National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 21, 2010
In reply refer to: A-10-62 through -86

The Honorable J. Randolph Babbitt
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On January 15, 2009, about 1527 eastern standard time,[1] US Airways flight 1549, an Airbus Industrie A320-214, N106US, experienced an almost total loss of thrust in both engines after encountering a flock of birds and was subsequently ditched on the Hudson River about 8.5 miles from LaGuardia Airport (LGA), New York City, New York. The flight was en route to Charlotte Douglas International Airport (CLT), Charlotte, North Carolina, and had departed LGA about 2 minutes before the in-flight event occurred. The 150 passengers, including a lap-held child, and 5 crewmembers evacuated the airplane via the forward and overwing exits. One flight attendant and four passengers received serious injuries, and the airplane was substantially damaged. The scheduled, domestic passenger flight was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 on an instrument flight rules flight plan. Visual meteorological conditions prevailed at the time of the accident.

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was the ingestion of large birds into each engine, which resulted in an almost total loss of thrust in both engines and the subsequent ditching on the Hudson River. Contributing to the fuselage damage and resulting unavailability of the aft slide/rafts were (1) the Federal Aviation Administration's (FAA) approval of ditching certification without determining whether pilots could attain the ditching parameters without engine thrust, (2) the lack of industry flight crew training and guidance on ditching techniques, and (3) the captain's resulting difficulty maintaining his intended airspeed on final approach due to the task saturation resulting from the emergency situation.

Contributing to the survivability of the accident was (1) the decision-making of the flight crewmembers and their crew resource management during the accident sequence; (2) the fortuitous use of an airplane that was equipped for an extended overwater (EOW) flight, including the availability of the forward slide/rafts, even though it was not required to be so equipped; (3) the performance of the cabin crewmembers while expediting the evacuation of the

[1] Unless otherwise noted, all times in this letter are eastern standard time based on a 24-hour clock.

airplane; and (4) the proximity of the emergency responders to the accident site and their immediate and appropriate response to the accident.[2]

Engine Issues

General

About 1 minute 37 seconds into the flight, both of the airplane's CFM International CFM56-5B4/P engines ingested birds into the engine cores.[3]According to flight data recorder (FDR) data, the bird encounter occurred when the airplane was at an altitude of 2,818 feet above ground level and a distance of about 4.5 miles north-northwest of the approach end of runway 22 at LGA. The engines were certificated to withstand the ingestion of birds of a specified weight in accordance with the certification standards and still produce sufficient power to sustain flight. However, during this event, each engine ingested at least two Canada geese weighing about 8 pounds each, which significantly exceeded the certification standards, and neither engine was able to produce sufficient power to sustain flight after ingesting these birds.

In-Flight Engine Problem Diagnostics

FDR data indicated that, although the engine power and fuel flow decreased immediately after the bird ingestion, both engines' low-pressure compressor spools continued to rotate, and no loss of combustion occurred. According to FDR and cockpit voice recorder (CVR) data, after the bird ingestion, the first officer followed the Engine Dual Failure checklist and spent about 30 to 40 seconds trying to relight the engines; however, since engine combustion was not lost, these attempts were ineffective in that they would not fix the problem, and the N_2 speeds could not increase during the remainder of the flight. The flight crew was unaware that the extent and type of the engine damage precluded any pilot action from returning them to operational status. If the flight crewmembers had known this, they could have proceeded to other critical tasks, such as completing only the US Airways Quick Reference Handbook (QRH) Engine Dual Failure checklist items applicable to the situation.

The NTSB notes that it is unreasonable to expect pilots to properly diagnose complex engine problems and take appropriate corrective actions while they are encountering an emergency condition under critical time constraints. Many modern engines are equipped with engine sensors and full-authority digital engine controls (FADEC) that can be programmed to advise pilots about the status of an engine so that they can respond better to engine failures.

However, currently, no commercially available engines have diagnostic capabilities to identify the type of engine damage (sensors and FADECs can only identify that a problem exists) and recommend mitigating or corrective actions to pilots; yet, work has been performed to

[2] For more information, see *Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River, US Airways Flight 1549, Airbus A320-214, N106US, Weehawken, New Jersey, January 15, 2009,* Aircraft Accident Report NTSB/AAR-10/03 (Washington, DC: National Transportation Safety Board, 2010), which will be available on the NTSB's website at <http://www.ntsb.gov/publictn/2010/AAR1003.pdf>.

[3] CFM is a partnership between General Electric (GE) in the United States and Société Nationale d'Etude et de Construction de Moteurs d'Aviation (Snecma) in France. The engines were jointly designed and manufactured in the United States and Europe. The CFM56 product line name is a combination of the two parent companies' commercial engine designations: GE's CF6 and Snecma's M56.

develop this technology for both military and civilian applications. For example, in 1998, the Department of the Navy, in conjunction with industry and the FAA, initiated the Survivable Engine Control Algorithm Development project, which was tasked, in part, to develop technology that would inform flight crews about an engine's condition following foreign-object or bird ingestion that resulted in engine gas path damage. The intent was to use existing engine sensors to define the type of engine damage and then apply appropriate mitigation through changing control schedules within the FADEC. Although a successful demonstration of this technology was conducted on the U.S. Navy's General Electric (GE) F414 turbofan engine, the project was terminated because of a lack of funding. In 2007, similar work was conducted on the GE T700 turboshaft engine; however, this project was also terminated before it was completed because of funding shortfalls.

Commercial applications for this type of technology were investigated in 2002 by the National Aeronautics and Space Administraton's (NASA) Aviation Safety and Security Program, which initiated the CEDAR (Commercial Engine Damage Assessment and Reconfiguration) project using a GE CF6-80C2 engine to develop damage detection algorithms. Again, initial efforts were terminated because of a lack of funding and shifted priorities.

The NTSB concludes that, if the accident engines' electronic control system had been capable of informing the flight crewmembers about the continuing operational status of the engines, they would have been aware that thrust could not be restored and would not have spent valuable time trying to relight the engines, which were too damaged for any pilot action to make operational. Therefore, the NTSB recommends that the FAA work with the military, manufacturers, and NASA to complete the development of a technology capable of informing pilots about the continuing operational status of an engine. The NTSB further recommends that, once the development of the engine technology has been completed, as asked for in Safety Recommendation A-10-62, the FAA require the implementation of the technology on transport-category airplane engines equipped with FADECs.

CFM56-5B4/P Bird-Ingestion Certification Tests

Each accident engine ingested one 8-pound bird into its core, preventing the engines from providing sufficient thrust to sustain flight, indicating that an engine of this size cannot withstand the ingestion of such a large bird into the core and continue to operate. Further, informal discussions with industry and the FAA revealed that it would not be practical to build an engine that could withstand ingesting a bird of this size into the core because of performance and weight penalties that such a design would entail. These discussions also revealed that ingesting one 2 1/2-pound bird into the engine core, which is the current engine core ingestion test requirement, is already considered a stringent test of the engine core. The NTSB concludes that the size and number of the birds ingested by the accident engines well exceeded the current bird-ingestion certification standards.

The accident event highlighted other considerations that could be addressed during the tests related to small, medium, and large flocking birds. These considerations are discussed below.

The test requirements contained in 14 CFR 33.76(c) for the ingestion of small and medium flocking birds require that, for an engine of this size, one 2 1/2-pound bird be volleyed into the core and four 1 1/2-pound birds be volleyed at other locations on the fan disk. Each accident engine ingested one 8-pound Canada goose through to its core, much more than the weight used in the current certification tests; therefore, the accident engines sustained a significantly greater impact force than that for which they were certificated. FDR data indicated that the fan speed of both engines just before the bird ingestion was only about 80 percent, which is consistent for the airplane and atmospheric conditions at that point in the flight and is well below the bird-ingestion test fan-speed requirement of 100 percent.

Current Section 33.76(c) small and medium flocking bird certification tests require that 100-percent fan speed be used; this condition involves the highest kinetic energy of the bird relative to the fan blade, which is likely the most critical condition for damage to the fan blade itself. However, an additional consideration for the severity of a core ingestion event is the volume or bird mass. Therefore, the lowest operational fan speed should be used during the tests related to small and medium flocking birds so that a larger portion of the bird mass passes through the fan blades. Additionally, a slower fan speed would cause less centrifuging of the bird mass as it passes through the fan, which would allow a larger portion of the bird mass to pass through to the inlet guide vanes and other core components, causing higher impact forces on them. Reducing the fan speed during the certification tests to that expected during takeoff conditions would allow more bird mass to enter the engine core.

The NTSB concludes that the current small and medium flocking bird tests required by 14 CFR 33.76(c) would provide a more stringent test of the turbofan engine core resistance to bird ingestion if the lowest expected fan speed for the minimum climb rate were used instead of 100-percent fan speed because it would allow a larger portion of the bird mass to enter the engine core. Therefore, the NTSB recommends that the FAA modify the 14 CFR 33.76(c) small and medium flocking bird certification test standard to require that the test be conducted using the lowest expected fan speed, instead of 100-percent fan speed, for the minimum climb rate.

Current Section 33.76(d) large flocking bird certification tests require the ingestion of one large flocking bird. However, during this test, the bird is not directed into the core; therefore, only the fan blades, flammable fluid lines, and support structure are tested. Further, the test is limited to engines with inlet areas greater than 3,875 square inches; smaller transport-category airplane engines, such as the CFM56-5B4/P, with an inlet area of 3,077 square inches, are exempt from this test. The evidence from this accident shows that large flocking birds can be ingested into smaller transport-category airplane engines and pose a threat to the engine core as well as the fan blades; however, the large flocking bird tests are not required as part of the certification process for this size engine.

