National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 19, 2009

In reply refer to: A-09-21 through -28

Ms. Lynne A. Osmus
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

On September 28, 2007, about 1313 central daylight time,[1] American Airlines flight 1400, a McDonnell Douglas DC-9-82 (MD-82),[2] N454AA, experienced an in-flight engine fire during departure climb from Lambert-St. Louis International Airport (STL), St. Louis, Missouri. During the return to STL, the nose landing gear failed to extend, and the flight crew executed a go-around, during which the crew extended the nose gear using the emergency procedure. The flight crew conducted an emergency landing, and the 2 flight crewmembers, 3 flight attendants, and 138 passengers deplaned on the runway. No occupant injuries were reported, but the airplane sustained substantial damage from the fire. The scheduled passenger flight was operating under the provisions of 14 *Code of Federal Regulations* Part 121 on an instrument flight rules flight plan. Visual meteorological conditions prevailed at the time of the accident.[3]

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was American Airlines' maintenance personnel's use of an inappropriate manual engine-start procedure, which led to the uncommanded opening of the left engine air turbine starter valve (ATSV), and a subsequent left engine fire, which was prolonged by the flight crew's interruption of an emergency checklist to perform nonessential tasks. Contributing to the accident were deficiencies in American Airlines' Continuing Analysis and Surveillance System program.

Flight Crew Performance

During the flight, the pilots encountered an uncommanded opening of the ATSV followed by indications of an engine fire. In a short time, the pilots also encountered several other

[1] Unless otherwise indicated, all times in this report are central daylight time based on a 24-hour clock.

[2] Boeing Commercial Airplane Group bought McDonnell Douglas.

[3] For more information, see National Transportation Safety Board, *In-Flight Left Engine Fire, American Airlines Flight 1400, McDonnell Douglas DC-9-82, N454AA, St. Louis, Missouri, September 28, 2007,* Aircraft Accident Report NTSB/AAR-09/03 (Washington, DC: NTSB, 2009).

abnormal events, including electrical and hydraulic system anomalies and the nose landing gear's failure to extend. The investigation revealed that the flight crew did not perform several of the appropriate checklists, and they interrupted an emergency fire-related checklist.

Detection of and Response to the Left Engine ATSV-Open Light

According to cockpit voice recorder (CVR) evidence, about 74 seconds after the takeoff roll began and while the airplane was climbing through about 1,500 feet mean sea level, the first officer detected the illumination of the ATSV-Open light for the left engine. About 1 minute later (1313:55), the Left Engine Fire aural warning sounded, and the Left Engine Fire warning light illuminated. A review of the CVR transcript revealed no evidence that the flight crew performed any of the L or R Start Valve Open checklist items during the 53-second period from the detection of the ATSV-Open light to the onset of the Left Engine Fire warning.[4]

During the Before Takeoff checklist, the pilots checked the status of the annunciator panel, and they made no comments about the illumination of the ATSV-Open light at that time. The time that the ATSV-Open light illuminated also could not be determined through aircraft inspection or CVR or flight data recorder information. No direct evidence exists of when exactly the light illuminated during the 74 seconds between the application of takeoff power and the first officer's detection of the ATSV-Open light at 1313:02.[5] Therefore, the NTSB evaluated the pilots' likely allocation of attention during discrete events in this period to determine when the ATSV-Open light might have illuminated. For example, the first officer interacted with the digital flight guidance system (DFGS) three times (at 1311:48, 1312:34, and 1313:02) and only detected the annunciator the third time. When not interacting with the DFGS, both crewmembers were likely focused elsewhere in the cockpit or making radio communications; therefore, they likely would not have noticed illumination of the ATSV-Open light. Although it is possible that the illumination of the light coincided with its detection, it is also possible that the light illuminated at some time between the second (1312:34) and third time (1313:02) the first offer interacted with the DFGS and was not detected.

