their smaller scale, (3) are more greatly impacted by ice as a result of their smaller scale, (4) tend to have deicing equipment (e.g., pneumatic deicing boots) rather than fully evaporative anti-icing equipment, and (5) may not be approved for flight in known icing conditions. If an airplane is not approved for flight in icing conditions, it may either not have an ice protection system installed, or it may have an ice protection system that is not certified.

Table 4: Icing and Winter Weather-Related Accidents and Fatalities for 1998 to 2009, Incidents from 1998 to 2007

	Large commercial airplanes	Small commercial airplanes	Noncommercial airplanes
Icing-related accidents, including in-flight and runway	6	49	510
Fatalities in icing-related accidents	0	27	202
Icing-related incidents in FAA's database	120	86	319
Icing-related incidents in NASA's ASRS database	628	102	422

Sources: GAO analysis of NTSB data for accidents and fatalities; GAO analysis of FAA and NASA data for incidents.

Notes: For all three types of airplanes, accident data for 2008 and 2009 are incomplete because NTSB has not completed all of its accident investigations that occurred during those years. For small commercial and noncommercial airplanes, the number of accidents and incidents also includes carburetor icing.

In December 2005, a passenger jet landed on a snowy runway at Chicago's Midway Airport, rolled through an airport perimeter fence onto an adjacent roadway, and struck an automobile, killing a child and injuring 4 other occupants of the automobile and 18 airline passengers. NTSB concluded that the probable cause of the accident was not related to icing or winter weather, but rather to the pilot's failure to use available reverse thrust in a timely manner to safely slow or stop the airplane after landing, which resulted in a runway overrun.

FAA Largely Met Its Own Inspection Requirements Related to Icing

As part of its Air Transportation Oversight System (ATOS), FAA assesses large carriers' ground deicing programs to ensure that they meet relevant safety regulations.[8] FAA requires itself to assess the design of each carrier's program twice every 5 years, with one of the assessments focused on ground crews and the other on flight crews. FAA also requires itself to assess the performance of each carrier's program twice each year, again with one assessment focused on ground crews and the other on flight crews. Design assessments ensure that an air carrier's operating systems comply with regulations and safety standards. Performance assessments confirm that an air carrier's operating systems produce intended results, including mitigation or control of hazards and associated risks. FAA bases each assessment of a carrier's performance on multiple inspections, which are typically conducted at several of the various locations where the carrier operates.[9] FAA considers assessments to be on-time if they are completed within 30 days of the end of the quarter in which they are scheduled for completion. From December 2007, when it first completed these assessments, through fiscal year 2009, FAA completed 103 of 108 design assessments on time (95 percent) and 303 of 315 required performance assessments on time (96 percent).

While this review focused on FAA's inspections related to ground deicing, the Department of Transportation Inspector General (IG) in March 2010 issued an initial report based on its broader ongoing review of FAA's inspections under ATOS.[10] The IG reported that FAA does not have an effective process for ensuring the timely completion of inspections. In particular, the IG found that FAA does not assign inspectors to all scheduled inspections, does not nationally track these unassigned inspections, and that these inspections could therefore "remain

[8]FAA implemented ATOS in 1998, and currently uses the system to oversee all 98 large commercial carriers. ATOS emphasizes a system safety approach that extends beyond periodically checking airlines for compliance with regulations to using technical and managerial skills to identify, analyze, and control hazards and risks. For example, under ATOS, inspectors develop surveillance plans for each airline, based on data analysis and risk assessment, and adjust the plans periodically based on inspection results. FAA also conducts inspections that partially address icing related requirements, such as inspections of carriers' flight crew training. We did not look at these inspections because of resource constraints.

[9]FAA bases assessments of design on a single inspection because, unlike performance assessments, assessing the design of a program does not involve inspecting activities at multiple locations.

[10]U.S. Department of Transportation Inspector General, *FAA's Process for Reviewing Air Transportation Oversight System (ATOS) Inspection Data* (Washington, D.C., Mar. 2010).

uncompleted for months or even years, and any associated risks within air carrier programs would remain unknown." The IG plans to issue a subsequent report with recommendations to FAA later this year.

For each design or performance inspection, an FAA inspector answers a series of questions about whether the carrier is in compliance with FAA's safety requirements. For inspections of large commercial carriers' ground deicing programs focused on ground crews in fiscal years 2005 through 2009, FAA inspectors indicated that carriers were meeting the requirement in 16,867 out of 20,513 cases (82 percent), were not meeting the requirement in 3,569 cases (17 percent), and that the question was not applicable in 77 cases (0.4 percent). For inspections of large commercial carriers' ground deicing programs focused on flight crews in fiscal years 2005 through 2009, FAA inspectors indicated that carriers were meeting the requirement in 13,734 out of 16,266 cases (84 percent), were not meeting the requirement in 2,122 cases (13 percent), and that the question was not applicable in 410 cases (3 percent).

For each design and performance assessment, FAA scores the carrier on a six-part scale ranging from "no issues observed—no action required" to "persistent, systemic safety and/or regulatory issues observed—system reconfiguration by air carrier required." Of the 423 assessments following inspections of ground deicing programs that FAA completed from December 2007 through the end of fiscal year 2009, 290 (69 percent) did not require any corrective action by the carrier, while 133 (31 percent) required some form of corrective action. Table 5 presents additional information on the results of these assessments.

Table 5: Assessment Results of FAA's Inspections of Large Commercial Carriers' Ground Deicing Programs (December 2007 through End of Fiscal Year 2009)

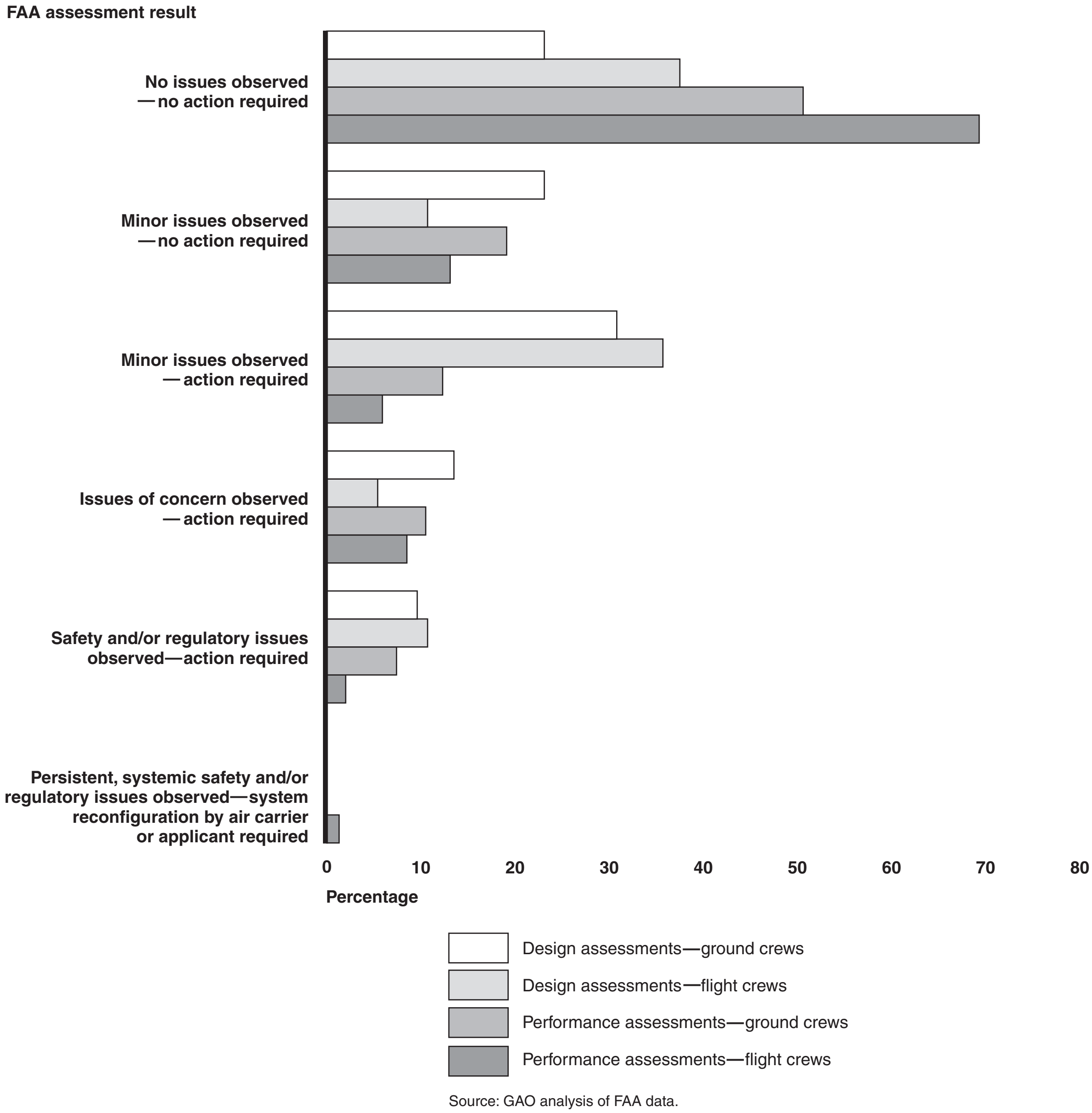
Assessment result	Number of assessments	Percent
No issues observed—no action required	221	52
Minor issues observed—no action required	69	16
Minor issues observed—action required	65	15
Issues of concern observed—action required	40	9
Safety and/or regulatory issues observed—action required	26	6
Persistent, systemic safety and/or regulatory issues observed—system reconfiguration by air carrier or applicant is required	2	<1
Total	**423**	**100**

Source: GAO analysis of FAA data.