The NTSB concludes that additional considerations need to be addressed related to the current 14 CFR 33.76(d) large flocking bird certification test standards because they do not require large flocking bird tests on smaller transport-category airplane engines, such as the accident engine, or a test of the engine core; the circumstances of the accident demonstrate that large birds can be ingested into the core of small engines and cause significant damage. The NTSB notes that the FAA engine and propeller directorate, jointly with the European Aviation Safety Agency (EASA), initiated a reevaluation of the existing engine bird-ingestion certification regulations by tasking a working group to update the bird-ingestion rulemaking database (BRDB) to include events through the end of 2008. Once the BRDB update is completed, the group is expected to perform a statistical analysis of the raw data and evaluate whether the current regulations still meet FAA and EASA safety objectives and whether additional actions or rule changes are necessary. Therefore, the NTSB recommends that, during the BRDB working group's reevaluation of the current engine bird-ingestion certification regulations, the FAA specifically reevaluate the 14 CFR 33.76(d) large flocking bird certification test standards to determine whether they should 1) apply to engines with an inlet area of less than 3,875 square inches and 2) include a requirement for engine core ingestion. If the BRDB working group's reevaluation determines that such requirements are needed, incorporate them into 14 CFR 33.76(d) and require that newly certificated engines be designed and tested to these requirements.

Engine Dual Failure Checklist

At 1527:23, about 12 seconds after the bird strike, the captain took control of the airplane. Five seconds later, the captain called for the QRH Engine Dual Failure checklist, and the first officer complied. Even though the engines did not experience a total loss of thrust, the Engine Dual Failure checklist was the most applicable checklist contained in the US Airways QRH, which was developed in accordance with the Airbus QRH, to address the accident event because it was the only checklist that contained guidance to follow if an engine restart was not possible and if a forced landing or ditching was anticipated (starting from 3,000 feet). However, according to postaccident interviews and CVR data, the flight crew did not complete the Engine Dual Failure checklist, which had 3 parts and was 3 pages long. Although the flight crewmembers were able to complete most of part 1 of the checklist, they were not able to start parts 2 and 3 of the checklist because of the airplane's low altitude and the limited time available.

The Engine Dual Failure checklist was designed assuming that a dual-engine failure occurred at a high altitude (above 20,000 feet). According to Airbus, the checklist was so designed because most Airbus operations were at high altitude, and, therefore, a dual-engine failure would most likely occur at altitudes above 20,000 feet. Airbus had not considered developing a checklist for use at a low altitude, when limited time is available before ground or water impact. Discussions with A320 operators and a manufacturer also indicated that low-altitude, dual-engine failure checklists are not readily available in the industry.

In 2005, Airbus amended the Engine Dual Failure checklist by including two parallel steps, one for a fuel remaining scenario that included steps to attempt to relight an engine and one for a no fuel remaining scenario that did not include steps to attempt to relight an engine, and by incorporating the ditching procedures, which had previously been located in a separate checklist. Although the amendment allowed pilots to use one checklist, instead of several, for a dual-engine failure, it resulted in a lengthy checklist.

As noted, the Engine Dual Failure checklist did not fully apply to a low-altitude, dual-engine failure and was unduly long for such an event given the limited time available. In fact, the first officer spent about 30 to 40 seconds attempting to relight the engines (as indicated in part 1 of the checklist) because he did not know the extent of the engine damage. Further, the flight crew never reached the ditching portion of the checklist, which most directly applied to the accident situation. A checklist for a dual-engine failure or other abnormal event occurring at a low altitude would increase the chances of a successful ditching and omit many of the steps that took up the flight crew's limited time.

The NTSB concludes that, although the Engine Dual Failure checklist did not fully apply to the accident event, it was the most applicable checklist contained in the QRH to address the event and that the flight crew's decision to use this checklist was in accordance with US Airways procedures. The NTSB further concludes that, if a checklist that addressed a dual-engine failure occurring at a low altitude had been available to the flight crewmembers, they would have been more likely to have completed that checklist. This accident demonstrates that abnormal events, including a dual-engine failure, can occur at a low altitude and, therefore, that a checklist is clearly needed to address such situations. Therefore, the NTSB recommends that the FAA require manufacturers of turbine-powered aircraft to develop a checklist and procedure for a dual-engine failure occurring at a low altitude. In addition, the NTSB recommends that, once the development of the checklist and procedure for a dual-engine failure occurring at a low altitude has been completed, as asked for in Safety Recommendation A-10-66, require 14 CFR Part 121, Part 135, and Part 91 Subpart K operators of turbine-powered aircraft to implement the checklist and procedure.

Abnormal and Emergency Events Checklist Design

NASA researchers have studied the difficulties inherent to designing checklists and procedures for emergency and abnormal situations. A 2005 NASA report noted that, although checklists and procedures cannot be developed for all possible contingencies, checklists should be developed for emergency and abnormal situations "for all phases of flight in which they might be needed."[4] Further, the report stated that emergency and abnormal checklists and procedures must include the necessary information and steps to respond appropriately and that, when designing checklists and procedures for emergency and abnormal situations, attention should be paid to the wording, organization, and structure of the checklists and procedures to ensure that they are easy to use, clear, and complete. The report also indicated that, because attention narrows during emergency and abnormal situations due to increased workload and stress, checklists and procedures should minimize the memory load on flight crews and that some airlines and manufacturers have reduced the number of memory items.

Accidents and incidents have shown that pilots can become so fixated on an emergency or abnormal situation that routine items (for example, configuring for landing) are overlooked.[5] For this reason, emergency and abnormal checklists often include reminders to pilots of items that may be forgotten. Additionally, pilots can lose their place in a checklist if they are required to alternate between various checklists or are distracted by other cockpit duties; however, as shown with the Engine Dual Failure checklist, combining checklists can result in lengthy procedures. Therefore, checklists should not be overly cumbersome but should still contain all of

[4] See B.K. Burian, I. Barshi, and K. Dismukes, *The Challenge of Aviation Emergency and Abnormal Situations*, NASA Technical Memorandum 2005-213462 (Moffett Field, California: National Aeronautics and Space Administration, 2005).

[5] For examples of such accidents and incidents, see (a) *Wheels-Up Landing, Continental Flight 1943, Douglas DC-9-32, N10556, Houston, Texas, February 19, 1996,* Aircraft Accident Report NTSB/AAR-97/01 (Washington, DC: National Transportation Safety Board, 1997). (b) The reports for NTSB case numbers CHI94FA039 and DCA06MA009 are available online at <http://www.ntsb.gov/ntsb/query.asp>.

the critical items that must be accomplished and should not require pilots to rely heavily on memory items. Shorter checklists increase the likelihood that pilots can complete all pertinent items related to the emergency or abnormal situation without distracting them from other cockpit duties. Unfortunately, many checklists are designed such that pilots become "stuck" in the checklist and, therefore, complete procedures that may not be appropriate or practical for a given emergency (such as trying to restart engines). According to a NASA representative's public hearing testimony, to minimize the risk of becoming stuck in an inapplicable portion of a checklist, checklists can be designed to give pilots "opt out" points or "gates," which are conditional if-then statements. (For example, "if the aircraft is below 3,000 feet, then go to step 27.") Incorporating such points into checklists will encourage pilots to reevaluate the situation and determine whether they are using the appropriate checklist or portion of a checklist and whether the task focus should be shifted.

The NTSB notes that this is not the first accident in which checklist design was recognized as a safety issue. For example, after the September 2, 1998, Swissair flight 111 accident in which a seemingly innocuous smoke event evolved, after several minutes, into a sudden and severe in-flight fire, the Transportation Safety Board of Canada determined that the checklist that the flight crew attempted to use would have taken about 20 to 30 minutes to complete.[6] However, only 20 minutes elapsed from the time that the on-board fire was detected until the crash occurred. In late 2004, the Flight Safety Foundation began an international initiative, which included the participation of manufacturers, airlines, pilots, and government representatives, to improve checklist procedures for airline pilots confronting smoke, fire, or fumes when no alerts are annunciated in the cockpit. As a result of the initiative, the Flight Safety Foundation published a report containing a streamlined Smoke, Fire, and Fumes checklist template to standardize and optimize flight crew responses to such events and that included considerations for an immediate landing.[7] The NTSB believes that a similar initiative to improve other emergency and abnormal checklists is warranted.

The NTSB concludes that comprehensive guidelines on the best means to design and develop emergency and abnormal checklists would promote operational standardization and increase the likelihood of a successful outcome to such events. Therefore**,** the NTSB recommends that the FAA develop and validate comprehensive guidelines for emergency and abnormal checklist design and development. The guidelines should consider the order of critical items in the checklist (for example, starting the auxiliary power unit), the use of opt outs or gates to minimize the risk of flight crewmembers becoming stuck in an inappropriate checklist or portion of a checklist, the length of the checklist, the level of detail in the checklist, the time needed to complete the checklist, and the mental workload of the flight crew. The NTSB notes that, on March 16, 2010, the FAA published Information for Operators 10002SUP, "Industries Best Practices Reference List," which included resources for checklist design and use. The NTSB reviewed these resources and does not believe that they adequately address the issues described in this recommendation.

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[6] See *In-Flight Fire Leading to Collision with Water, SwissAir Transport Limited, McDonnell Douglas MD-11, HB-IWF, Peggy's Cove, Nova Scotia, 5 nm SW, 2 September 1998,* Aviation Investigation Report A98H0003 (Quebec, Canada: Transportation Safety Board of Canada, 2003).

[7] See "Flight Crew Procedures Streamlined for Smoke/Fire/Fumes," *Flight Safety Digest* (Alexandria, Virginia: Flight Safety Foundation, 2005), pp. 31–35.

Pilot Training

Dual-Engine Failure Training

US Airways dual-engine failure training, which was provided during initial training in a full-flight simulator session, was consistent with the training provided by Airbus. The dual-engine failure scenario was presented at 25,000 feet, included two engine restart attempts, and was considered complete after the restart of one engine, typically at an altitude from about 8,000 to 10,000 feet. During the training scenarios, at least one engine was always restarted; therefore, the pilots never reached the point of having to conduct a forced landing or ditching. No dual-engine failure training scenarios were presented at or near traffic pattern altitudes, and no scenarios were used to train pilots to conduct a possible ditching or forced landing. The scenarios were focused on restarting an engine in flight. Dual-engine failure scenarios were not presented during recurrent training.