The ATSV-Open light is static in appearance and illuminates as amber words against a black background on a large annunciator panel. These characteristics can make it hard to detect the light during daytime conditions. The light remains illuminated after onset, but because the light does not flash, its initial illumination is the only means to capture a pilot's attention. Research has shown that the reliable and timely detection of abrupt onset events in the periphery is difficult because it depends on factors difficult to control, such as where a pilot's visual attention is focused.[6] In addition, competing visual demands, especially during high-workload

[4] In postlanding statements recorded by the CVR and during postaccident interviews, the pilots indicated that they thought that only a few seconds elapsed between the illumination of the ATSV-Open light and the Engine Fire warning.

[5] The proper operation of the ATSV Open light system could not be verified during postaccident inspections because the wiring harness within the nacelle sustained too much fire damage to confirm electrical signal continuity.

[6] R.A. Rensink, J.K. O'Regan, and J.J. Clark, "To See or Not to See: The Need for Attention to Perceive Changes in Scenes," *Psychological Science*, Vol. 8 (1997), pp. 368-373.

phases of flight, can prevent a pilot from actively scanning the annunciator panel. As a result, a light can go undetected for a varying amount of time.[7]

Regardless, once the light was detected, the pilots did not initiate the L or R Start Valve Open checklist. As pilot-in-command (PIC), the captain had the primary responsibility to address the abnormal condition and call for the associated checklist in a timely manner, and the first officer shared this responsibility. However, at the time of the accident, American Airlines guidance and training indicated that an open ATSV was an abnormal event that did not require immediate action. Further, when the first officer noticed the light, the pilots were involved in air traffic control (ATC) communications and configuration changes during a high-workload period. In addition, time is needed to assess a situation when an abnormal light illuminates.

The NTSB concludes that the pilots might not have immediately detected the ATSV-Open light illumination because of its location, static appearance, and color and that, once they detected the light, the pilots did not immediately respond to it because an open ATSV was considered an abnormal situation that did not require immediate action and they were involved in ATC communications and airplane configuration changes.

In August 2008, American Airlines initiated action to modify its MD-80 airplanes so that the onset of the ATSV-Open light would trigger the light,[8] which is located near the pilots' normal field of vision and, therefore, provides a more robust signal to quickly alert the pilots that a problem exists. A caution light would capture pilots' attention and lead pilots to scan the annunciator panel to determine the specific problem, something they would otherwise be less likely to do during a high-workload period. However, the NTSB recognizes that unintended consequences, such as high-speed rejected takeoffs, could result from coupling the ATSV-Open light to the Master Caution system because, if the Master Caution light came on late in the takeoff, it might give the pilots only seconds to determine if an aborted takeoff should occur and might lead them to abort unnecessarily. According to American Airlines, this risk would be mitigated by training its pilots to reject a takeoff only if the annunciator illuminates before the takeoff decision speed (V_1) is reached and, for later onsets, to initiate corrective action only after an operationally safe altitude is reached, which for this accident was about 1,200 feet mean sea level (about 580 feet above ground level [agl]). (The first officer detected the ATSV-Open light when the airplane was at an altitude of about 1,500 feet or about 880 feet agl.) Although these efforts would appear to provide American Airlines' pilots with a more reliable way to rapidly detect the onset of the ATSV-Open light, there is not sufficient evidence to determine that the rest of the MD-80 fleet should be modified. For example, an open ATSV does not necessarily result in an engine fire. Because of this, Boeing considers the current alerting method for an open-ATSV condition to be adequate.

The NTSB concludes that coupling the ATSV-Open light with the Master Caution system might increase pilots' ability to detect the presence of an abnormal ATSV condition; however, unintended consequences, such as aborted takeoffs, may occur and, therefore, more study is

[7] In postaccident interviews, the American Airlines MD-80 Fleet Training Manager stated that the ATSV-Open light could be hard to see and that he had observed pilots miss the presence of the annunciator in the simulator.