Note: Percents do not sum to 100 percent due to rounding.

Carriers generally did better on the performance assessments than the design assessments. Carriers also generally did better on the assessments related to flight crews than on those related to ground crews. Figure 2 presents additional details on the assessment results of FAA's ground deicing inspections.

Figure 2: Assessment Results of FAA's Inspections of Large Commercial Carriers' Ground Deicing Programs by Type of Inspection (December 2007 through End of Fiscal Year 2009)



Source: GAO analysis of FAA data.

Because not all large commercial carriers were covered by ATOS until April 2008, FAA also inspected some large commercial carriers' ground deicing programs under the agency's National Work Program Guidelines (NPG). FAA's policy was to conduct these inspections of each carrier once a year. In fiscal years 2005 and 2006, FAA completed 327 out of 345 required inspections (95 percent) of large commercial carriers' ground deicing programs under NPG. An FAA official told us that resource constraints prevented the agency from being able to complete all the required inspections, and that some were not completed under NPG because the carriers were transitioned to ATOS. In fiscal years 2007 and 2008, FAA conducted far fewer of these inspections as the agency completed its transitioning of large commercial carriers from NPG to ATOS. Under NPG, FAA also plans additional inspections of some carriers on an "as resources allow" basis, and conducts other additional inspections that were not planned. In fiscal years 2005 through 2009, FAA completed 3,757 out of 3,946 planned inspections (95 percent) of large commercial carriers' ground deicing programs under NPG, and it completed an additional 1,704 inspections that were not planned.

When FAA determines that a carrier has violated a safety regulation (through inspections or other means such as accident investigations or public complaints), the agency can take enforcement action against the carrier, which may include imposing monetary fines or temporarily or permanently shutting down the carrier's operations.[11] In fiscal years 2005 through 2009, FAA initiated enforcement actions against large commercial carriers in 274 cases following one or more violations of icing-related regulations. FAA had closed 254 of these actions by March 2010; of these, 226 were administrative actions, such as letters to carriers specifying required corrective actions; 22 were monetary fines, with a median amount of $20,000 and ranging from $675 to $175,000; 3 were closed with no action taken; 2 were suspensions of operating certificates, 1 for 60 days and the other for 90 days; and 1 was a revocation of an operating certificate.

FAA also inspects commercial carriers that operate small airplanes (small commercial carriers) to check whether they are complying with FAA's safety regulations. For inspections that cover areas that FAA deems critical to safety, including ground deicing programs, FAA requires that each carrier be inspected once every 12 months. For less critical areas, FAA establishes inspection annual plans for each carrier that includes what the agency believes are the most important areas for that carrier. In fiscal years 2005 through 2009, FAA completed 942 of 1,026 required inspections (92 percent) of small commercial carriers' ground deicing programs. In addition, over the same time period, FAA completed 2,029

[11] 49 U.S.C. §46301 (civil penalties) and 49 U.S.C. §44709 (license revocation).

out of 2,099 planned inspections (97 percent) of small commercial carriers' ground deicing programs under NPG, and it completed an additional 431 inspections that were not planned.

In fiscal years 2005 through 2009, FAA initiated enforcement actions against small commercial carriers in 274 cases following one or more violations of icing-related regulations. FAA had closed 209 of these actions by March 2010; of these, 112 were administrative actions, such as letters to carriers specifying required corrective actions; 29 were monetary fines, with a median amount of $5,800 and ranging from $1,000 to $186,150; 28 were closed with no action taken; 28 were suspensions of operating certificates, with a median duration of 60 days and ranging from 7 to 270 days; and 12 were revocations of operating certificates.

In fiscal years 2005 through 2009, FAA completed 256 inspections covering icing-related requirements of private operators, 2 of which were required, 125 of which were planned, and 129 of which were not planned. During this time period, FAA did not take any enforcement actions against private operators related to violations of icing-related regulations.

FAA and Other Aviation Stakeholders Have Undertaken a Variety of Efforts Aimed at Improving Safety in Icing and Winter Weather Conditions

FAA and others have undertaken many efforts to improve safety in icing and winter weather conditions. In addition to conducting inspection and enforcement activities as we previously described, FAA's efforts include issuing a multiyear plan in 1997 related to in-flight icing and providing funding for icing-related purposes. Other government entities that have taken steps to increase aviation safety in icing conditions include NTSB, which has issued numerous recommendations as a result of its aviation accident investigations, and NASA, which has contributed to research related to icing. In addition, the private sector has deployed various FAA-required technologies on aircraft, such as wing deicers and ice detectors, and operated ground deicing and runway clearing programs at airports.

FAA Has Taken Actions to Implement Objectives of a Safety Plan Issued in 1997, but Information about Recent Initiatives to Promote Safety in Icing Conditions Has Not Been Readily Accessible

Following the 1994 fatal crash of American Eagle Flight 4184 in Roselawn, Indiana, FAA issued a multiyear plan in 1997 for improving the safety of aircraft flying in icing conditions.[12] FAA distributed the plan to a broad range of aviation stakeholders, including airlines, airports, and pilot organizations, asking for their support in implementing the plan. It also posted the plan on its public Web site, and it created an icing steering committee to monitor the progress of the planned activities. The steering committee is composed of FAA icing specialists who work together to resolve aircraft icing issues.

Over the last decade, FAA made progress on the implementation of the objectives specified in its multiyear plan by issuing or amending regulations, airworthiness directives, and voluntary guidance to provide icing-related safety oversight. For example:

- In August 2007, FAA issued a final rule for new airworthiness standards to establish comprehensive requirements for the performance and handling characteristics of transport category airplanes in icing conditions.[13]
- In January 2009, FAA also issued a proposed rule that would amend the regulations for crewmember and dispatcher training programs, requiring many new training elements and procedures for air carriers including some relevant to icing training.[14]
- In August 2009, FAA issued a final rule requiring a means to ensure timely activation of the ice protection system on transport category airplanes.[15]

[12]FAA's 1997 *Inflight Aircraft Icing Plan* describes various activities planned to improve safety for aircraft flying in icing conditions.

[13]72 Fed. Reg. 44656, Aug. 8, 2007. In general, a transport category airplane is an airplane with maximum takeoff weight (MTOW) greater than 12,500 pounds or with 10 or more passenger seats, except for propeller-driven, multiengine airplanes and recently certified commuter category aircraft with an exemption to 14 C.F.R. § 23.3(d), in which case the transport category airplanes are those with MTOW greater than 19,000 pounds or with 20 or more passenger seats. FAA certifies the design of transport category airplanes under 14 C.F.R. part 25.

[14]74 Fed. Reg. 1280, Jan. 12, 2009.

[15]74 Fed. Reg. 38328, Aug. 3, 2009.

- In November 2009, FAA issued a proposed rule that would require the timely activation of ice protection equipment on commercial aircraft during icing conditions and weather conditions conducive to airframe icing.[16]

- In June 2010, FAA issued a proposed rule to amend its standards for certain transport category airplanes and certain aircraft engines to address supercooled large droplet icing, ice crystal, and mixed phase icing conditions, which are outside the range of icing conditions covered by the current standards; FAA plans to issue the final rule by January 2012.[17]

- Since 1997, FAA has issued over 100 airworthiness directives to address icing safety issues involving more than 50 specific types of aircraft, including directives that require revising the FAA-Approved Airplane Flight Manual limitations to provide the flight crew with recognition cues and procedures for exiting severe icing conditions or inserting a copy of the airworthiness directive in the manual.

- FAA has sponsored research and provided subsequent guidance material incorporating information on critical ice accretions that it believes has resulted in a significant increase in the level of safety of new airplanes.