During informal discussions, A320 operators indicated that their dual-engine failure training was conducted at high altitudes in accordance with Airbus recommendations and industry practices. The operators revealed that the training scenarios were intended to simulate a high-altitude engine failure and train pilots on the available methods to restart an engine in flight, not to simulate a catastrophic engine failure for which a restart was unlikely. None of the contacted A320 operators included a dual-engine failure scenario at a low altitude in their training curricula. The A320 operators indicated that the training scenarios generally presented situations for which the course of action and landing location were clear and sufficient time was available to complete any required procedures before landing. The only low-altitude scenarios presented during training were single-engine failures at, or immediately after, takeoff. The A320 operators also indicated that dual-engine failure training was generally only provided during initial, not recurrent, training. The NTSB is concerned that pilots are not taught how to handle low-altitude abnormal events or to use critical thinking, task shedding, decision-making, and proper workload management to achieve a successful outcome when such events occur.

The NTSB concludes that training pilots how to respond to a dual-engine failure occurring at a low altitude would challenge them to use critical thinking and exercise skills in task shedding, decision-making, and proper workload management to achieve a successful outcome. Therefore, the NTSB recommends that the FAA require 14 CFR Part 121, Part 135, and Part 91 Subpart K operators to include a dual-engine failure scenario occurring at a low altitude in initial and recurrent ground and simulator training designed to improve pilots' critical-thinking, task-shedding, decision-making, and workload-management skills.

Ditching Training

US Airways provided ditching training during initial ground school. During the training, the QRH Ditching checklist, which assumes at least one engine is running, was reviewed. US Airways ditching training is similar to industry guidance on ditching, which focuses primarily on a high-altitude ditching for which sufficient time and altitude exists for the flight crew to prepare the airplane and its occupants. Further, during ditching training, power is available from at least one engine. The training also addressed atmospheric conditions, sea states, and recommended direction of landing, based on the direction of wind and water swells.

However, the training did not highlight the visual illusions that can be associated with landing on water, as noted by the accident captain during postaccident interviews when he stated that landing on water was more difficult than landing on a runway due to “a much more uniform visual field, less contrast, and fewer landmarks.” Specifically, when ditching or making a forced landing on water, a pilot is susceptible to the height perception illusion (the pilot perceives a greater height above the terrain than actually exists because of a lack of contrast or visual references).[8]

Further, US Airways and Airbus manuals contain very little guidance to pilots on flying techniques to use during a ditching to achieve recommended airplane attitude and airspeed at touchdown, with and without engine power. In fact, only the US Airways Flight Operations Manual Training Manual included guidance for a ditching without engine power, and the guidance was not airplane specific. The NTSB notes that this guidance should also include the importance of maintaining a proper bank angle in addition to a proper attitude, airspeed, and descent rate. The NTSB is concerned that critical information about ditching techniques is not provided in industry guidance. Although the NTSB acknowledges that pilots are responsible for reading and familiarizing themselves with company manuals, it is unrealistic to expect them to recall the relevance of such critical information during an emergency without regular periodic reinforcement.

The NTSB concludes that the flight crewmembers would have been better prepared to ditch the airplane if they had received training and guidance about the visual illusions that can occur when landing on water and on approach and about touchdown techniques to use during a ditching, with and without engine power. Therefore, the NTSB recommends that the FAA require 14 CFR Part 121, Part 135, and Part 91 Subpart K operators to provide training and guidance to pilots that inform them about the visual illusions that can occur when landing on water and that include approach and touchdown techniques to use during a ditching, with and without engine power. The NTSB further recommends that the FAA work with the aviation industry to determine whether recommended practices and procedures need to be developed for pilots regarding forced landings without power both on water and land.

Operational Difficulties Not Factored Into Certification Tests

An FAA representative testified during the public hearing that operational procedures were evaluated during the A320 ditching certification process. These procedures, which were contained in the ditching portion of the Engine Dual Failure checklist, included touching down the airplane “with approximately 11° pitch and minimum aircraft vertical speed.” However, with respect to validating checklist procedures, an FAA test pilot stated at the public hearing, “it’s not necessarily an evaluation of the flying qualities of an airplane but an evaluation of the system characteristics in accomplishing each step to ensure that the system responds as it’s expected to respond.” Although airplane systems are evaluated to determine if they respond as expected, the operational procedures themselves and the ability of pilots to achieve the parameters are not.

[8] This information was obtained from <http://www.chinook-helicopter.com/standards/Illusions/Visual_Illusions.html> (accessed February 17, 2010) and from *Seaplane, Skiplane, and Float/Ski Equipped Helicopter Operations Handbook* FAA-H-8083-23, issued August 2004.

Because operational procedures and the ability of pilots to achieve the Airbus ditching parameters have not been tested, the assumption of a mostly intact fuselage when evaluating the "probable structural damage and leakage" resulting from a ditching, as required by 14 CFR 25.801(d), rests on an assertion that this condition can be reliably attained rather than on a demonstration or analysis to that effect.

Postaccident flight simulations indicated that attaining the Airbus ditching parameters without engine power is possible but highly unlikely without training. Further, attaining the parameters may not prevent a significant fuselage breach for a number of plausible conditions. The factors that increase the likelihood that, during an actual ditching, the touchdown criteria will not be met and that a significant fuselage breach will occur include the following:

- The analyses of the fuselage strength upon which the assumption of fuselage integrity is based may not consider ditching at heavy airplane weights, such as those pertaining to takeoff and climb.
- Different touchdown flight condition targets exist for ditching on flat water and on water with swells, but only the pitch angle target applicable to flat-water conditions is mentioned in guidance material available to pilots.
- Certain combinations of winds and sea swells require contradictory procedures, making a solution impossible in these cases.
- Deliberately or inadvertently slowing the airplane into the alpha-protection mode may result in an attenuation of pilot nose-up stick inputs, making it more difficult to flare the airplane, even if angle-of-attack (AOA) margin to alpha maximum exists.
- Attaining the touchdown flight condition targets is an exceptionally difficult flight maneuver, and pilots cannot be expected to conduct the maneuver proficiently when the airplane has no engine power.
- Attaining the touchdown flight conditions at night or when other poor-visibility conditions exist would likely be very hard to accomplish given that, in a flight simulator in daylight conditions, the touchdown flight condition targets were only achieved once out of 12 attempts, even by pilots who were aware of the importance of maintaining sufficient airspeed, were fully expecting the dual-engine failure to occur, and knew that their failure to accomplish the maneuver would not be life-threatening.

The NTSB concludes that the review and validation of the Airbus operational procedures conducted during the ditching certification process for the A320 airplane did not evaluate whether pilots could attain all of the Airbus ditching parameters, nor was Airbus required to conduct such an evaluation. The NTSB further concludes that, during an actual ditching, it is possible but unlikely that pilots will be able to attain all of the Airbus ditching parameters because it is exceptionally difficult for pilots to meet such precise criteria when no engine power is available, and this difficulty contributed to the fuselage damage. (The relationship between the assumption that the fuselage will most likely significantly breach during a ditching and the need for the availability of survival equipment after such an event is discussed later in this letter.) Therefore, the NTSB recommends that the FAA require applicants for aircraft certification to demonstrate that their ditching parameters can be attained without engine power by pilots without the use of exceptional skill or strength.

High-AOA-Related Issues

High-AOA and Low-Airspeed Awareness

Typically, pilots are made aware that an airplane has reached alpha-protection speed and that, therefore, the high-AOA protection has become active, by viewing a black and amber strip along the airspeed scale. Under normal circumstances, the black and amber strip is sufficient to alert pilots visually that they have entered alpha-protection mode. However, in emergency situations, when visual resources are overloaded, pilots may inadvertently overlook the airspeed tape. The airplane was flown at $V_{LS,}$ which is the lowest selectable airspeed providing an appropriate margin to the stall speed, or slightly less for most of the descent. Maintaining a sufficiently higher airspeed makes it possible to maintain sufficient energy to significantly reduce the descent rate during the flare. The Airbus simulation indicated that the airplane performed as designed and was in the alpha-protection mode from 150 feet to touchdown. As discussed previously, the captain's attention was narrowed, which would have made it difficult for him to maintain awareness of the airplane's low-speed condition during the descent.

Although the A320 airplane does not provide tactile cues that a low-speed or -energy condition exists, it does have an aural speed warning, which repeats every 5 seconds and is available when the airplane is configured with full flaps, flaps 2, or flaps 3. However, the system is designed such that the warning is inhibited when the airplane is below 100 feet radio altitude or when a ground proximity warning system (GPWS) alert is triggered. The A320 was designed with an alert prioritization hierarchy that considered inputs from various airplane systems, including the GPWS, flight warning computer, traffic collision avoidance system, and radar, and the GPWS-triggered alerts had priority over a low-speed warning. CVR and FDR data indicated that 15 GPWS alerts were triggered during the descent from 300 feet to touchdown and that no low-speed aural alert was triggered during this time. Considering the alert prioritization hierarchy, low-speed warnings were likely inhibited by the GPWS alerts.

The US Airways and Airbus Ditching checklists included steps to select the GPWS and the terrain alerts to OFF to avoid nuisance warnings during final descent. The NTSB notes that, although the Engine Dual Failure checklist had been amended to incorporate the procedures for preparing and configuring the airplane for ditching, the ditching portion of the checklist did not include the step to select the GPWS system and terrain alerts to OFF. The NTSB acknowledges that the flight crew did not have sufficient time to accomplish the ditching portion of the Engine Dual Failure checklist. Regardless, the NTSB believes that the ditching procedures should be consistent in all applicable checklists.

The NTSB concludes that the guidance in the ditching portion of the Engine Dual Failure checklist is not consistent with the separate Ditching checklist, which includes a step to inhibit the GPWS and terrain alerts. Therefore, the NTSB recommends that the FAA require Airbus operators to amend the ditching portion of the Engine Dual Failure checklist and any other applicable checklists to include a step to select the GPWS and terrain alerts to OFF during the final descent.

High-AOA Envelope Limitations

The airplane's airspeed in the last 150 feet of the descent was low enough to activate the alpha-protection mode of the airplane's fly-by-wire envelope protection features. The captain progressively pulled aft on the sidestick as the airplane descended below 100 feet, and he pulled the sidestick to its aft stop in the last 50 feet, indicating that he was attempting to raise the airplane nose to flare and soften the touchdown on the water. The A320 alpha-protection mode incorporates features that can attenuate pilot sidestick pitch inputs. Because of these features, the airplane could not reach the maximum AOA attainable in pitch normal law for the airplane weight and configuration; however, the airplane did provide maximum performance for the weight and configuration at that time.