[8] Other lights, including the hydraulic temperature high or the hydraulic pressure low lights, are also coupled to the Master Caution system.

needed to determine whether the Federal Aviation Administration (FAA) should mandate the modification of the ATSV-Open light in the MD-80 fleet. Therefore, the NTSB recommends that the FAA evaluate the history of uncommanded ATSV-open events in the MD-80 fleet and the effectiveness of coupling the ATSV-Open light to the Master Caution system to determine whether all MD-80 airplanes need to be modified to couple the ATSV-Open light to the Master Caution system. Once the evaluation is completed, the FAA should require any necessary modifications.

Response to Left Engine Fire Warning and Subsequent Events

About 1313:55, about 1 minute after the first officer detected the ATSV-Open light, the Engine Fire aural warning sounded, and the Left Engine Fire warning light illuminated. After the Left Engine Fire warnings activated, the first officer contacted ATC to report the emergency and the flight's immediate return to STL. When the first officer asked the captain about task allocation, the captain told him to "run the checklist" and stated that he, the captain, would fly the airplane. The captain did not indicate who should handle radio communications, even though, as PIC, it was his responsibility to allocate tasks. About 3 seconds later, before starting the checklist, the first officer engaged in communications with ATC. During emergency conditions, task allocation should change to better manage workload and effectively resolve problems. The American Airlines Aircraft Operating Manual (AOM) stated that, during an emergency, the captain should designate a flying pilot, who should not perform other duties that could detract from airplane control. However, the guidance did not explicitly address whether the flying pilot or the pilot monitoring should be responsible for radio communications during emergency situations. This ambiguity might have contributed to the misallocation of tasks during the accident flight, specifically, the first officer's handling of radio communications while conducting the checklist.

About 1314:50 (about 54 seconds after the fire warning sounded), the CVR recorded the first officer calling out, "autothrottle off," which is the first item on the Engine Fire/Damage/Separation checklist. The first officer then called for the left engine throttle to be placed in the idle position, which is the second item on the checklist. Shortly after the captain moved the throttle, ATC contacted the flight crew, and the first officer interrupted performance of the checklist for about the next 38 seconds to respond to several ATC queries. Subsequently, without asking the first officer the status of the Engine Fire/Damage/Separation checklist, the captain transferred control of the airplane to the first officer because he wanted to brief the flight attendants, even though according to the checklist, this task was to be completed after all critical items, including shutting off the fuel supply to the engine and stabilizing any possible in-flight fire, had been accomplished.

The sustained interruption of the checklist occasioned by the ATC communications provided an opportunity for the captain to proceed to a noncritical task and for both pilots to fail to recognize that the critical items on the checklist had not been completed. Research has shown that interruptions can distract pilots and impede their completion of tasks because it becomes more difficult for them to maintain an awareness of what steps remain to be performed.[9] The

[9] K. Dismukes, "Concurrent Task Management and Prospective Memory: Pilot Error as a Model for the Vulnerability of Expert," *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting* (2006) pp. 901-913.

NTSB notes that the circumstances did not warrant further interrupting the checklist to brief the flight attendants because the event occurred during the initial climb, which meant that the cabin was in its takeoff configuration with passengers and flight attendants in their seats and carry-on baggage and carts stowed. As a result, the time needed to prepare for an evacuation would have been minimal.

After the captain briefed the flight attendants, the pilots made remarks about the valve indications, and the first officer continued to handle communications with ATC. CVR evidence clearly shows that handling the radio communications affected the first officer's ability to complete the Engine Fire/Damage/Separation checklist. The first officer could have taken steps to ameliorate the situation. For example, he could have told ATC to stand by so that he could complete the critical items on the checklist, or he could have handed off communications to the captain. However, as PIC, the captain should have recognized that handling the radio communications was making it difficult for the first officer to run the checklist and that he, the captain, could handle ATC communications without interfering with airplane control.[10]

More than 2 minutes after the captain interrupted the Engine Fire/Damage/Separation checklist, the CVR recorded the first officer resuming its performance as the captain took back control of the airplane. Before the third item could be acknowledged by the captain, the aural fire warning again activated about 1317:02. About 1317:16, as a result of the electrical anomalies caused by the fire, the captain detected a reverser-unlocked annunciator, the cockpit door opened, and the power transfer[11] occurred, all of which further distracted the pilots from the checklist.