While FAA points to its actions to implement its 1997 plan as having contributed to a decline in icing-related accidents, the agency also acknowledges that additional steps were and still are needed to further reduce the risks that icing continues to pose to aviation safety. Since it issued the plan, FAA's icing steering committee has identified many additional actions to reduce risks from icing, such as researching and developing approaches to mitigate the risk of turboengine power loss from ice crystal ingestion. At our request, FAA provided us with a lengthy compilation of the tasks it is undertaking with respect to icing; however, its *Inflight Aircraft Icing Plan* has not been publicly updated since the

[16] 74 Fed. Reg. 61055, Nov. 23, 2009. This proposed rule only applies to airplanes with an MTOW of less than 60,000 pounds being operated under 14 C.F.R. part 121.

[17] 75 Fed. Reg. 37311, June 29, 2010. Supercooled large droplets have a diameter greater than 50 microns and include freezing drizzle and freezing rain. These droplets can result in ice accretion beyond the normally protected areas of the aircraft. Mixed-phase icing conditions are a mixture of supercooled water droplets and ice crystals. Exposing engines and externally mounted probes to ice crystal or mixed-phase conditions, especially high ice water content conditions, could result in hazardous ice accumulations within the engine that may cause engine damage, power loss, and loss of or misleading airspeed indications.

initial release in 1997. FAA told us it has reported the status of key tasks in the icing plan to aviation stakeholders via different methods, such as during FAA Icing Conferences in 1999 and 2003; yet because FAA has not formally updated the plan, stakeholders do not have a consolidated and readily accessible source of information on the key in-flight icing actions FAA has under way or planned. Furthermore, because the plan only addresses initiatives related to in-flight icing, FAA is missing an opportunity to take a more holistic and coordinated approach to the broader range of issues related to winter weather, including ground icing and deicing and contaminated runways.

While FAA's *Inflight Aircraft Icing Plan* does not cover ground icing, FAA officials said the agency has maintained a ground icing program whereby FAA provides guidance on ground winter operations on a yearly basis and conducts research on endurance times for deicing and anti-icing fluids. FAA said it also investigates new issues that may arise as a result of special industry concerns or changes in FAA policy. Regulations and guidance developed as a result of the ground icing program include a rule that no longer permits frost to be polished smooth on critical surfaces prior to takeoff and requires pilots to ensure that the wings of their aircraft are free of all frost prior to takeoff.[18]

FAA has also provided funding for a variety of icing-related purposes. For example, FAA has supported NASA research related to severe icing conditions and NCAR research related to weather and aircraft icing. Furthermore, FAA has provided almost $200 million to airports through the Airport Improvement Program (AIP) to construct deicing facilities and to acquire aircraft deicing equipment from 1999 to 2009. (See app. II for a detailed listing of AIP icing-related funding by state, city, and year for 1999 to 2009.) Since runway safety is a key concern for aviation safety and especially critical during winter weather operations, FAA has also provided about $200 million per year in AIP funding for the creation of runway safety areas since 2000.[19] According to the Flight Safety Foundation, from 1995 through 2008, 30 percent of global aviation

[18]74 Fed. Reg. 62691, Dec. 1, 2009. 14 C.F.R. §135.227 and 14 C.F.R. §91.527. Frost-polishing is accomplished by scraping or buffing frost accumulations so as to obtain a smooth surface. Previous FAA guidance recommended removal of all wing frost prior to takeoff, but allowed frost to be polished smooth if the operator followed the manufacturer's procedures. The polished frost requirement does not apply to large commercial aircraft (part 121) because part 121 already did not permit operations with polished frost.

[19]A runway safety area is a 1,000-foot safety zone at the end of a runway.

accidents were runway-related and "ineffective braking/runway contamination" is the fourth largest causal factor in runway excursions that occur during landing. In fiscal year 2000, FAA's Office of Airport Safety and Standards initiated a program to accelerate improvements in runway safety areas at commercial service airports that did not meet FAA design standards. According to FAA officials, of the 619 runways that FAA determined needed improvement, 465 (74 percent) have been completed and 154 (26 percent) remain to be completed by 2015. The estimated cost to complete the remaining projects is about $835 million.[20] In some cases where (1) land is not available, (2) it would be very expensive for the airport sponsors to buy land off the end of the runway, or (3) it is otherwise not possible to have the 1,000 foot safety area, FAA has approved the use of an Engineered Materials Arresting System (EMAS).[21] FAA supports EMAS installations through AIP funding, and currently, EMAS installations have been completed for 44 runways at 30 airports in the United States, with seven more installations scheduled for 2010.[22] To date there have been six successful EMAS captures of overrunning aircraft.

Other Stakeholders Support and Augment FAA Efforts to Increase Safety in Icing and Winter Weather Conditions

Government and industry stakeholders, external to FAA, also contribute to the effort to increase aviation safety in icing and winter weather conditions. For example, as a result of its civil aviation accident investigations, NTSB issues safety recommendations to FAA and others, some of which it deems most critical and places on a list of "Most Wanted" recommendations.[23] Since 1996, NTSB has issued 82 recommendations to FAA aimed at reducing risks from in-flight structural icing, engine and aircraft component icing, runway condition and contamination, ground

[20]The Transportation [and other] Agencies Appropriations Act, 2006. Pub.L.No. 109-115, Div. A, Title I, 119 Stat. 2396, 2401 adopted FAA's 2015 goal for owners or operators of airports to improve the airport's runway safety areas to comply with FAA's design standards required by 14 C.F.R. part 39. FAA considers runway safety areas that meet 90 percent of the standards to be substantially compliant.

[21]EMAS uses materials of closely controlled strength and density placed at the end of the runway to stop or greatly slow an aircraft that overruns the runway. According to FAA, the best material found to date is a lightweight crushable concrete.

[22]Airports that are scheduled for 2010 installation of EMAS beds are Arcata, California; Winston-Salem, North Carolina; Wilmington, Delaware; Key West, Florida.; Teterboro, New Jersey; Telluride, Colorado; and Stuart, Florida.

[23]This list, which NTSB has maintained since 1990 and revises annually, includes important safety recommendations identified for special attention and intensive follow-up.

icing, and winter weather operations. NTSB's icing-related recommendations to FAA have called for FAA to, among other things, strengthen its requirements for certifying aircraft for flying in icing conditions, sponsor the development of weather forecasts that define locations with icing conditions, and enhance its training requirements for pilots. NTSB has closed 41 of these recommendations (50 percent) as having been implemented by FAA, and has classified another 22 (27 percent) as FAA having made acceptable progress.[24] This combined 77 percent acceptance rate is similar to the rate for all of NTSB's aviation recommendations. A complete listing of and additional information on NTSB's icing-related recommendations made since 1996 can be viewed at GAO-10-679SP.

For more than 30 years, NASA has conducted and sponsored fundamental and applied research related to icing. The research addresses icing causes, effects, and mitigations. For instance, NASA has conducted extensive research to characterize and simulate supercooled large droplet icing conditions to inform a pending FAA rule related to the topic. NASA participated in research activities, partially funded by FAA, that developed additional knowledge and strategies which allowed forecasters to more precisely locate supercooled large droplet icing conditions. Furthermore, NASA has an icing program, focused generally on research related to the effects of in-flight icing on airframes and engines for many types of flight vehicles. NASA has developed icing simulation capabilities that allow researchers, manufacturers, and certification authorities to better understand the growth and effects of ice on aircraft surfaces. NASA also produced a set of training materials for pilots operating in winter weather conditions.

NOAA, the National Weather Service, and NCAR have efforts directed and funded by FAA related to predicting the location and severity of icing occurrences. The National Weather Service operates icing prediction systems and NCAR conducts research to determine more efficient methods to complete this task. In response to FAA's 1997 *Inflight Aircraft Icing Plan*, FAA sponsored NCAR's development of two in-flight icing weather products to improve icing diagnoses and forecasting. They are the