Airbus performed a simulation of the last 300 feet of the accident flight, which indicated that the airplane was performing as designed and was in alpha-protection mode from 150 feet to touchdown. The Airbus simulation indicated that the captain's aft sidestick inputs in the last 50 feet of the flight were attenuated, limiting the airplane nose-up response of the airplane even though about 3.5° of margin existed between the airplane's AOA at touchdown (between 13° and 14°) and the maximum AOA for this airplane weight and configuration (17.5°). Airbus' training curricula do not contain information on the effects of alpha-protection mode features that might affect the airplane's response to pilot sidestick pitch inputs. The flight envelope protections allowed the captain to pull full aft on the sidestick without the risk of stalling the airplane.

The NTSB concludes that training pilots that sidestick inputs may be attenuated when the airplane is in the alpha-protection mode would provide them with a better understanding of how entering the alpha-protection mode may affect the pitch response of the airplane. Therefore, the NTSB recommends that the FAA require Airbus operators to expand the AOA-protection envelope limitations ground-school training to inform pilots about alpha-protection mode features while in normal law that can affect the pitch response of the airplane.

Bird- and Other Wildlife-Strike Issues

Wildlife Hazard Mitigation at Part 139-Certificated Airports

The FAA has provided guidance material to airports for use in constructing, implementing, and evaluating wildlife hazard management plans (WHMP). In particular, the FAA recommends that airport operators follow the standards and practices contained in Advisory Circular (AC) 150/5200-33B, "Hazardous Wildlife Attractants on or near Airports," which recommends that all airports consider wildlife attractants within 10,000 feet of the airport and, if the attractant could cause hazardous wildlife movement into or across the approach or departure airspace, out to 5 statute miles from the airport. The AC is intended to encourage airports to monitor and limit land-use activities near the airport that are attractive to wildlife. However, except for the habitat considerations referred to in the AC, an airport cannot monitor or control wildlife that enters the airspace around the airport at all altitudes. Although the accident bird strike occurred within a 5-mile radius of LGA, it occurred at an altitude of almost 3,000 feet.

During the investigation, LGA's WHMP was examined and determined to be in accordance with the requirements of 14 CFR 139.337, "Wildlife Hazard Management." The NTSB notes that LGA routinely disperses, removes, or destroys birds found on or near the airfield and annually removes birds and eggs from Rikers Island, which is near the airport. Although these activities help manage wildlife near the airport, they are unlikely to affect wildlife entering the airspace above it. The NTSB concludes that the accident bird strike occurred at a distance and altitude beyond the range of LGA's wildlife hazard responsibilities and, therefore, would not have been mitigated by LGA's wildlife management practices.

The FAA does not require all Part 139-certificated airports to conduct wildlife hazard assessments (WHA) or maintain WHMPs. In fact, according to an FAA representative's public hearing testimony, only about half of certificated airports in the United States have conducted a WHA. According to 14 CFR 139.337, a serious wildlife strike is required to initiate the process of wildlife-strike mitigation. The NTSB believes that Part 139-certificated airports should take action to mitigate wildlife hazards before a dangerous event occurs. Further, a WHA is needed for an airport to adequately estimate wildlife numbers and sizes and their relative hazards.

Following two serious bird-strike events involving Part 121 air carrier airplanes,[9] on November 19, 1999, the NTSB issued Safety Recommendation A-99-88, which asked the FAA, in consultation with the U.S. Department of Agriculture (USDA), to require that WHAs be conducted at all Part 139 airports where such assessments have not already been conducted. On February 22, 2000, the FAA stated that it was not necessary to initiate additional regulations to require all Part 139 airports to conduct WHAs and that doing so would place an undue burden on many airports that do not have a history of wildlife strikes. The FAA stated that the actions it was taking in response to other bird strike-related safety recommendations would address the safety issue and that it planned no further action. On May 11, 2000, the NTSB classified Safety Recommendation A-99-88 "Closed—Unacceptable Action."

Although the bird strike occurred beyond the range of LGA's wildlife hazard responsibilities, the NTSB still strongly feels that all airports, regardless of their location, should become aware of the potential hazards of wildlife strikes because wildlife strikes are most likely to occur near airports. Further, the NTSB notes that, if an airport truly has minimal wildlife presence and attractants, then a WHA for that airport would be commensurately less burdensome and costly. Further, the cost of the assessment would be incurred anyway if a triggering event occurred.

The NTSB concludes that a proactive approach to wildlife mitigation at 14 CFR Part 139-certificated airports would provide a greater safety benefit than the current strategy of waiting for a serious event to occur before conducting a WHA. Therefore, the NTSB recommends that the FAA require all 14 CFR Part 139-certificated airports to conduct WHAs to proactively assess the likelihood of wildlife strikes, and, if the WHA indicates the need for a WHMP, require the airport to implement a WHMP into its airport certification manual. The NTSB notes that the FAA initiated rulemaking in late summer 2009 to make WHAs mandatory at all Part 139 airports whether or not a "triggering event" has occurred and hopes that a notice of proposed rulemaking (NPRM) will be issued by the end of 2010 as indicated by the FAA.

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[9] On February 22, 1999, a Boeing 757 operated under Part 121 by Delta Air Lines, Inc., as a scheduled passenger flight, sustained substantial damage after penetrating a flock of birds during takeoff from Covington, Kentucky. The flight crew entered the airport traffic pattern for an immediate return for landing and landed the airplane without further incident. On March 4, 1999, a Douglas DC-9-15F, operated under Part 121 by USA Jet Airlines, Inc., as a domestic air cargo flight, sustained a severe engine-power loss after encountering a flock of large birds while on final approach for landing in Kansas City, Missouri. The pilot regained enough power in one engine to continue the approach and land the airplane. The reports for these accidents, NTSB case numbers NYC99LA064 and CHI99FA012, respectively, can be found online at <http://www.ntsb.gov/ntsb/query.asp>.

USDA Research and Other Activities

During the June 2009 public hearing on this accident, a USDA Wildlife Services representative outlined the agency's current wildlife research projects, including a project to determine if pulsating lights on airplanes would make them more conspicuous to birds. Preliminary results from the project indicate that pulsating lights affect the behavior of some birds but not others. The USDA intends to continue this research using an airplane outfitted with pulsating lights. In addition, the USDA reported that the use of lasers has been shown to be effective in repelling birds from hangars and other areas on the airfield and that there is anecdotal evidence, but no conclusive evidence, that using weather radar on airplanes disperses birds from the airplane's flightpath. Another area of USDA research involves planting grasses and other vegetation unattractive to wildlife to deter them from airfields and surrounding areas. Additional research relates, in part, to modifying trash transfer stations, implementing fencing, eradicating earthworms, and designing water retention facilities to deter wildlife.

In addition to its research endeavors, the USDA assists the FAA in wildlife mitigation efforts by providing technical experts to assess and control wildlife on and around airports. USDA wildlife biologists routinely conduct WHAs around airports, as was done for LGA, to identify types and numbers of wildlife in the vicinity and then help airports to develop and implement WHMPs. In 2008, USDA wildlife biologists assisted 764 airports in wildlife mitigation activities and trained 2,200 airport personnel to FAA standards, as required under Part 139. The NTSB believes that the USDA's research activities in wildlife mitigation and guidance and its assistance to airports on these issues contribute significantly to the safety of the airport environment and strongly encourages the USDA to continue these efforts.

Preliminary reports of the effectiveness of using various bird hazard mitigation strategies, including pulsating lights, lasers, and weather radar, suggest that these techniques have potential as bird repellents and may be helpful in keeping birds away from an airplane's flightpath. However, according to witnesses at the public hearing, the effectiveness of these methods is not well understood, and further research in these areas is needed. The NTSB believes that it is important to pursue all potentially useful approaches to bird hazard mitigation and is particularly interested in those that use aircraft systems to repel birds away from airplanes.

The NTSB concludes that research on the use of aircraft systems such as pulsating lights, lasers, and weather radar may lead to effective methods of deterring birds from entering aircraft flightpaths and, therefore, reduce the likelihood of a bird strike. Therefore, the NTSB recommends that the FAA work with the USDA to develop and implement innovative technologies that can be installed on aircraft that would reduce the likelihood of a bird strike.

Survival Factors Issues

Frame 65 Vertical Beam

Flight attendant B, who was located at the forward-facing, "direct-view" jumpseat (aft, center aisle), sustained a deep, V-shaped laceration to her left shin during the accident. Although she could not remember being injured and only noticed the injury after she had evacuated the airplane, the investigation determined that the frame (FR) 65 vertical beam had penetrated the floor directly beneath the aft, direct-view jumpseat on which flight attendant B had been seated. The shape of the beam matched the description and location of flight attendant B's injury. It is likely that she did not immediately notice the injury because of the shock of the impact and immediate submersion of her legs in near-freezing water.

According to Airbus, the FR65 vertical beam is a nonstructural beam installed between the passenger and cargo floors at the aircraft centerline that is held in place by two quick-release, removable pins at its uppermost attachment point with the subfloor structure. Removing the pins and rotating the beam down allows maintenance personnel to access the waste water tank. Physical evidence indicated that, during the impact, the beam was pushed upward and rotated, allowing the removable pins to slide from the upper bracket and the beam to puncture the cabin floor above.

In April 2009, an A321 was involved in a tail strike and incurred similar damage to the FR65 vertical beam; however, the beam did not puncture the floor. Airbus' analysis of this incident and the accident event indicated that the damage to the accident airplane was more severe because of the continuous pressure applied to the fuselage skin by the water, which led to more skin and vertical beam movement.