The increased time allocated to running the Engine Fire/Damage/Separation checklist as a result of interruptions also increased the pilots' workload as the situation deteriorated. During the final interruption, electrical problems resulting from the engine fire caused some instrumentation loss, the illumination of multiple annunicators, and the aforementioned malfunctioning of the cockpit door, all of which increased the pilots' workload. Coping with partial instrumentation increased the captain's flying workload, and the multiple annunciators[12] increased both pilots' troubleshooting workload by creating confusion about the actual state of the airplane and forcing the pilots to constantly reassess the situation. Responding to the malfunctioning cockpit door also increased the pilots' workload and distracted them during their efforts to configure the airplane for landing.[13]

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[10] During normal operations, pilots have been observed trading assigned duties, such as radio communications, to prevent the pilot not flying from being interrupted during high-priority tasks and to manage workload. For example, see the 2001 research report by D.L. Damos and B.G. Tabchnick titled "Cockpit Task Prioritization: Jump Seat Observations,"published by Damos Research Associates, Los Angeles.

[11] Power transfer is a condition in which loads normally powered by the left side of the electrical system start to be powered by the right side.

[12] The captain estimated that two-thirds of the annunciators were illuminated and, therefore, he considered the information useless. The off-duty pilot also stated that most of the annunciator lights were on when he entered the cockpit. Postaccident evaluations using an American Airlines simulator suggested that about one-third of the annunciators were illuminated.

[13] Although the open cockpit door should have been a low priority task, since September 11, 2001, pilots have been acutely aware of the importance of securing the cockpit, and this likely influenced the pilots' behavior.

As noted, the workload associated with ATC communications was also relatively high during this portion of the flight. After the accident, the captain described the workload during the event "[as] busy as he could handle at the time." The first officer stated that it was an "extremely compressed period of time and they had a lot to do." The pilots could have used various methods to manage the increasing workload but primarily used task shedding. For example, as noted previously, the pilots did not complete several checklists, most likely because they were focused on flying the airplane and communicating with ATC and because of the workload and stress associated with addressing the emergency situation. However, the NTSB notes that, after the go-around, the captain did request that the off-duty pilot come to the cockpit, which was a good decision because it reduced each pilots' workload. The off-duty pilot helped with flight attendant and passenger communications and troubleshooting the nose landing gear situation. After the accident, the captain stated that he felt that they had completed the items needed to safely land the airplane.

The NTSB concludes that the pilots failed to properly allocate tasks, including checklist execution and radio communications, and they did not effectively manage their workload, which adversely affected their ability to conduct essential cockpit tasks, such as completing appropriate checklists. The NTSB further concludes that no preexisting indicators in the pilots' training or performance histories were found that could explain their poor performance during the accident flight. The NTSB recommends that the FAA require principal operations inspectors to review their operators' pilot guidance and training on task allocation and workload management during emergency situations to verify that they state that, to the extent practicable, the pilot running the checklists should not engage in nonessential operational tasks, such as radio communications.

Retraction of the Fire Handle

After landing, the pilots had to wait for a tug to tow the airplane to the terminal. While waiting for the tug, the first officer opened the left pneumatic crossfeed valve to provide air to the cabin. Shortly thereafter, aircraft rescue and firefighting personnel informed the pilots that fuel had spilled out of the engine area onto the ground, and the first officer pulled the left engine shutoff valve.