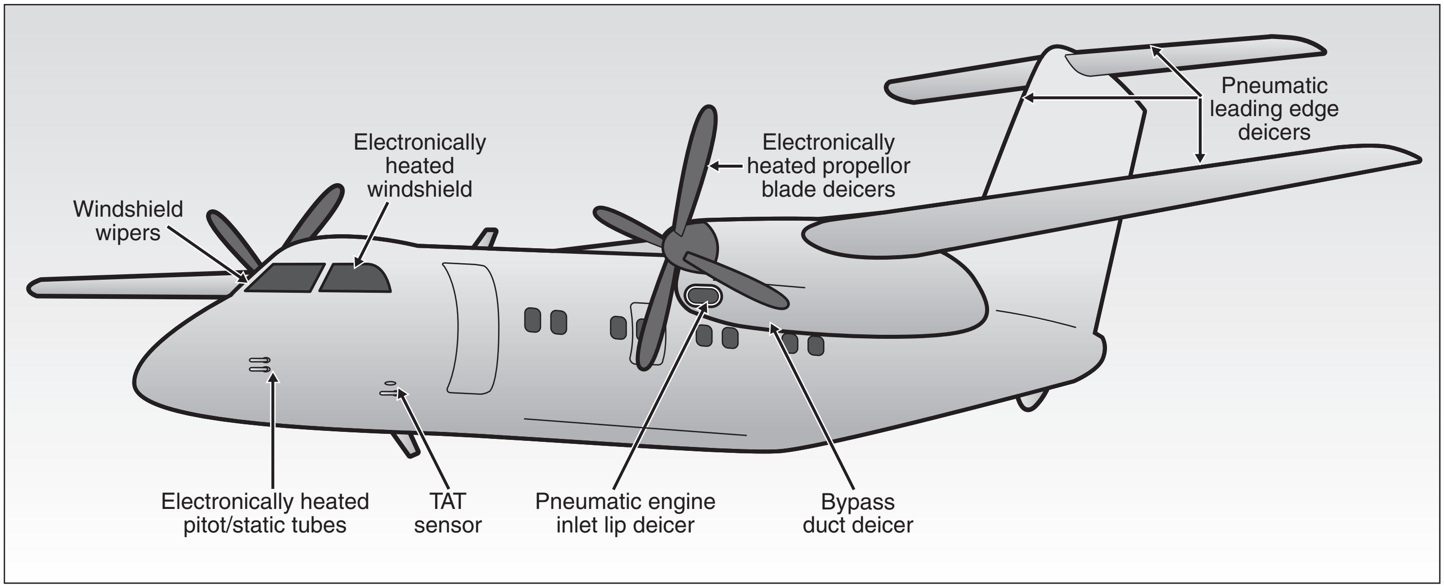
[24] In addition, NTSB has closed eight of these recommendations as "unacceptable response" by FAA; has classified seven of the open recommendations as "unacceptable response" by FAA; has closed three of these recommendations after concurring with FAA's rationales for disagreeing with the recommendations; and is awaiting FAA's response on one of these recommendations.

(1) Current Icing Product (CIP), which combines satellite, radar, surface, lighting, and pilot report observations with model output to create a detailed three-dimensional diagnosis of the potential for the existence of icing, and (2) Forecast Icing Potential (FIP), which calculates the likelihood of icing and supercooled large droplet conditions. FIP allows meteorologists and airline dispatchers to advise pilots about icing hazards up to 12 hours in advance. The CIP and FIP are now fully operational and are available at NOAA's aviation weather Web site, as are maps showing advisories of severe and moderate icing conditions, pilot reports, and freezing-level graphics. FAA has also supported the development and use of operationally available sensors. Observational datasets from those sensors are used in the CIP algorithm.

In commenting on a draft of this report, the National Science Foundation said that members from the Aircraft Icing Research Alliance (AIRA) conduct a significant amount of icing-related research in a collaborative manner. According to the AIRA Web site, its members include NASA; Environment Canada; Transport Canada; National Research Council, Canada; FAA; NOAA; National Defence, Canada; and Defence Science and Technology Laboratory, United Kingdom. AIRA's mission is to coordinate among the parties the conduct of collaborative aircraft icing research activities that improve the safety of aircraft operations in icing conditions.

The private sector has also contributed to efforts to prevent accidents and incidents related to icing and winter weather conditions, as required by FAA. For example, as shown in figure 3, aircraft manufacturers have deployed various technologies such as wing deicers, anti-icing systems, and heated wings. In addition, airports operate ground deicing and runway clearing programs that help ensure clean wings (see fig. 4) and runways.

Figure 3: Aircraft Ice Protection Systems



Source: GAO, based on information from NTSB.

Notes: Pneumatic leading edge deicers are inflatable rubber "boots" on the leading edges of airfoil surfaces (including wings, horizontal stabilizers, and vertical stabilizers) that can be rapidly inflated and deflated with air pressure to break up ice accumulation. Similar technology is used for the pneumatic engine inlet lip deicer (the engine inlet lip is the edge of the opening through which air enters the engine), and the bypass duct deicer (in turbofan engines, the bypass duct channels the outer airflow past the core engine, minimizing large inertia objects such as snow, ice, and water drops from entering the engine). The TAT (Total Air Temperature) sensor helps the pilot determine critical flight parameters such as true airspeed computation and static air temperature. Electronically heated propeller blade deicers, windshield, and pitot/static tubes operate in-flight to rid the aircraft of ice buildup and to prevent ice accumulation.

Figure 4: Example of Ground Deicing to Help Ensure Clean Aircraft

Source: Gerald R. Ford International Airport.

Continued Attention to Regulation, Training, and Coordination Issues Could Further Mitigate the Risks of Winter Weather Operations

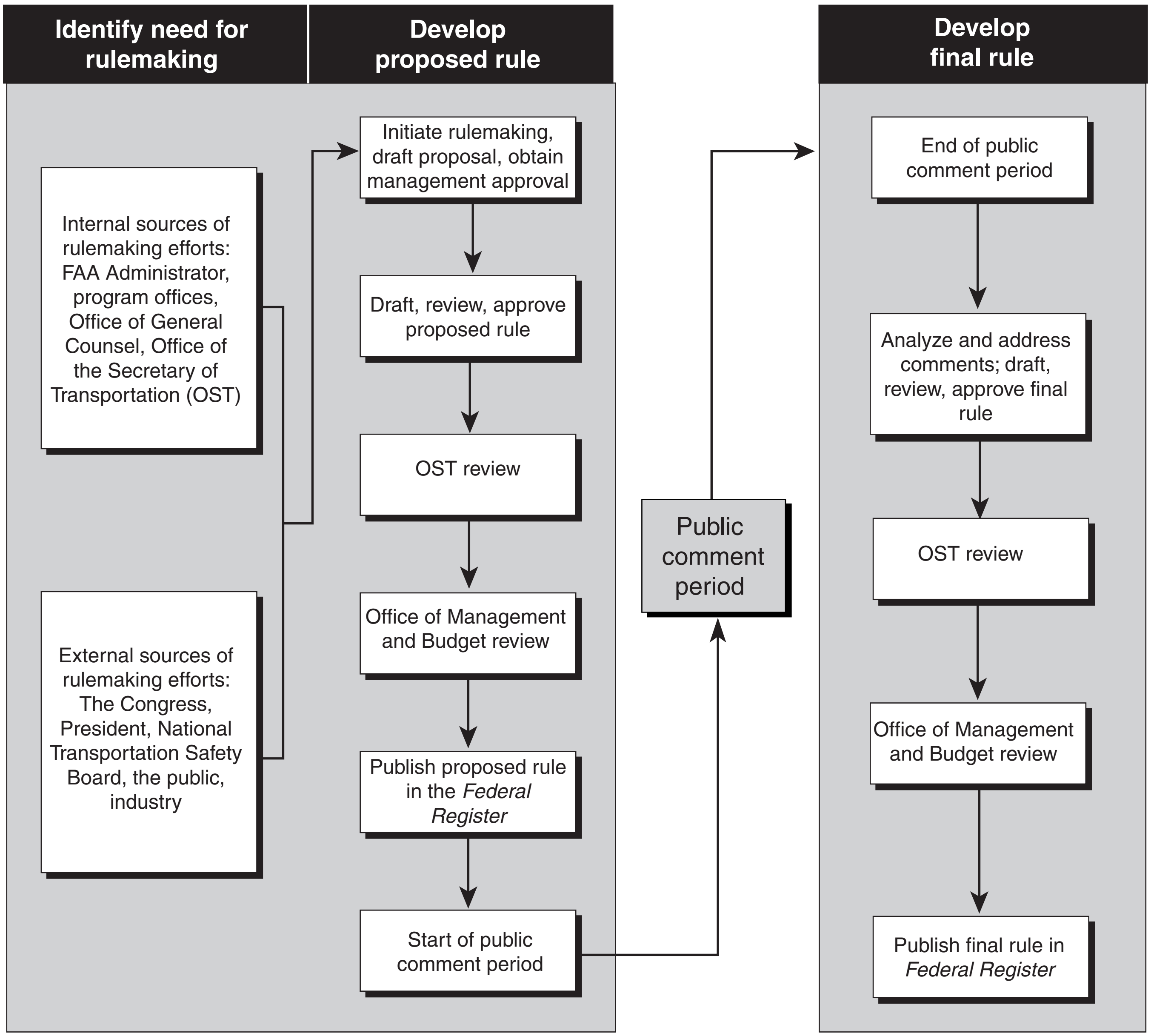
While FAA and others are undertaking efforts to mitigate the risks of aircraft icing and winter weather operations, through our interviews and discussions with government and industry stakeholders, we have identified challenges related to these risks that, if addressed by ongoing or planned efforts, could improve aviation safety. These challenges include (1) improving the timeliness of FAA's winter weather rulemaking efforts; (2) ensuring the availability of adequate resources for icing-related research and development (R&D); (3) ensuring that pilot training is thorough, relevant, and realistic; (4) ensuring the collection and distribution of timely and accurate weather information; (5) addressing the environmental impacts of deicing fluids; and (6) developing a more integrated approach to effectively manage winter operations.