The NTSB concludes that flight attendant B was injured by the FR65 vertical beam after it punctured the cabin floor during impact and that, because of the beam's location directly beneath the flight attendant's aft, direct-view jumpseat, any individual seated in this location during a ditching or gear-up landing is at risk for serious injury due to the compression and/or collapse of the airplane structure. The NTSB notes that the A318, A319, A320, and A321 series airplanes have similar structures. Therefore, the NTSB recommends that the FAA require Airbus to redesign the FR65 vertical beam on A318, A319, A320, and A321 series airplanes to lessen the likelihood that it will intrude into the cabin during a ditching or gear-up landing and Airbus operators to incorporate these changes on their airplanes.

Brace positions

Of the four passengers who sustained serious injuries, three received their injuries during impact. The two female passengers who sustained very similar shoulder fractures both described assuming similar brace positions, putting their arms on the seat in front of them and leaning over. They also stated that they felt that their injuries were caused during the impact when their arms were driven back into their shoulders as they were thrown forward into the seats in front of them. The brace positions they described were similar to the one depicted on the US Airways safety information card, which is shown in figure 1.

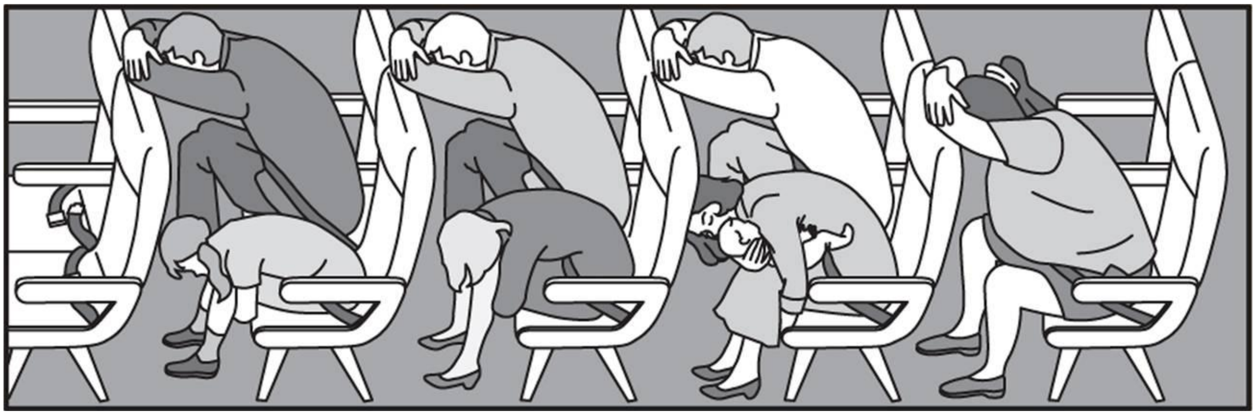

Figure 1. Passenger brace positions shown in the US Airways safety information card.

The brace positions shown on the US Airways safety information card were in accordance with current FAA guidance on brace positions contained in Appendix 4 of AC 121-24C, "Passenger Safety Information Briefing and Briefing Card," which states, "in aircraft with high-density seating or in cases where passengers are physically limited and are unable to place their heads in their laps, they should position their heads and arms against the seat (or bulkhead) in front of them." (See figure 2.)

Figure 2. Passenger brace position shown in AC 121-24C.

A 1988 Civil Aerospace Medical Institute (CAMI) paper explained that "the primary goal for the brace for impact position is to reduce the effect of secondary impact of the body with the interior of the aircraft."[10] The paper indicated that the idea is to preposition the body in the direction that it will likely be driven during impact. The paper further stated the following:

[10] See R.F. Chandler, "Brace for Impact Positions," *Proceedings of the Fifth Annual International Cabin Safety Symposium, February 1988, Los Angeles, California* (Los Angeles, California: University of Southern California, Federal Aviation Administration, and Southern California Safety Institute, 1988), pp. 279–290.

> If resting against a seat back with a 'break-over feature,' it may be possible to get slightly better support if the seat can be folded over until it stops or until it rests gently on the occupant in front. But if this is not done, good support will still be provided by the seat back as it folds forward of its own inertia during the crash, and is followed by the arms and head. The head and arms will slide down the seat back as it folds, but shouldn't be seriously injured.

The passenger seats on the accident airplane were 16-G compatible seats[11] that had a nonbreakover seatback design, meaning that the breakover hinge feature was "locked out" and that the seatbacks were designed to be essentially rigid and to not easily or quickly collapse forward as passengers struck them from behind. All newly manufactured 16-G compatible seats have a nonbreakover seatback design, which minimizes head movement and body acceleration before striking the seatback from behind, resulting in less serious head injuries. The NTSB notes that the guidance in AC 121-24C did not take into consideration the effects of striking seats that do not have the breakover feature because research on this issue has not been conducted.

The NTSB concludes that the FAA's current recommended brace positions do not take into account newly designed seats that do not have a breakover feature and that, in this accident, the FAA-recommended brace position might have contributed to the shoulder fractures of two passengers. Therefore, the NTSB recommends that the FAA conduct research to determine the most beneficial passenger brace position in airplanes with nonbreakover seats installed. If the research deems it necessary, issue new guidance material on passenger brace positions.

EOW and Ditching-Related Equipment

Availability of Slide/Rafts After a Ditching

The accident airplane was equipped for EOW operations; however, the flight route from LGA to CLT was not an EOW route. Therefore, the flight could have been operated with a non-EOW-equipped airplane. The amount and type of safety equipment carried by EOW-equipped airplanes differs greatly from that carried by non-EOW-equipped airplanes. Most significantly, EOW-equipped airplanes must carry passenger life vests and sufficient slide/rafts and/or life rafts to contain all of the airplane's occupants even if one slide/raft or life raft of the largest capacity is unavailable. In contrast, non-EOW-equipped airplanes may operate with just evacuation slides and flotation seat cushions. (After the ditching, two slide/rafts on the accident airplane were unavailable because of water entry in the aft cabin.)

The accident airplane was equipped with 4 slide/rafts, 2 at the front of the airplane and 2 at the back of the airplane, each of which was rated for 44 passengers with an overload capacity of 55 passengers. Because the two aft slide/rafts were unusable after water entered the airplane, only two rafts, with a combined capacity to carry 110 people, were available. However,

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[11] A 16-G seat is tested in a manner that simulates the loads that could be expected in an impact-survivable accident. Two separate dynamic tests are conducted to simulate two different accident scenarios: one in which the forces are predominantly in the vertical downward direction and one in which the forces are predominantly in the longitudinal forward direction. The highest load factor is in the forward direction at 16 G, which is why these seats are commonly referred to as 16-G seats. Amendment 121-315, effective October 27, 2005, required that transport-category airplanes in Part 121 operations, certificated after January 1, 1958, and manufactured on or after October 27, 2009, must comply with the 16-G dynamic standard.

given that this was a non-EOW flight, it was fortunate that the airplane was EOW equipped and, therefore, had any slide/rafts available at all for passenger use.

According to information gathered from 146 of the passengers and the flight and cabin crewmembers, about 64 occupants were rescued from the forward slide/rafts, and about 87 occupants were rescued from the wings and off-wing ramp/slides, which were neither detachable nor considered part of the airplane's EOW emergency equipment. Both passenger statements and photographic evidence indicated that the wings were very near to, if not at, standing capacity. Therefore, the wings did not have room for the additional 64 occupants who were rescued from the slide/rafts. If the airplane had not been EOW equipped, the rafts that held those occupants would not have been available. Further, at the public hearing, a US Airways representative stated that, if the accident airplane had not been equipped with slide/rafts, the flight attendants would have detached the single-lane slides at the forward doors and instructed passengers to jump into the water and hold onto them, exposing many passengers to cold water for sufficient time to likely cause serious injuries and/or fatalities.

The NTSB concludes that, although the airplane was not required by FAA regulations to be equipped for EOW operations to conduct the accident flight, the fact that the airplane was so equipped, including the availability of the forward slide/rafts, contributed to the lack of fatalities and the low number of serious cold-water immersion-related injuries because about 64 occupants used the forward slide/rafts after the ditching.

Water immediately entered the aft area of the airplane after impact and rose quickly because the impact damage to the aft fuselage structure and galley floor allowed a large volume of water to enter the airplane. There were conflicting statements regarding the left aft passenger door, 2L, and how it got "cracked" open, which allowed some additional water to enter the airplane. However, due to the large volume of water that had already entered the aft area of the airplane, it is immaterial how door 2L was cracked open.

As discussed previously, because of the operational difficulty of ditching within the Airbus ditching parameters and the additional difficulties that water swells and/or high winds may cause, it is very likely that, in general, after ditching an A320 airplane without engine power, the "probable structural damage and leakage" will include significant aft fuselage breaching and subsequent water entry into the aft area of the airplane. Therefore, it should be assumed that, after a ditching, water entry will prevent the aft exits and slide/rafts from being available for use during an evacuation. The NTSB understands that, during the ditching certification process, the FAA examines the manufacturer's assumptions regarding the airplane's expected integrity and buoyancy calculations. However, based on this accident, the NTSB questions the FAA's acceptance of the assumption that a ditching in which the fuselage is not significantly breached is a reasonable expectation across a range of realistic environmental conditions and pilot skills and experience.

Based on this evidence, the NTSB concludes that the determination of cabin safety equipment locations on the A320 airplane did not consider that the probable structural damage and leakage sustained during a ditching would include significant aft fuselage breaching and subsequent water entry into the aft area of the airplane, which prevents the aft slide/rafts from being available for use during an evacuation. Although this investigation only determined that an

A320 airplane will most likely significantly breach after a ditching, the NTSB is concerned that the A320 may not be the only airplane that could sustain such damage after a ditching and that might have slide/rafts stowed in locations that, in the event of a ditching, would render them unusable. Therefore, the NTSB recommends that the FAA require, on all new and in-service transport-category airplanes, that cabin safety equipment be stowed in locations that ensure that life rafts and/or slide/rafts remain accessible and that sufficient capacity is available for all occupants after a ditching. The following sections will describe required EOW equipment.