According to the Boeing MD-80 Flight Crew Operating Manual,[14] opening the pneumatic crossfeed valve on the MD-82 airplane causes the associated engine fire handle to retract. In this case, opening the pneumatic crossfeed valve caused the left engine fire handle to retract and fuel to be reintroduced to the left engine area. Although the American Airlines AOM indicated that the fire handle was mechanically linked to the pneumatic crossfeed lever and pilots are told during training that pulling the fire handle will mechanically shut off the pneumatic crossfeed valve, American Airlines' manuals and training did not indicate that opening the crossfeed valve causes the fire handle to retract, reversing the shutoff of fuel.

The NTSB concludes that the first officer did not have a clear understanding of the relationship between the pneumatic crossfeed handle and the engine fire handle, most likely because of inadequate company guidance and training on the issue; this resulted in the first

[14] Manufacturer's flight crew operating manuals are not generally made available to flight crews. Instead, crews must rely on information provided by operators in their training and manuals.

officer inadvertently reintroducing fuel to the left engine, creating potential unnecessary risk of fire. As a result of this accident, the FAA issued Safety Alert for Operators (SAFO) 08018, which explained the fire handle characteristics of DC-9, MD-80, and MD-90 series airplanes and the relationship of the engine fire handle and the pneumatic crossfeed valve. The SAFO recommended that operators review their training and operating manuals to ensure that the design and interrelationship of the systems affected by the fire handle are adequately explained. It further recommended that they add a caution to their checklists stating that opening the crossfeed handle will retract the fire handle and potentially reintroduce fuel to a fire.

The NTSB commends the FAA for issuing SAFO 08018; however, the actions recommended in a SAFO are not mandatory, and more permanent action is warranted to prevent the recurrence of a potential unnecessary risk of fire. Therefore, the NTSB recommends that the FAA require MD-80 series airplane operators to incorporate information about the relationship between the pneumatic crossfeed valve and the engine fire handle into their training programs and written guidance.

Multiple Abnormal and Emergency Situations Training

The pilots might not have been faced with multiple problems if they had completed the emergency fire-related checklist, adequately allocated tasks, such as radio communications, and managed their workload. If the pilots had completed the emergency fire-related checklist in a timely manner, they could have precluded the electrical anomalies, including the problems with the cockpit door opening, and the hydraulic problems, including the failure of the nose landing gear to extend.

The pilots ultimately had to manage and prioritize cascading failures after interrupting the Left Engine Fire checklist, increasing their workload to beyond what would normally be required to manage a single-system problem. American Airlines training was conducted under an Advanced Qualification Program that did not include multiple emergencies training; however, it did incorporate training on an emergency event that produced associated abnormal conditions. After the accident, the company began working on a formal proposal to the FAA to add multiple emergencies to its training program.

Research demonstrates that emergency situations increase workload and require additional effort to manage effectively because of the stress involved and the lack of opportunity for pilots to practice these skills compared to those used in normal operations.[15] The National Aeronautics and Space Administration Emergency and Abnormal Situations (EAS) study noted that, during high-workload conditions, performance deficiencies, including narrowing of attention and impairment of short-term memory, could result from inherent limitations in cognitive processes and the effect of stress on human performance. The EAS study further noted that pilots may jump to the wrong item or checklist when dealing with the many distractions, interruptions, and competing demands for attention that typically occur during emergency or abnormal situations and that realistic interruptions and distractions needed to be incorporated into training.

[15] R.K. Dismukes, G.E. Young, and R.L. Sumwalt, "Cockpit Interruptions and Distractions: Effective Management Requires a Careful Balancing Act," *ASRS Directline*, Vol. 10 (1998) pp 4-9.

Industry has not universally accepted the need for multiple emergencies training. Boeing and the FAA have both indicated that such training could be "negative" because it might overload a student. They further argue that training to student failure or saturation should be avoided, especially if the multiple system failures faced by the student seem artificial. However, the NTSB notes that, if the system failures are layered in such a way that they would be linked normally to inaction or collateral damage, such training may not be problematic. Additionally, using line operational evaluations derived from actual events involving multiple emergencies may not be negative training.