Improving the timeliness of FAA's winter weather rulemaking efforts. FAA's rulemaking, like that of other federal agencies, is a complicated, multistep process that can take many years. One purpose of the rulemaking process is to ensure that all aspects of any regulatory change are fully analyzed before the change goes into effect. To begin a rulemaking, FAA may seek input from ARAC,[25] and it may conduct research and development to enhance existing technologies or to introduce new technologies. NTSB, the Air Transport Association, and other stakeholders have recognized that such research and development can be time-consuming. In addition, FAA generally is required to develop and publish each rule in the *Federal Register*—first as a proposed rule and then as a final rule.[26] During the public comment period that follows the publication of the proposed rule, interested parties may submit written comments, which FAA examines and may consider when making any changes before publishing the final rule. The final rule is then incorporated into the United States Code of Federal Regulations, but it may not take effect immediately. For example, FAA may phase in requirements over time or it may give industry time—sometimes several years—to implement changes. Figure 5 provides an overview of the federal rulemaking process as it applies to FAA.

[25]ARAC is an advisory committee consisting of representatives from the aviation community. Established by the FAA Administrator in 1991, ARAC provides industry information, advice, and recommendations to be considered during FAA's rulemaking activities. ARAC affords FAA additional opportunities to obtain firsthand information and insight from those parties that are most affected by existing and proposed regulations.

[26]The APA includes exceptions to notice and comment procedures for categories of rules such as those dealing with military or foreign affairs and agency management or personnel. 5 U.S.C. § 553(a). APA requirements to publish a proposed rule generally do not apply when an agency finds, for "good cause," that those procedures are "impracticable, unnecessary, or contrary to the public interest." 5 U.S.C. § 553(b).

Figure 5: FAA's Rulemaking Process for Significant Rules



Source: Based on FAA's Rulemaking Manual, Dec. 1998.

Notes: Executive Order 12866 (58 Fed. Reg. 51735, September 30, 1993) defines "regulatory action" as any substantive action by an agency that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking. The executive order defines a "significant" rulemaking as, among other things, one that is likely to result in a rule that may have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, or tribal governments or communities. The order states that agencies should submit detailed cost-benefit analyses to the Office of Management and Budget for all economically significant rulemakings.

NTSB, FAA, and we have previously expressed concerns about the efficiency and timeliness of FAA's rulemaking efforts. In 2001, we reported that a major reform effort begun by FAA in 1998 did not solve long-standing problems with its rulemaking process, as indicated both by the lack of improvement in the time required to complete the rulemaking process and by the agency's inability to consistently meet the time frames imposed by statute or its own guidance.[27] External pressures—such as highly-publicized accidents, recommendations by NTSB, and congressional mandates—as well as internal pressures, such as changes in management's emphasis, continued to add to and shift the agency's priorities. For some rules, difficult policy issues continued to remain unresolved late in the process. Our 2001 report contained 10 recommendations designed to improve the efficiency of FAA's rulemaking through, among other things, (1) more timely and effective participation in decision making and prioritization; (2) more effective use of information management systems to monitor and improve the process; and (3) the implementation of human capital strategies to measure, evaluate, and provide performance incentives for participants in the process. FAA has implemented 8 of our 10 recommendations.[28]

NTSB's February 2010 update on the status of its Most Wanted recommendations related to icing characterized FAA's related rulemaking efforts as "unacceptably slow." In December 2009, at FAA's International Runway Safety Summit, NTSB's Chairman commented, "How do safety improvements end up taking 10 years to deliver? They get delayed one day at a time . . . and every one of those days may be the day when a preventable accident occurs as the result of something we were 'just about ready to fix.'" In particular, NTSB has expressed concern about the pace of FAA's rulemaking project to amend its standards for transport category

[27]GAO, *Aviation Rulemaking: Further Reform Is Needed to Address Long-standing Problems*, GAO-01-821 (Washington, D.C.: July 9, 2001).

[28]Additional information about the status of these recommendations is available at GAO-01-821.

airplanes to address supercooled large droplets, which is outside the range of icing conditions covered by the current standards. FAA began this rulemaking effort in 1997 in response to a recommendation made by NTSB the prior year, and the agency currently expects to issue its proposed rule in July 2010 and the final rule by January 2012. However, until the notice of proposed rulemaking is published and the close of the comment period is known, it will be unclear as to when the final rule will be issued.[29] The Department of Transportation, in its monthly report on the department's significant rulemakings, has classified this rulemaking effort as "behind schedule" since March 2010. Much of the time on this rulemaking effort has been devoted to research and analysis aimed at quantifying the atmospheric conditions that lead to supercooled large droplet icing, as well as developing tools that would allow industry to comply with the forthcoming rule.

In 2009, FAA completed an internal review of its rulemaking process and concluded that several of the concerns from 1998 that led to the agency's major reform effort remain, including:

- inadequate early involvement of key stakeholders;
- inadequate early resolution of issues;
- inefficient review process;
- inadequate selection and training of personnel involved in rulemaking; and
- inefficient quality guidance.

According to FAA's manager for aircraft and airport rules, the agency is taking steps to implement recommendations made by the internal review, such as revising the rulemaking project record form and enhancing training for staff involved in rulemaking. In addition, in October 2009, FAA tasked ARAC with reviewing its processes and making recommendations for improvement within a year. According to an FAA rulemaking manager, ARAC is finalizing its recommendations and writing its report, which FAA expects to receive in December 2010. We believe these efforts have the

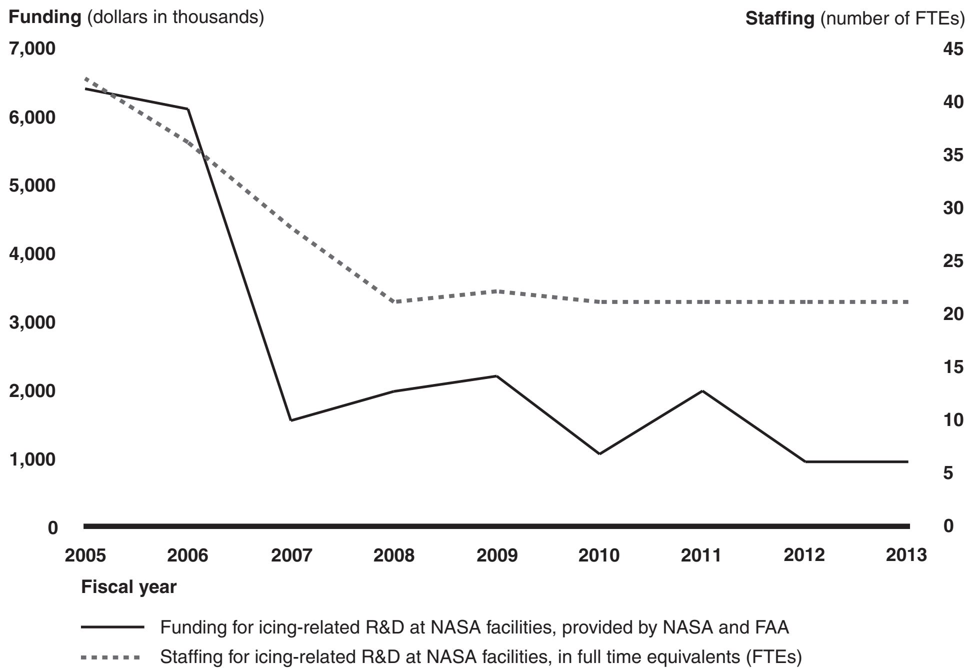
[29]FAA is required by statute to issue a final regulation, or take other final action, within 16 months of the last day of the comment period; or if an Advance Notice of Proposed Rulemaking is issued, FAA has not more than 24 months after the date of publication in the *Federal Register* of the proposed rule to issue a final regulation. 49 U.S.C. § 106(f)(3)(A).

potential to improve the efficiency of FAA's rulemaking process. Progress in rulemaking will be critical for FAA because, as we have reported in our recent reviews of the transition to the Next Generation Air Transportation System (NextGen), many of the proposals for safely enhancing the efficiency and capacity of the national airspace system will depend on timely development of rules and procedures.[30]

Ensuring the availability of adequate resources for icing-related R&D. NASA is a key source of R&D related to icing. The agency performs fundamental research related to icing in-house and sponsors such research at universities and other organizations. According to NASA officials, possible areas for increased support for R&D that could be helpful include pilot training, supercooled large droplet simulation (both experimental and computational), engine icing, and the effects of icing on future aircraft wing designs. However, the amount of NASA resources (including combined amounts from NASA's budget and from FAA for aircraft icing R&D at NASA facilities) and staffing for icing research have declined significantly since fiscal year 2005, as shown in figure 6. According to NASA officials, there were several contributing factors to the decline in available resources, including the fiscal constraints on the overall federal budget, a shift in the administration's priorities for NASA, as well as a restructuring within NASA's aeronautical programs to reflect the available resources and priorities. Because the outcomes of R&D are often a required precursor to the development of rules and standards, as well as technological innovation, a decline in R&D resources can delay actions that would promote safe operation in icing conditions. For example, FAA's chief scientist for icing told us the decline in NASA's icing research budget has adversely affected NASA's research to understand how icing affects various makes and models of aircraft in real time—research that would ultimately help pilots determine how to respond to specific icing encounters. He said that without NASA's research efforts, it would be uncertain who would conduct this and other potentially important icing research. In commenting on a draft of this report, the National Science Foundation agreed that this is a major concern and noted that icing-related research conducted by NASA has been extremely valuable.