Immersion Protection

As noted in NTSB Safety Study 85/02, "Air Carrier Overwater Emergency Equipment and Procedures," "at least 179 fully certified airports in the U.S. are located within 5 miles of a body of water of at least one-quarter square mile surface area."[12] Similarly, a 1996 FAA report found that 75.8 percent (194 of 256) of large airports worldwide had at least one overwater approach.[13] The report concluded that "approximately two-thirds of all worldwide accidents occur during those flight phases within close proximity of the airport" and that "the majority of water related mishaps occur within close proximity of the airport during these flight phases." In 1988, the FAA also stated the following in NPRM 88-11, which proposed improved water survival equipment:

> The likelihood of at least some part of passenger-carrying flights conducted under either Part 121 or Part 135 within the United States occurring over water is quite high and is sufficient to warrant applicability of the proposals to all passenger-carrying aircraft operated under those parts.

According to information gathered from 146 of the passengers and the flight and cabin crewmembers, about 87 occupants were rescued from the wings and off-wing ramp/slides, which were neither detachable nor considered part of the airplane's EOW emergency equipment. Although passengers would not have been instructed by the flight attendants to use the overwing exits during a planned ditching in an EOW-equipped airplane, as evidenced, many passengers did use these exits during the evacuation. Therefore, one possible means of providing additional passenger protection from water immersion could be to equip Type IV exit ramp/slides with quick-release girts so that they could be detached from the airplane if it is sinking. In fact, NTSB Safety Study 85/02 stated the following regarding immersion protection:

> Since water impact accidents occur primarily during the takeoff or landing phases of flight, not during the 'extended overwater' phase, and are not limited to aircraft equipped with slide/raft combinations, it is important that the evacuation slides on narrow-body (and, where still used, on wide-body) aircraft be modified to offer a means to avoid immersion.

At the time, CAMI was testing improvements to narrow-body evacuation slides, primarily to increase the capacity of the slides when used as a raft, and quick-release girts. The NTSB asked the FAA to monitor the progress of the developments and issue standards for the

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[12] See *Air Carrier Overwater Emergency Equipment and Procedures*, Safety Study NTSB/SS-85/02 (Washington, DC: National Transportation Safety Board, 1985).

[13] See *Transport Water Impact and Ditching Performance*, DOT/FAA/AR-95/54 (Washington, DC: Federal Aviation Administration, 1996).

modifications as they were proven. The NTSB stated that, until such time, evacuation slides should at least be required to include handholds and quick-release girts. As a result, the NTSB issued Safety Recommendation A-85-41, which asked the FAA to do the following:

> Amend [Technical Standard Order] TSO-C69a to require quick-release girts and handholds on emergency evacuation slides; amend 14 CFR 121 and 125 to specify a reasonable time from the adoption of the revision of the TSO by which all transport passenger air carrier aircraft being operated under these Parts must be equipped with slides conforming to the revised TSO.

The FAA revised TSO-C69a in response to Safety Recommendation A-85-41 and included requirements for quick-release girts and handholds on slides and slide/rafts (but not on ramp/slides). However, the FAA did not amend 14 CFR Parts 121 and 125 as recommended. Therefore, on March 29, 2002, the NTSB classified Safety Recommendation A-85-41 "Closed—Unacceptable Action."

The off-wing Type IV ramp/slides were not designed to be used during a water evacuation or required to have quick-release girts or handholds; however, they automatically deployed as designed when the overwing exits were opened after the ditching. Some passengers immediately recognized their usefulness and boarded the ramp/slides to get out of the water. Eventually, about 8 passengers succeeded in boarding the left off-wing slide and about 21 passengers, including the lap-held child, succeeded in boarding the right off-wing ramp/slide. Although passengers attempted to disconnect the off-wing ramp/slides from the airplane, they were unable to do so because the ramp/slides did not have quick-release girts like slides and slide/rafts. The NTSB recognizes that A320 off-wing slides are not currently part of the EOW equipment on the airplane and are not designed to be used by passengers in this manner. However, this accident clearly demonstrates that passengers can and will successfully use the off-wing ramp/slides as a means of flotation in an emergency if they are available. However, the lack of quick-release girts prevented passengers from being able to disconnect the slides, and, if the airplane had sunk more quickly, the passengers would have had to abandon them and enter the water. Therefore, adding quick-release girts on all evacuation slides could be one method to prevent passenger immersion after an accident involving water.

The NTSB concludes that, given the circumstances of this accident and the large number of airports located near water and of flights flown over water, passenger immersion protection needs to be considered for non-EOW operations, as well as EOW operations. Therefore, the NTSB recommends that the FAA require quick-release girts and handholds on all evacuation slides and ramp/slide combinations.

Life Lines

All of US Airways' A320 EOW-equipped airplanes were required to be equipped with four life lines in accordance with 14 CFR 91.509(b)(5), "Survival Equipment for Overwater Operations." Life lines located at the overwing exits were intended to be used after a ditching by people on the wings to prevent them from falling into the water. However, it is unclear under what circumstances the life lines could be used effectively. For example, flight attendants were trained to direct passengers to exit into slide/rafts via the four floor-level exits during a planned ditching on an EOW-equipped airplane. Flight attendants were also trained to only use the overwing exits as secondary exits if a primary exit was unavailable (and it was safe to do so). Even then, given the flight attendants' locations in the cabin (at the forward- and aft-most areas of the airplane), it would be extremely difficult to physically reach the overwing exits because of the evacuating passengers. Additionally, as occurred in this accident, overwing exits are typically opened by passengers.

No information is contained on the US Airways passenger safety information card about the use or location of the life lines. Further, no information is provided to passengers about life lines during the preflight safety demonstration or individual exit row briefings. The NTSB is concerned that passengers most likely will not see or understand the placards above the overwing exit signs depicting deployed life lines and, therefore, that they will be unaware of the existence of life lines. Further, given that flight attendants will be unable to reach them during an unexpected emergency, the NTSB fails to see how life lines will be effectively used. The NTSB notes that, after exiting the airplane through the overwing exits, at least nine passengers unintentionally fell into the water from the wings.

The NTSB concludes that, if the life lines had been retrieved, they could have been used to assist passengers on both wings, possibly preventing passengers from falling into the water. Therefore, the NTSB recommends that the FAA require 14 CFR Part 121, Part 135, and Part 91 Subpart K operators to provide information about life lines, if the airplane is equipped with them, to passengers to ensure that the life lines can be quickly and effectively retrieved and used.

Life Vest and Flotation Seat Cushion Equipage

Because the accident airplane was equipped for EOW operations, it carried life vests for both passengers and crewmembers. However, given that the accident flight route was not an EOW operation, the airplane could very well have been equipped with only slides and flotation seat cushions as the primary means for passenger flotation. In that case, flight attendants would have detached the forward slides and instructed passengers to jump into the water with their flotation seat cushions and hold onto the slide.

If no slide/rafts had been available at the forward door exits, many of the passengers egressing from these exits would have had no choice but to jump into the water with no flotation device. (About 42 percent of the passengers did not exit with a flotation seat cushion.) Even if they had retrieved their flotation seat cushions, many passengers would have experienced extreme difficulty holding onto a seat cushion for more than a few minutes because of the effects of cold-water immersion. Self-righting life vests designed in accordance with TSO-C13f, such as those on the accident airplane, are designed to keep an individual's head above water even after he or she is unable to swim or effectively move his or her arms and legs.

In Safety Study 85/02, the NTSB issued Safety Recommendations A-85-35 through -37, which recommended that all Part 121, 125, and 135 passenger-carrying air carrier aircraft be equipped with approved life vests meeting the latest TSO and to ensure Part 25 requirements were consistent with the amendments made to Parts 121, 125, and 135. In response to these recommendations, on June 30, 1988, the FAA published NPRM 88-11, which proposed new requirements that "would ensure that each occupant is provided a life preserver which provides the basic benefits of high buoyancy and water stability…regardless of whether the airplane is involved in overwater operation."

In 1997, the FAA informed the NTSB that a final rule was expected to be published in the *Federal Register* by the end of that year; however, no final rule was issued. Subsequently, the FAA stated that "due to the amount of comments received and the amount of time since the NPRM was originally issued," it had decided to publish a supplemental NPRM by October 2000. When that date passed and no communication was received, on March 29, 2002, the NTSB classified Safety Recommendations A-85-35 through -37 "Closed—Unacceptable Action." On July 24, 2003, more than 15 years after it was originally published, the FAA withdrew the original NPRM 88-11 and stated, "we find the costs of proceeding with this rulemaking as proposed exceed the benefits to the public and that existing water survival equipment requirements are satisfactory."

Despite the drawbacks of using flotation seat cushions in a cold-water environment, they play an important role by providing a redundant source of personal flotation. This role was recognized by the FAA in NPRM 88-11, which proposed requiring, in addition to life vests, flotation seat cushions for each occupant on all flights, regardless of route.[14] More than half of the passengers on the accident flight evacuated with a flotation seat cushion, demonstrating not only their familiarity with the equipment, but also their ability and willingness to retrieve it in an emergency. Additionally, in a water accident that results in fuselage breakup and rapid cabin flooding, flotation seat cushions may break free and float to the surface, offering perhaps the only ready means of flotation available to survivors.

Because so many airports are located near bodies of water and most emergencies occur during the takeoff or landing portions of flight, life vests are critical equipment on all flights, regardless of the route. The NTSB concludes that equipping aircraft with flotation seat cushions and life vests on all flights, regardless of the route, will provide passengers the benefits of water buoyancy and stability in the event of an accident involving water. Therefore, the NTSB recommends that the FAA require that aircraft operated by 14 CFR Part 121, Part 135, and Part 91 Subpart K operators be equipped with flotation seat cushions and life vests for each occupant on all flights, regardless of the route.

Life Vest and Flotation Seat Cushion Briefings

As noted, only about 77 passengers retrieved flotation seat cushions and evacuated with them, whereas only about 10 passengers retrieved life vests themselves after impact and evacuated with them. Passenger interviews revealed that most of the passengers were frequent travelers who were very familiar with the preflight briefing and that, over the years, the information about the seat cushions had "sunk in" to their consciousness. Several passengers stated that, even in their stressed state, they were able to specifically recall how they were supposed to hold the cushion to their chests with their arms crossed.