The NTSB acknowledges the concerns raised by Boeing and the FAA and recognizes that operators have a limited amount of time to allocate to this type of training. However, the initial efforts of the EAS study, the circumstances of this accident, and other accidents and incidents suggest that pilots could benefit from the chance to develop the skills and decision-making abilities needed during multiple systems failures, competing task demands, and increased workloads and from knowing the possible consequences of interrupting or deviating from an emergency checklist and not taking timely corrective action during single or multiple emergency situations.

The NTSB concludes that improved pilot training methods for responding to multiple systems failures, competing task demands, and increased workload would help pilots develop the skills and decision-making abilities needed during both single and multiple abnormal and emergency situations. Therefore, the NTSB recommends that the FAA establish best practices for conducting both single and multiple emergency and abnormal situations training. The NTSB further recommends that, once the best practices for both single and multiple emergency and abnormal situations training asked for in Safety Recommendation A-09-24 have been established, the FAA require that these best practices be incorporated into all operators' approved training programs.

Emergency Evacuation Preparedness

After landing, the airplane was not configured to facilitate an evacuation. If evacuation had become necessary, the aft galley and tailcone exits would not have been usable because of the engine fire, and, at different times during the event, the L1 evacuation slide was not available because the airstairs were either parked in front of the door or the slide was disarmed. To maintain readiness during unusual events that do not require an immediate evacuation, pilots and flight attendants should continually assess the situation for changes by actively exchanging information about conditions inside and outside of the airplane to maintain readiness to evacuate if necessary.

After the accident, American Airlines revised its procedures to ensure that, when an airplane is stopped away from the gate after a significant in-flight event, pilots establish a configuration and mindset that would allow them to rapidly perform an evacuation and to maintain those conditions until the situation has been resolved. Pilots are instructed to configure the airplane up to the point of commanding an evacuation. The NTSB commends American Airlines' change of its operational procedures to address this safety issue.

The NTSB concludes that operational procedures requiring that an airplane be configured for an evacuation when it is stopped away from the gate after a significant event would help expedite an emergency evacuation if one became necessary. Therefore, the NTSB recommends that the FAA require that operators provide pilots with guidance requiring that pilots and flight attendants actively monitor exit availability and configure the airplane and cabin for an evacuation when the airplane is stopped away from the gate after a significant event to help expedite an emergency evacuation if one becomes necessary.

Flight and Cabin Crew Communication Issues

CVR evidence and postaccident statements indicate that the flight attendants did not detect smoke or fumes in flight. However, during the flight, the two flight attendants seated in the aft cabin did discuss hearing some popping noises that they thought could be associated with the left engine, but they did not convey this information to the cockpit or the lead flight attendant. At the time that the noises were heard, the pilots were shutting down the left engine and using the fire-extinguishing agent, and, therefore, it is unlikely that this information would have changed the outcome because the information was consistent with the known situation. Regardless, the NTSB is concerned that the information was not conveyed to the cockpit, as required by proper crew resource management (CRM) procedures and company guidance that all crewmembers provide pertinent information to the captain to help in decision-making.

Further, after landing, the pilots did not actively seek information from the flight attendants because they believed that the flight attendants would pass any significant information to them.[16] However, long after the fuel spill, during the debriefing on the ground, a flight attendant stated that she had smelled fuel earlier, but she did not pass this information to the cockpit when it happened, which was, again, inconsistent with the pilots' expectations and with company guidance and proper CRM.

The NTSB has had longstanding concerns about the need for effective communications between pilots and flight attendants and has issued numerous safety recommendations and reports on this subject.[17] For example, the NTSB's report on the December 20, 1995, Tower Air accident at John F. Kennedy International Airport in which the airplane departed the runway during an attempted takeoff highlighted communication problems between the cockpit and cabin.[18] The report noted that the flight attendants did not relay to the cockpit pertinent information, including that an engine had separated, significant floor intrusion had occurred above the nose gear, a flight attendant had been seriously injured, and the public address system in the aft cabin had failed.