[30]GAO, *Responses to Questions for the Record; Hearing on the Future of Air Traffic Control Modernization*, GAO-07-928R (Washington, D.C.: May 30, 2007) and *Next Generation Air Transportation System: Status of Transformation and Issues Associated with Midterm Implementation of Capabilities*, GAO-09-479T (Washington, D.C.: Mar. 18, 2009).

Figure 6: NASA Funding and Staffing for Icing-Related R&D, Fiscal Years 2005 to 2013, as of February 2010



Sources: GAO presentation of NASA data.

Notes: Amounts for fiscal years 2005 through 2009 represent actual allocations, while amounts for fiscal years 2010 through 2013 represent projected allocations. Funding data represent three sources of funding for icing research at NASA. According to NASA, complete data are available for one source, while data for another source are only available for fiscal years 2005 to 2010, and data for the third source are only available for fiscal years 2005 to 2009. Amounts do not reflect icing-related funds received or could be received through other government programs or external partnership (e.g., Boeing) agreements. The funding costs do not include amounts for staffing.

Ensuring that pilot training is thorough, relevant, and realistic. Another icing-related challenge to aviation safety is pilot training. Aviation experts told us that pilots are likely to encounter icing conditions beyond their aircraft's capabilities at least once in their career. Currently, icing must be covered in a commercial pilot's initial training and, while recurrent training may not always emphasize icing, it is covered on a rotational basis. Different weather conditions affect aircraft performance in a variety of ways, making it critical that pilots receive training relevant to the conditions they are likely to encounter. For example, it is important that regional airline operators provide region-specific training to their pilots as regional airline consolidations may cause pilots to fly a geographically wider variety of routes with more variation in weather conditions. Further, in February 2010, the Executive Air Safety Chairman of the Airline Pilots

Association International testified on the importance of pilots knowing the effects icing has on the controllability of the specific airplane they are flying. He stressed that, currently, the pilot community has inconsistent information and guidance when having to decide how to react after encountering in-flight icing conditions or whether to take off or proceed into reported freezing rain or drizzle. Furthermore, in commenting on a draft of this report, NASA said the current FAA written tests for pilot certification have little relevance to the competence required in icing and winter weather operations. For example, NASA said one issue is that the pilot-applicant can pass the test without answering weather-related questions correctly, but that even correct answers provide very little operational information compared with what a pilot needs to know when faced with icing. NASA said it has participated in developing materials to help fill this information gap and while the materials have been adopted by a number of users, they have not been endorsed by FAA. NASA believes that these or other expanded materials should be utilized and included as part of the formal pilot training requirement.

Regarding pilot training, in January 2010, the FAA Administrator said, "The flying public needs to have confidence that no matter what size airplane they board, the pilots have the right qualifications, are trained for the mission, are fit for duty. . . . We know we need to reexamine pilot qualifications to make sure commercial pilots who carry passengers have the appropriate operational experience—they need to be trained for the mission they are flying."[31] FAA has begun to take steps to address shortcomings in pilot training. For example, in January 2009, FAA issued a notice of proposed rulemaking to establish new training requirements, such as requiring the use of flight simulators for training flight crewmembers and requiring training on special hazards such as loss of control and controlled flight into terrain.[32] However, as of June 2010, FAA did not have a target date for issuing a final rule. In June 2009, FAA took

[31]J. Randolph Babbitt, *Focus and Vision: Moving Forward*, remarks as prepared for a speech before the Aero Club (Washington, D.C., January 26, 2010).

[32]74 Fed. Reg. 1280, Jan. 12, 2009. Currently, simulators are used to train pilots of large commercial airplanes for in-flight icing because it is not feasible to train in actual icing conditions, as they are difficult to predict and hazardous. However, reliance on simulators for training means that pilots may not be sufficiently prepared for a variety of real-world icing conditions. According to representatives of the Aerospace Industries Association, some characteristics of icing cannot currently be replicated, and to improve simulators, researchers need to develop engineering tools to characterize ice shapes such as those resulting from supercooled large droplets.

the additional step of issuing an action plan to improve airline safety and pilot training. The plan called for specially focused inspections of carriers' flight crew training and qualifications programs. In February 2010, the IG reported that these inspections were generally completed on time, but inspectors lacked guidance from FAA headquarters and surveillance questions were inadequate.[33] As a result, the IG reported that the consistency and quality of the inspections may not have been comprehensive enough to detect flaws in the carriers' training and qualifications programs.

Ensuring the collection and distribution of timely and accurate weather information. Improving the quality of weather information could reduce the safety risks associated with winter weather operations. Pilots and operators use weather forecasts to decide whether it is safe to start a flight or, once aloft, whether it is preferable to continue on to the destination or divert to an alternate airport. Weather experts explained that weather forecasters are still far from being able to precisely predict icing conditions in the atmosphere and the impact of such conditions on individual aircraft. For this reason, FAA said icing forecasters generally provide overly cautious forecasts that cover a broad area. While this serves to warn pilots that icing could occur, representatives of the Air Line Pilots Association said that too many false alarms result in pilots ignoring subsequent forecasts of icing. These representatives also said that pilots do not know when they are entering severe conditions, as they are only given generalized statements about icing conditions.

Providing pilots with accurate weather information has been a long-standing concern: FAA's 1997 *Inflight Aircraft Icing Plan* recommended improving the quality and dissemination of icing weather information to dispatchers and flight crews. Since 1997, FAA, in conjunction with NOAA and NCAR, has developed improved icing forecasting products. As previously mentioned, these icing forecasting products are now fully operational, yet FAA and others told us that further improvements to weather forecasts are still needed. Currently, NextGen weather researchers are focused on creating technology and procedures that enable forecasters to provide pilots with more precise and accurate predictions of icing conditions, which they believe will address the problem of pilots ignoring traditionally unreliable icing forecasts and

[33]Department of Transportation Inspector General, *Progress and Challenges With FAA's Call to Action for Airline Safety* (Washington, D.C., Feb. 4, 2010).

better communicate the existence of dangerous weather conditions to pilots.

Addressing the environmental impacts of deicing fluids. While critical to safe, efficient winter operations, continuing to keep aircraft and airport pavement free of ice and snow while complying with EPA's proposed rule on the use of deicing fluids could be challenging for affected airports.[34] These programs involve treating aircraft and airport pavement with millions of pounds of deicing and anti-icing compounds annually. These compounds contain chemicals that can harm the environment. Some airports can control deicing pollution by capturing the fluids used to deice aircraft using technologies such as AIP-funded deicing pads, where aircraft are sprayed with deicing fluids before takeoff and the fluids are captured and treated; drainage collection systems; or vacuum-equipped vehicles. Third-party contractors, rather than individual air carriers, are increasingly performing deicing operations at commercial airports. FAA does not currently have a process to directly oversee these third-party contractors but indicates that it has one under development.

In its official comments on EPA's proposed rule, an association of airports expressed several concerns, including that (1) complying with the proposed rule would require additional vehicles around terminals, taxiways, and runways to recover deicing fluid, potentially slowing or halting operations and posing a safety hazard; (2) the proposed rule offers no alternative means of compliance to airports which do not have enough space to construct deicing pads; and (3) EPA's estimate of the costs of complying with the proposed rule did not include several necessary expenditures, including certain infrastructure and maintenance costs and the cost of consultants or other staff needed to help comply with the rule. According to EPA, the agency worked closely with FAA in developing the proposed rule, which FAA determined would have no impact on the safety of operations. Several state environmental agencies supported the need for this type of rule, but some of the agencies believed that the proposal could be improved by, for example, including stricter requirements for the treatment of deicing fluid or by giving airports more time to comply with new requirements.