One probable reason that more passengers were aware that flotation seat cushions were on board the airplane than were aware that life vests were on board is that preflight briefings address the use of the flotation seat cushions on virtually all flights, whereas only briefings on

[14] Currently, EOW-equipped airplanes are not required to carry seat cushions for auxiliary passenger flotation; however, the accident airplane was so equipped.

EOW flights generally address the location and use of life vests.[15] Passenger interviews indicated that about 70 percent of the passengers did not watch any of the preflight safety briefing, indicating that passenger attention to the preflight briefings was generally low. However, it appears that, over time, frequent travelers have become accustomed to hearing the phrase, "your seat cushion may be used as a flotation device," and have remembered it. (Passenger education will be discussed later in this letter.)

In Safety Study 85/02, the NTSB issued Safety Recommendation A-85-39, which asked the FAA to amend the relevant sections of Parts 121, 125, and 135 to require that all predeparture briefings include a full demonstration of correct life preserver donning procedures. The FAA took no action on Safety Recommendation A-85-39; therefore, on June 1, 1987, the NTSB classified it "Closed–Unacceptable Action." The FAA changed its position a year later and, in NPRM 88-11, proposed a requirement that "before each takeoff passengers be briefed on the location and use of required flotation equipment. In addition, a demonstration of the method of donning and inflating the life preservers would have to be given." However, NPRM 88-11 was withdrawn in 2003, and no action was taken on this issue.

Although life vests were not required for the accident flight, because they were installed on the airplane, the flight attendants were required by federal regulations to brief the passengers on their location and use.[16] However, a life vest demonstration was not required because the flight was not an EOW operation. CVR data indicated that the preflight safety briefing provided by flight attendant B included information about the flotation seat cushions but that it omitted information about the location, removal, donning, and inflation of the life vests. This omission was not in accordance with federal regulations or company procedures, which stated that this information should be provided.

The NTSB concludes that briefing passengers on, and demonstrating the use of, all flotation equipment installed on an airplane on all flights, regardless of the route, will improve the chances that the equipment will be effectively used during an accident involving water. Therefore, the NTSB recommends that the FAA require 14 CFR Part 121, Part 135, and Part 91 Subpart K operators to brief passengers on all flotation equipment installed on an airplane, including a full demonstration of correct life vest retrieval and donning procedures, before all flights, regardless of route.

Life Vest and Flotation Seat Cushion Stowage and Retrieval

Although the accident flight attendants did not command passengers to don their life vests before the water impact, two passengers realized that they would be landing in water and retrieved and donned their life vests before impact, and a third passenger attempted to retrieve his life vest but was unable to do so and, therefore, abandoned his attempt. Many passengers reported that their immediate concern after the water impact was to evacuate as quickly as possible, that they forgot about or were unaware that a life vest was under their seat, or that they

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[15] The NTSB notes that some airlines use video presentations on certain airplanes and on all flights that show the location and use of life vests.

[16] On an airplane equipped with both flotation seat cushions and life vests (such as the accident airplane), flight attendants were required to brief passengers on both types of equipment.

did not want to delay their egress to get one.[17] Other passengers stated that they wanted to retrieve their life vest but could not remember where it was stowed.

Overall, 19 passengers physically attempted to obtain a life vest from under a seat, and 10 of these passengers reported difficulties retrieving it. Of those 10 passengers, only 3 were persistent enough to eventually obtain the life vest; the other 7 either retrieved a flotation seat cushion or abandoned the idea of retrieving flotation equipment altogether.

As noted in NTSB Safety Study 85/02, life vest stowage is addressed in various ways in FAA regulations. The study stated that, taken together:

> these regulations require that each life preserver have its own stowage compartment, that a stowed life preserver be within easy reach[18] of each seated occupant, that it be easily accessible in a ditching without appreciable time for preparatory procedures, that the stowage compartment be conspicuously marked and be approved, and that the stowage compartment protect the life preserver from inadvertent damage.

In the safety study, the NTSB noted that, despite the requirements for life vest accessibility, several accident investigations had revealed that passengers have repeatedly had difficulty retrieving life vests from their usual stowage location under the seat. For example, the safety study stated that, in the 1970 Overseas National Airways ditching, passengers spent about 5 to 7 minutes from the time they were told of a possible ditching to the moment of impact trying to retrieve their life vests from under their seats and to unpackage and don them. Some of the passengers had to get on their hands and knees to get the life vests out of their stowage compartments, and some passengers never got them out of the compartments at all. According to the safety study, not being able to access or don a life vest contributed to several of the 23 deaths that resulted from this accident. The investigation of several other accidents revealed that passengers had similar problems retrieving their life vests.[19] As noted in the safety study, the problems identified during the investigation of these accidents were confirmed during timing tests at CAMI in 1983. In those tests, which were conducted under ideal conditions, adults took from 9 to 80 seconds (an average of 17 seconds) to retrieve a life vest from beneath their seat.

In May 2003, CAMI tested four different configurations of under-seat life vest stowage pouches.[20] Although none of the configurations were identical to the one in the economy-class section of the accident airplane, the average retrieval time for the most similar configuration was 8.5 seconds. Another configuration, which was similar to the first-class containers on the

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[17] Many of the passengers who stated that they were aware that the airplane was equipped with life vests indicated that they knew this because of information they had received on previous flights, indicating that they believed all airplanes were equipped with life vests on all flights.

[18] The term "easy reach" is not defined in any published FAA guidance or policy documents.

[19] These accidents include the 1978 crash of National Airlines into Escambia Bay, Florida; the 1982 World Airways runway overrun; and the 1983 Eastern Air Lines L-1011 near-ditching offshore of Miami, Florida. See Safety Study 85/02 for more information.

[20] See V. Gowdy and R. DeWeese, *Human Factors Associated With The Certification of Airplane Passenger Seats: Life Preserver Retrieval*, FAA Office of Aerospace Medicine, Report No. AM-03/9 (Oklahoma City, Oklahoma: 2003).

accident airplane, resulted in an average retrieval time of 7.4 seconds. Both of these retrieval times were considered to be in the "easy range."

The experiences from the accident flight validate the results of the 1983 and 2003 CAMI tests and confirm that many passengers may take at least 7 to 8 seconds to retrieve a life vest and that many passengers will not wait that long before abandoning the retrieval attempt and evacuating without a life vest. Additionally, if water enters the cabin after a water impact, which is likely, passengers will also be deterred from retrieving their life vests because doing so would delay evacuation. The FAA stated the following in NPRM 88-11:

> Accident experience and research testing have demonstrated that typical airline passengers have difficulty in retrieving life preservers and that such stowage beneath a passenger's seat makes the life preservers vulnerable to water impact damage, seat collapse, and post-impact flooding.

Despite this, the FAA stated that "the advantages that would be gained by prohibiting under seat stowage of life preservers would not outweigh the disadvantages." The FAA stated that there was insufficient basis to conclude that passenger safety would be increased by relocating life preserver stowage. However, the FAA did propose a rule revision that would have required an approved stowage pocket that "allows the passenger, using only one hand, to readily locate the pocket, open it, grasp the life preserver, and retrieve it." As noted, NPRM 88-11 was withdrawn in 2003, and no action was taken on this issue.

The NTSB concludes that passenger behavior on the accident flight indicated that most passengers will not wait 7 to 8 seconds, the reported average life vest retrieval time, before abandoning the retrieval attempt and evacuating without a life vest. Therefore, the NTSB recommends that the FAA require modifications to life vest stowage compartments or stowage compartment locations to improve the ability of passengers to retrieve life vests for all occupants.

Life Vest Donning

Most of the passengers who eventually donned, or attempted to don, life vests did so after they were outside the airplane while they were seated in a slide/raft or standing on a wing. Of the estimated 33 passengers who reported eventually having a life vest,[21] only 4 confirmed that they were able to complete the donning process by securing the waist strap themselves. Most of passengers who had life vests either struggled with the strap or chose not to secure it at all for a variety of reasons.

The NTSB has a long history of issuing recommendations to simplify life vest donning. In Safety Study 85/02, the NTSB noted that it had issued several safety recommendations to the FAA as a result of the 1970 Overseas National Airways ditching, the 1978 National Airlines crash, and the 1983 near-ditching of Eastern Airlines L-1011 to improve "the requirements for

[21] By the time the last passengers reached the overwing exits, some of the passengers outside the airplane realized that they did not have a flotation device and called back into the airplane for assistance. Subsequently, several passengers who were still in the airplane began retrieving life vests from beneath the seats and passing them to the passengers on the wings. Further, the captain and first officer handed out life vests to some of the passengers in the forward slide/raft.

life vests to make them easily and quickly usable in the actual environment of a water impact." The safety recommendations that resulted from these accidents led the FAA to revise TSO-C13c in January 1983 to include a requirement that an adult can don a life vest within 15 seconds (unassisted) while seated.[22]

The safety study noted that the revision to the TSO had little effect on the donning of life vests, as confirmed by the 1983 CAMI tests.[23] These tests were conducted on life vests newly certified under TSO-C13d, and test results showed that passengers still had difficulty donning vests. Of 100 attempts to don the vests, only 4 were successfully completed within 15 seconds, and, in 21 attempts, users either did not don the life vests correctly within 2 minutes or gave up trying altogether. The CAMI report indicated that the life vests' waist straps were the major obstacle to correct donning and that "users fail to tighten the straps, or do not fasten them correctly, or do not fasten them at all."

CAMI also tested two unapproved[24] experimental devices, both modified from "angler's vests." These devices proved much easier to don, with 29 of 50 users donning them correctly within 15 seconds. CAMI attributed the improved performance to the fact that the device looked like a vest (and was meant to be donned like one), had an obvious front-to-rear position, and had no straps (just a plastic-tooth zipper up the front). Despite these promising results, the NTSB is not aware of any further development of this type of device.

As a result of these findings, the NTSB issued numerous safety recommendations to amend TSO-C13d (currently version TSO-C13f) to make it easier for passengers to don life vests. Although the FAA implemented some of the recommended changes, the circumstances of this accident again demonstrate that passengers have problems correctly donning life vests.