[16] The captain stated during postaccident interviews that, if there had been smoke or fumes in the cabin during or after the flight, he knew that the flight attendants would not have hesitated to tell him.

[17] National Transportation Safety Board, *Emergency Evacuation of Commercial Airplanes*, Safety Study NTSB/SS-00/01 (Washington, DC: NTSB, 2000).

[18] National Transportation Safety Board, *Runway Departure During Attempted Takeoff, Tower Airlines Flight 41, Boeing 747-136, N605FF, JFK International Airport, New York, December 20, 1995,* Aircraft Accident Report NTSB/AAR-96-04 (Washington, DC: NTSB, 1996).

The issue of communication has also been examined by the research community[19] and by industry training. However, this accident shows that this issue needs to be addressed further. Advisory Circular (AC) 120-48, "Communication and Coordination Between Flight Crewmembers and Flight Attendants," which provides guidance on how to handle and avoid common problems that occur in coordination among flight crewmembers and flight attendants, is the most recent AC focused on best practices for cockpit and cabin communications during normal and emergency situations; yet, it was issued more than 20 years ago and has not been updated; therefore, it does not reflect current industry knowledge based on research and lessons learned from relevant accidents and incidents.[20] The AC also does not address the communication and coordination issues associated with the environment of increased security in which flight crews now work as a result of the events on September 11, 2001.

The NTSB concludes that, during the emergency situation, the flight attendants did not relay potentially pertinent information to the captain in accordance with company guidance and training. The NTSB recommends that the FAA revise AC 120-48 to update guidance and training provided to flight and cabin crews regarding communications during emergency and unusual situations to reflect current industry knowledge based on research and lessons learned from relevant accidents and incidents over the last 20 years.

Inadequate Air Turbine Starter Valve-Air Filter Inspection Criteria

As a result of this investigation and a subsequent uncommanded ATSV-open event in Salt Lake City, Utah,[21] American Airlines sent seven serviceable[22] ATSV-air filters to the NTSB for evaluation. Three of the seven ATSV-air filters revealed evidence of the onset of fatigue in the filter elements' outer mesh. In addition, American Airlines sent 15 serviceable ATSV-air filters to PTI, the ATSV-air filter manufacturer, for bubble testing and visual inspections, which were performed in accordance with the PTI Component Maintenance Manual (CMM). The testing and inspections revealed that five of the filters had damaged mesh and required replacement. The NTSB also determined that the early-stage fatigue fractures within the outer mesh were too small to be seen by the naked eye or when using the 5- to 7-power magnification recommended in the PTI CMM. In fact, a 40-power magnification was required to identify some early-stage fatigue areas in the outer mesh. In addition, PTI found that the approved bubble test method did not adequately detect early-stage fatigue cracks in the filter. The NTSB notes that inspection guidelines do not require an inspection of the inner mesh; however, this is understandable given

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[19] See, for example, R.D. Chute's and E.L. Wiener's "Cockpit-Cabin Communication: Shall We Tell the Pilots?" in *The International Journal of Aviation Psychology*, Vol. 6(3) (1996) pp. 211-231.

[20] The NTSB notes that AC 120-51E, "Crew Resource Management Training," briefly addresses the importance of effective flight crew and flight attendant communications and states that "communications and coordination problems between cockpit crewmembers and flight attendants continue to challenge air carriers and the FAA." AC 120-48 is referenced in AC 120-51E as related reference material.

[21] On January 23, 2008, the right engine ATSV-Open and Fire warning lights illuminated during climbout from Salt Lake City International Airport (SLC), Salt Lake City, Utah. No fire was found upon return to SLC. An on-ground inspection revealed damage to the air turbine starter and engine case. The airplane had no history of ATSV problems. The filter element was found completely detached from its base. The ATSV and ATSV-air filter were replaced, and no repeat events occurred. The NTSB investigated the SLC event because, similar to the American Airlines flight 1400 event, a fire warning and an uncommanded ATSV opening occurred during the flight.