Developing a more integrated approach to effectively manage winter operations. FAA indicated that developing an integrated approach to

[34] 74 Fed. Reg. 44676, Aug. 28, 2009.

effectively manage winter operations is among its top challenges related to aviation icing. FAA said that, in conjunction with the aviation industry, it needs to begin focusing on winter operations holistically because there are many vital elements to safe operations in winter weather conditions, including airport surface conditions, aircraft ground deicing, aircraft in-flight icing and icing certification, dissemination of airport condition information, air traffic handling of aircraft in icing conditions, and air traffic arrival and departure sequencing. An academic expert on icing agreed with this view when he told us an integrated approach is critical because there are so many different players involved. Other industry stakeholders we contacted cited specific examples that demonstrated a lack of an integrated approach to winter operations. For example, representatives from a pilots' association told us air traffic control procedures at large airports cause aircraft to spend more time than necessary in icing conditions, which is a safety hazard for small aircraft. Representatives from the National Air Transportation Association told us consistent language does not exist across all stakeholders, with subjective terminology used to report runway conditions and in-flight icing encounters that could be interpreted in various ways by pilots. FAA stressed that it is important for FAA and the aviation industry to focus on how components of the aviation system interact and affect one another during winter operations and not view the components in isolation.

Conclusions

FAA and other aviation stakeholders have taken many steps to improve aviation safety in icing and winter weather conditions. These steps have likely contributed to the fact that large commercial airplanes have experienced few icing-related accidents since 1998. Nevertheless, the many reported icing incidents suggest that icing is an ongoing risk to aviation safety, including the safety of large commercial airplanes. Further, aviation stakeholders have identified challenges that if addressed, could improve safety. Among others, these challenges include improving the timeliness of FAA's winter weather rulemaking efforts, ensuring the availability of adequate resources for icing-related R&D, and developing a more integrated approach to effectively manage winter operations. Although FAA and other stakeholders are continuing their efforts to reduce safety risks associated with icing and winter weather operating conditions, these efforts could benefit from more formal and holistic planning. FAA has not formally updated its 1997 *Inflight Aircraft Icing Plan*, meaning the stakeholders do not have a consolidated and readily accessible source of information on the key in-flight icing actions FAA has under way or planned. Furthermore, the scope of the 1997 plan did not include icing issues occurring on the ground, yet contaminated runways resulting from icing and winter weather pose hazards to planes during takeoff and landing, and removing ice or preventing ice from forming on aircraft occurs not only during flight, but also on the ground prior to takeoff. A plan that addresses both in-flight and ground icing issues, as well as the challenges stakeholders identified for this report, would help FAA measure its ongoing and planned efforts against its goals for improving safety. Furthermore, a comprehensive plan could help identify gaps or other areas for improvement and assist FAA in developing an integrated approach to winter operations. Although stakeholders identified multiple challenges for this report, we believe several of them could be addressed in the plan.

Recommendation for Executive Action

To help facilitate FAA's and other stakeholders' efforts to address challenges to improving safety in icing and winter weather conditions, we recommend that the Secretary of Transportation direct the Administrator, FAA, to develop a comprehensive plan, in consultation with public and private stakeholders, to guide these efforts. The plan should focus on winter operations holistically, be clearly communicated to all affected parties, and include detailed goals, milestones, and time frames that can be used to gauge performance and progress, identify gaps, and determine areas for improvement. FAA should also periodically report to affected parties on its progress in implementing the plan, as well as any updates to the plan.

Agency Comments

We provided a draft of this report to the Department of Transportation (which contains FAA), the Department of Commerce (which contains NOAA), NTSB, NASA, and the National Science Foundation (which contains NCAR) for their review and comment. In response, the Department of Transportation agreed to consider our recommendation and provided technical comments which we incorporated as appropriate. The Department of Commerce and NTSB also provided technical comments which we incorporated as appropriate.

In commenting on a draft of this report, NASA emphasized the importance of updated and timely aircraft certification requirements and the need for research to develop computer models and simulations to provide the understanding needed to support new certification requirements. With respect to our recommendation, NASA said that while FAA's development of a comprehensive plan for winter operations is a good first step, NASA suggested that greater emphasis be placed on FAA's implementation activities once the plan is in place. NASA also provided technical comments which we incorporated as appropriate.

In its comments, the National Science Foundation (NSF) said our report adequately addresses the state of aircraft operations during winter. Of the challenges we identified, NSF said developing a more integrated approach to effectively manage winter operations is the most critical and will result in the most improvements to aviation safety and icing. NSF said that a number of universities, under funding from NSF, conduct research into the physics of icing and also had provided *in situ* measurements (using a storm penetration aircraft) of icing and other conditions associated with large convective storms. NSF indicated that our discussion of CIP and FIP as fully operational products illustrates that advances are being made, but that constant updates are needed as a result of additional research.

We are sending copies of this report to interested congressional committees, the Secretary of Transportation, the Secretary of Commerce, the Chairman of NTSB, the Administrator of NASA, and the Acting Director of the NSF. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you have any questions concerning this report, please contact me at (202) 512-2834 or dillinghamg@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

Gerald L. Dillingham, Ph.D.
Director, Physical Infrastructure Issues

List of Requesters

The Honorable John D. Rockefeller IV
Chairman
The Honorable Kay Bailey Hutchison
Ranking Member
Committee on Commerce, Science,
and Transportation
United States Senate

The Honorable James L. Oberstar
Chairman
The Honorable John L. Mica
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Byron L. Dorgan
Chairman
The Honorable Jim DeMint
Ranking Member
Subcommittee on Aviation Operations, Safety,
and Security
Committee on Commerce, Science,
and Transportation
United States Senate

The Honorable Jerry F. Costello
Chairman
The Honorable Thomas E. Petri
Ranking Member
Subcommittee on Aviation
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Charles E. Schumer
United States Senate

Appendix I: Objectives, Scope, and Methodology

We reviewed (1) the extent to which large commercial airplanes have experienced accidents and incidents related to icing and contaminated runways, (2) the Federal Aviation Administration's (FAA) inspection and enforcement activities related to icing, (3) the efforts of FAA and other aviation stakeholders to improve safety in icing and winter weather operating conditions, and (4) the challenges that continue to affect aviation safety in icing and winter weather operating conditions.

To review the extent to which large commercial airplanes have experienced accidents and incidents related to icing and contaminated runways, we analyzed data obtained from FAA, the National Transportation Safety Board (NTSB), and the National Aeronautics and Space Administration (NASA). More specifically, NTSB provided us both raw and summary data from its aviation accident database on accidents involving large commercial carriers, small commercial carriers, or private operators in which any of the following were cited as a cause of the accident, a contributing factor, or a finding: icing of the airframe and associated equipment and structures, engines and engine intakes, fuel lines, or carburetors; contamination of airport surfaces by snow or ice; and snow removal.[1] We analyzed this data to identify and remove several duplicate accident records. FAA and NASA provided us data from their aviation incident databases on incidents related to the same types of factors as the accidents we analyzed. We tabulated the incident data to determine the numbers of incidents by type of factor and by type of operator.

To review FAA's inspection and enforcement activities related to icing we obtained FAA's inspection and enforcement policies and analyzed data from FAA's inspection and enforcement databases. More specifically, to assess the timeliness of FAA's inspection-based assessments of large commercial carriers ground deicing programs under the Air Transportation Oversight System (ATOS), we obtained and analyzed data from the system to determine how many assessments were completed within FAA's required time frames. To determine the extent to which

[1]In determining the probable causes of an accident, NTSB seeks to consider all facts, conditions, and circumstances. Any information that contributes to the explanation of an accident is identified as a "finding" and may be further designated as either a "cause" or "factor." The term "factor" is used to describe situations or circumstances that contributed to the accident cause. Just as accidents often include a series of occurrences, the reasons why these occurrences lead to an accident may be the combination of multiple causes and factors. For this reason, a single accident record may include multiple causes and factors.

FAA's inspections found that large commercial carriers were in compliance with FAA's safety requirements, we analyzed inspection data from ATOS on inspectors' responses to compliance-related questions. We also analyzed data from ATOS on the results of inspectors' overall assessments of each large commercial carrier's compliance with ground deicing regulations. To determine the extent to which FAA had completed all required and planned inspections of large and small commercial carriers' ground deicing programs that were covered by the National Work Program Guidelines (NPG), we obtained and analyzed data from FAA's Program Tracking and Reporting Subsystem (PTRS) on the numbers of required and planned inspections that FAA completed, as well as those that it terminated or cancelled. To determine the enforcement actions that FAA initiated against carriers that violated icing-related regulations, we obtained and analyzed data on these actions from FAA's Enforcement Information System, including whether the actions were administrative, fines, or suspensions or revocations of carriers' operating certificates. For the cases that are closed, we analyzed data to determine the minimum, median, and maximum dollar amounts of fines and durations of suspensions.