[22] A serviceable component is one that came from an airplane that was in operation.

that it is hidden from view and cannot be adequately inspected for evidence of fatigue. The NTSB is concerned that ATSV-air filters cannot be adequately inspected, which may lead to future problems.

The NTSB concludes that the Boeing and PTI inspection criteria for the ATSV-air filter are inadequate to detect early-stage fatigue fractures of the outer mesh of the filter element and that, because of the ATSV-air filter design, the inner mesh of the filter element cannot be inspected for evidence of fatigue. Based on the investigation findings, American Airlines replaced the ATSV-air filters on its entire fleet of MD-82 aircraft. However, because the ATSV-air filter cannot be adequately inspected for fatigue damage, further action is warranted. Therefore, the NTSB recommends that the FAA require Boeing to establish an appropriate replacement interval for ATSV-air filters installed on all MD-80 series aircraft.

Therefore, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Evaluate the history of uncommanded air turbine starter valve (ATSV)-Open events in the MD-80 fleet and the effectiveness of coupling the ATSV-Open light to the Master Caution system to determine whether all MD-80 airplanes need to be modified to couple the ATSV-Open light to the Master Caution system. Once the evaluation is completed, require any necessary modifications. (A-09-21)
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> Require principal operations inspectors to review their operators' pilot guidance and training on task allocation and workload management during emergency situations to verify that they state that, to the extent practicable, the pilot running the checklists should not engage in additional nonessential operational tasks, such as radio communications. (A-09-22)
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> Require MD-80 series airplane operators to incorporate information about the relationship between the pneumatic crossfeed valve and the engine fire handle into their training programs and written guidance. (A-09-23)
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> Establish best practices for conducting both single and multiple emergency and abnormal situations training. (A-09-24)
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> Once the best practices for both single and multiple emergency and abnormal situations training asked for in Safety Recommendation A-09-24 have been established, require that these best practices be incorporated into all operators' approved training programs. (A-09-25)
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> Require that operators provide pilots with guidance requiring that pilots and flight attendants actively monitor exit availability and configure the airplane and cabin for an evacuation when the airplane is stopped away from the gate after a significant event to help expedite an emergency evacuation if one becomes necessary. (A-09-26)

Revise Advisory Circular 120-48, “Communication and Coordination Between Flight Crewmembers and Flight Attendants,” to update guidance and training provided to flight and cabin crews regarding communications during emergency and unusual situations to reflect current industry knowledge based on research and lessons learned from relevant accidents and incidents over the last 20 years. (A-09-27)

Require Boeing to establish an appropriate replacement interval for air turbine starter valve air filters installed on all MD-80 series aircraft. (A-09-28)

The NTSB also issued a safety recommendation to American Airlines.

In response to the recommendations in this letter, please refer to Safety Recommendations A-09-21 through A-09-28. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our Tumbleweed secure mailbox procedures. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Acting Chairman ROSENKER and Members HERSMAN, HIGGINS, and SUMWALT concurred with these recommendations. Member Sumwalt filed a concurring statement, which is attached to the aviation accident report for this accident. He was joined by Acting Chairman Rosenker.

[Original Signed]

By: Mark V. Rosenker
Acting Chairman

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
A-09-024	1	AAR-12-01	6/18/2012	Runway Overrun of American Airlines Flight 2253, Boeing 757-200, N668AA	Jackson Hole	WY	12/29/2010

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
A-09-025	1	AAR-12-01	6/18/2012	Runway Overrun of American Airlines Flight 2253, Boeing 757-200, N668AA	Jackson Hole	WY	12/29/2010

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
A-09-027	1	AAR-16-02	10/6/2016	Runway Excursion During Landing	New York	New York	3/5/2015
A-09-027	2	AAR-18-01	2/6/2018	Uncontained Engine Failure and Subsequent Fire, American Airlines Flight 383, Boeing 767-323, N345AN	Chicago	Illinois	10/28/2016