To determine the efforts FAA and other stakeholders have undertaken to improve safety in icing and winter weather operating conditions and the challenges that remain, we interviewed government officials from FAA, NTSB, NASA, the National Oceanic and Atmospheric Administration (NOAA), and the National Center for Atmospheric Research (NCAR), as well as the Flight Safety Foundation and an academic expert from the University of Illinois. We also contacted a variety of industry representatives, as shown in table 6.

Table 6: Industry Groups We Contacted

Industry group name	Representation
Aerospace Industries Association	Represents manufacturers and suppliers of civil, military, and business aircraft.
Air Line Pilots Association, International	Represents the collective interests of pilots in commercial aviation in the United States and Canada.
Air Transport Association	Represents the nation's leading airlines.
Aircraft Owners and Pilots Association	Represents general aviation.
Airports Council International of North America	Represents local, regional, and state governing bodies that own and operate commercial airports in the United States and Canada.
General Aviation Manufacturers Association	Represents manufacturers of fixed-wing general aviation airplanes, engines, avionics, and components.

Industry group name	Representation
National Air Traffic Controllers Association	Represents air traffic controllers, engineers, and other safety-related professionals.
National Air Transportation Association	Represents the legislative, regulatory, and business interests of general aviation service companies.
National Business Aviation Association	Represents companies that rely on general aviation aircraft for business purposes.
Regional Airline Association	Represents North American regional airlines and the manufacturers of products and services supporting the regional airline industry.

Source: GAO, based on industry information.

We also reviewed key documents on the efforts undertaken by these entities, including FAA's 1997 *Inflight Aircraft Icing Plan* and a status update on the plan and FAA's other winter-weather initiatives that FAA developed at our request; FAA's 2009 report on its review of its rulemaking process; FAA's *Answering the Call to Action on Airline Safety and Pilot Training*; and the Environmental Protection Agency's proposed rule on the use of deicing fluids and related effluents, as well as public comments on the proposed rule submitted to the docket by Airports Council International of North America and several state environmental agencies. We also obtained and reviewed data related to several key stakeholder efforts, such as data on Airport Improvement Program (AIP) funding FAA has provided to airports to construct deicing facilities and to acquire aircraft deicing equipment; data from NTSB's recommendation database on the status of its recommendations related to aviation icing and winter weather; and data on NASA funding and staffing for icing research.

We conducted this review from August 2009 to July 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient and appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. To assess the reliability of the inspection and enforcement data that we received from FAA, we performed electronic testing of the data elements that we used, obtained and reviewed documentation about the data and the systems that produced them, and interviewed knowledgeable FAA officials. To assess the reliability of the accident data we received from NTSB and the incident data we received from FAA and NASA, we obtained and reviewed documentation about the data and the systems that produced them.

Appendix II: FAA's Funding to the Airport Improvement Program for 1999 to 2009, by State and City

State/City	Year	Acquire aircraft deicing equipment	Construct deicing containment facility	Total amount
Ark.				
Fairbanks	2003		√	**2,069,333**
Colo.				
Denver	2000		√	**299,974**
Denver	2001		√	**6,200,000**
Denver	2004		√	**7,700,000**
Denver	2005		√	**13,120,975**
Denver	2006		√	**2,634,739**
Conn.				
New Haven	2001		√	**67,092**
Iowa				
Dubuque	2006	√		**221,417**
Ill.				
Belleville	2005		√	**202,572**
Belleville	2009	√		**507,900**
Ind.				
Indianapolis	1999		√	**5,654,999**
Kans.				
Wichita	1999	√		**128,350**
Manhattan	2001	√		**37,438**
Manhattan	2002	√		**123,971**
Ky.				
Covington	1999		√	**1,210,000**
Covington	2000		√	**269,057**
Lexington	2000		√	**198,000**
Lexington	2001		√	**2,399,244**
Paducah	2007		√	**91,037**
Md.				
Baltimore	1999		√	**3,403,519**
Maine				
Bangor	2004		√	**399,599**
Bangor	2005		√	**1,384,222**
Mich.				
Detroit	2005		√	**2,950,000**

State/City	Year	Acquire aircraft deicing equipment	Construct deicing containment facility	Total amount
Detroit	2008		√	**3,800,000**
Detroit	2009		√	**1,889,237**
Kalamazoo	2004		√	**203,468**
Minn.				
Bemidji	2005		√	**12,065**
Bemidji	2005	√		**161,478**
Brainerd	2008	√		**204,250**
Hibbing	2005	√		**280,690**
International Falls	2007	√		**205,899**
Minneapolis	2001		√	**7,660,984**
Minneapolis	2003		√	**10,204,941**
St. Cloud	2000		√	**58,500**
St. Cloud	2007	√		**204,250**
Mo.				
Kansas City	2003		√	**150,000**
Kansas City	2005		√	**5,589,005**
Kansas City	2006		√	**4,463,462**
Mont.				
Bozeman	1999		√	**91,328**
Missoula	2008		√	**4,363,460**
N.C.				
Charlotte	1999		√	**145,051**
Kinston	2001	√		**167,943**
N.J.				
Morristown	2004		√	**1,579,259**
N.M.				
Roswell	2008	√		**116,051**
N.Y.				
Buffalo	2006		√	**816,891**
Buffalo	2008		√	**500,000**
Islip	2007		√	**46,550**
Islip	2009	√		**288,591**
Ithaca	2009	√		**113,735**
New York	2003		√	**6,856,488**
Newburgh	2000		√	**1,400,000**
Rochester	2000		√	**1,858,022**

State/City	Year	Acquire aircraft deicing equipment	Construct deicing containment facility	Total amount
Rochester	2001		√	**973,860**
White Plains	2003		√	**369,855**
White Plains	2003	√		**262,678**
White Plains	2007	√		**581,613**
White Plains	2008	√		**296,283**
White Plains	2009	√		**473,991**
Ohio				
Akron	2005		√	**4,993,313**
Akron	2006		√	**5,000,000**
Columbus	2002		√	**5,173,023**
Toledo	2005		√	**746,756**
Toledo	2006		√	**861,735**
Toledo	2007		√	**77,524**
Youngstown/Warren	2007		√	**22,609**
Youngstown/ Warren	2008	√		**246,687**
Okla.				
Tulsa	2004		√	**381,239**
Ore.				
Portland	2000		√	**6,173,126**
Portland	2001		√	**9,645,738**
Portland	2002		√	**488,743**
Penn.				
Bradford	2003	√		**144,425**
Harrisburg	2000	√		**86,920**
Latrobe	2006	√		**118,883**
Philadelphia	2000	√		**17,915,168**
Pittsburgh	2001		√	**1,000,000**
Pittsburgh	2002		√	**2,430,965**
Pittsburgh	2007		√	**6,115,219**
Pittsburgh	2008		√	**6,775,000**
State College	2002		√	**89,092**
State College	2003		√	**221,883**
State College	2004		√	**3,919,476**
Tenn.				
Memphis	2007		√	**1,440,412**

State/City	Year	Acquire aircraft deicing equipment	Construct deicing containment facility	Total amount
Memphis	2008		√	**286,591**
Nashville	1999		√	**1,356,970**
Nashville	1999	√		**214,294**
Nashville	2000		√	**832,306**
Nashville	2000	√		**131,416**
Nashville	2007		√	**44,491**
Tx.				
Beaumont/Port Arthur	2006	√		**88,825**
Dallas-Fort Worth	1999		√	**7,878,022**
Dallas-Fort Worth	2000		√	**1,223,254**
Dallas-Fort Worth	2003		√	**750,000**
Fort Worth	2003		√	**13,075**
Va.				
Roanoke	2002	√		**387,827**
Wash.				
Bellingham	1999		√	**75,000**
Wis.				
Eau Claire	2005	√		**220,000**
Green Bay	2001		√	**605,700**
W.Va.				
Clarksburg	2001		√	**66,825**
Clarksburg	2002		√	**230,683**
Clarksburg	2004	√		**220,139**
Huntington	1999		√	**577,789**
Wyo.				
Sheridan	1999		√	**58,850**

Source: GAO analysis of FAA data.

Appendix III: GAO Contact and Staff Acknowledgments

GAO contact

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Staff Acknowledgments

In addition to the contact above, other key contributors to this report were Sally Moino, Assistant Director; Laurel Ball; Richard Brown; Shareea Butler; Colin Fallon; David Goldstein; Brandon Haller; David Hooper; and Joshua Ormond.

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