The NTSB concludes that the current life vest design standards contained in TSO-C13f do not ensure that passengers can quickly or correctly don life vests. Therefore, the NTSB recommends that the FAA revise the life vest performance standards contained in TSO-C13f to ensure that they result in a life vest that passengers can quickly and correctly don.

Passenger Education

About 70 percent of the passengers did not watch any of the preflight safety demonstration. In addition, more than 90 percent did not read the safety information card before or during the flight. The NTSB believes that these responses clearly indicate that passenger safety information is still routinely ignored by most travelers. The most frequently cited reason for this was that the passengers flew frequently and were familiar with the equipment on the airplane, making them complacent.

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[22] TSO-C13f currently states, "It must be demonstrated…that at least 75% of the total number of test subjects and at least 60% of the test subjects in each age group…can don the life preserver within 25 seconds unassisted, starting with the life preserver in its storage package."

[23] The NTSB notes that, although the life vests had been newly certified under the revised TSO, the life vest design was essentially unchanged.

[24] At the time, two inflation chambers were required, and the unapproved vest only had one. Currently, TSO-C13f allows single-chamber devices.

The NTSB has previously issued several safety recommendations addressing the improvement of passenger attention to preflight safety briefings and safety information cards.[25] The NTSB reexamined the issue most recently in Safety Study 00/01, "Emergency Evacuation of Commercial Airplanes."[26] Safety Study 00/01 indicated that, of 377 responding passengers, 13 percent reported that they did not watch any of the briefing, and 39 percent reported that they watched less than 75 percent of the briefing. Worse still, 68 percent of the responding passengers indicated that they did not read the safety information card meant to supplement the oral briefing.[27] The NTSB concluded that the problem of passenger inattention to briefings continued to exist and that "passengers…need to pay attention to the safety information." The NTSB noted that, with the exception of using videotaped briefings, little had changed in how safety information was presented to passengers. Therefore, the NTSB issued Safety Recommendation A-00-86, which recommended that the FAA do the following:

> Conduct research and explore creative and effective methods that use state-of-the-art technology to convey safety information to passengers. The presented information should include a demonstration of all emergency evacuation procedures, such as how to open the emergency exits and exit the aircraft, including how to use the slides.

In response, the FAA stated that the current state-of-the-art technology (video safety briefings) was effective and already being used in the aviation industry. On May 6, 2004, the NTSB classified Safety Recommendation A-00-86 "Closed—Unacceptable Action" because the FAA did not conduct any research on creative and effective methods to use new technology to address the problem of passenger inattention to briefings.[28]

The NTSB concludes that most of the passengers did not pay attention to the oral preflight safety briefing or read the safety information card before the accident flight, indicating that more creative and effective methods of conveying safety information to passengers are needed because of the risks associated with passengers not being aware of safety equipment. Therefore, the NTSB recommends that the FAA conduct research on, and require 14 CFR Part 121, Part 135, and Part 91 Subpart K operators to implement, creative and effective methods of overcoming passengers' inattention and providing them with safety information.

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[25] For example, in 1974, the NTSB issued Safety Recommendation A-74-113, which recommended that the FAA issue an AC that would provide standardized guidance to the air transport industry on effective methods and techniques for conveying safety information to passengers. On September 27, 1977, the NTSB classified Safety Recommendation A-74-113 "Closed—Acceptable Action" based on the FAA's issuance of AC 121-24. In 1985, the NTSB issued Safety Recommendation A-85-101, which recommended that the FAA require that recurrent flight attendant training programs contain instructions on the use of the public address system and techniques for maintaining effective safety briefings and demonstrations that will improve the motivation of passengers to pay attention to the oral briefings and demonstrations. Although the FAA issued AC 121-24A, the NTSB classified Safety Recommendation A-85-101 "Closed—Unacceptable Action" on August 21, 1991, because the AC did not meet the intent of the recommendation.

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

[27] Of those who did not read the safety information card, 89 percent indicated that their reason for not doing so was that they had read the card on previous flights.

[28] The NTSB notes that public hearing testimony indicated that US Airways had deactivated and/or removed the video equipment from their entire A320 fleet for "financial considerations."

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

> Work with the military, manufacturers, and National Aeronautics and Space Administration to complete the development of a technology capable of informing pilots about the continuing operational status of an engine. (A-10-62)
>
> Once the development of the engine technology has been completed, as asked for in Safety Recommendation A-10-62, require the implementation of the technology on transport-category airplane engines equipped with full-authority digital engine controls. (A-10-63)
>
> Modify the 14 *Code of Federal Regulations* 33.76(c) small and medium flocking bird certification test standard to require that the test be conducted using the lowest expected fan speed, instead of 100-percent fan speed, for the minimum climb rate. (A-10-64)
>
> During the bird-ingestion rulemaking database (BRDB) working group's reevaluation of the current engine bird-ingestion certification regulations, specifically reevaluate the 14 *Code of Federal Regulations* (CFR) 33.76(d) large flocking bird certification test standards to determine whether they should 1) apply to engines with an inlet area of less than 3,875 square inches and 2) include a requirement for engine core ingestion. If the BRDB working group's reevaluation determines that such requirements are needed, incorporate them into 14 CFR 33.76(d) and require that newly certificated engines be designed and tested to these requirements. (A-10-65)
>
> Require manufacturers of turbine-powered aircraft to develop a checklist and procedure for a dual-engine failure occurring at a low altitude. (A-10-66)
>
> Once the development of the checklist and procedure for a dual-engine failure occurring at a low altitude has been completed, as asked for in Safety Recommendation A-10-66, require 14 *Code of Federal Regulations* Part 121, Part 135, and Part 91 Subpart K operators of turbine-powered aircraft to implement the checklist and procedure. (A-10-67)
>
> Develop and validate comprehensive guidelines for emergency and abnormal checklist design and development. The guidelines should consider the order of critical items in the checklist (for example, starting the auxiliary power unit), the use of opt outs or gates to minimize the risk of flight crewmembers becoming stuck in an inappropriate checklist or portion of a checklist, the length of the checklist, the level of detail in the checklist, the time needed to complete the checklist, and the mental workload of the flight crew. (A-10-68)

Require 14 *Code of Federal Regulations* Part 121, Part 135, and Part 91 Subpart K operators to include a dual-engine failure scenario occurring at a low altitude in initial and recurrent ground and simulator training designed to improve pilots' critical-thinking, task-shedding, decision-making, and workload-management skills. (A-10-69)

Require 14 *Code of Federal Regulations* Part 121, Part 135, and Part 91 Subpart K operators to provide training and guidance to pilots that inform them about the visual illusions that can occur when landing on water and that include approach and touchdown techniques to use during a ditching, with and without engine power. (A-10-70)

Work with the aviation industry to determine whether recommended practices and procedures need to be developed for pilots regarding forced landings without power both on water and land. (A-10-71)

Require applicants for aircraft certification to demonstrate that their ditching parameters can be attained without engine power by pilots without the use of exceptional skill or strength. (A-10-72)

Require Airbus operators to amend the ditching portion of the Engine Dual Failure checklist and any other applicable checklists to include a step to select the ground proximity warning system and terrain alerts to OFF during the final descent. (A-10-73)

Require Airbus operators to expand the angle-of-attack-protection envelope limitations ground-school training to inform pilots about alpha-protection mode features while in normal law that can affect the pitch response of the airplane. (A-10-74)

Require all 14 *Code of Federal Regulations* Part 139-certificated airports to conduct wildlife hazard assessments (WHA) to proactively assess the likelihood of wildlife strikes, and, if the WHA indicates the need for a wildlife hazard management plan (WHMP), require the airport to implement a WHMP into its airport certification manual. (A-10-75)

Work with the U.S. Department of Agriculture to develop and implement innovative technologies that can be installed on aircraft that would reduce the likelihood of a bird strike. (A-10-76)

Require Airbus to redesign the frame 65 vertical beam on A318, A319, A320, and A321 series airplanes to lessen the likelihood that it will intrude into the cabin during a ditching or gear-up landing and Airbus operators to incorporate these changes on their airplanes. (A-10-77)

Conduct research to determine the most beneficial passenger brace position in airplanes with nonbreakover seats installed. If the research deems it necessary, issue new guidance material on passenger brace positions. (A-10-78)

Require, on all new and in-service transport-category airplanes, that cabin safety equipment be stowed in locations that ensure that life rafts and/or slide/rafts remain accessible and that sufficient capacity is available for all occupants after a ditching. (A-10-79)

Require quick-release girts and handholds on all evacuation slides and ramp/slide combinations. (A-10-80)

Require 14 *Code of Federal Regulations* Part 121, Part 135, and Part 91 Subpart K operators to provide information about life lines, if the airplane is equipped with them, to passengers to ensure that the life lines can be quickly and effectively retrieved and used. (A-10-81)

Require that aircraft operated by 14 *Code of Federal Regulations* Part 121, Part 135, and Part 91 Subpart K operators be equipped with flotation seat cushions and life vests for each occupant on all flights, regardless of the route. (A-10-82)

Require 14 *Code of Federal Regulations* Part 121, Part 135, and Part 91 Subpart K operators to brief passengers on all flotation equipment installed on an airplane, including a full demonstration of correct life vest retrieval and donning procedures, before all flights, regardless of route. (A-10-83)

Require modifications to life vest stowage compartments or stowage compartment locations to improve the ability of passengers to retrieve life vests for all occupants. (A-10-84)

Revise the life vest performance standards contained in Technical Standard Order-C13f to ensure that they result in a life vest that passengers can quickly and correctly don. (A-10-85)

Conduct research on, and require 14 *Code of Federal Regulations* Part 121, Part 135, and Part 91 Subpart K operators to implement, creative and effective methods of overcoming passengers' inattention and providing them with safety information. (A-10-86)

The National Transportation Safety Board has also issued one safety recommendation to the U.S. Department of Agriculture and eight safety recommendations to the European Aviation Safety Agency.

In response to the recommendations in this letter, please refer to Safety Recommendations A-10-62 through -86. 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 secure mailbox. 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).

Chairman HERSMAN, Vice Chairman HART, and Member SUMWALT concurred with these recommendations. Member SUMWALT filed a concurring statement, which is attached to the aviation accident report for this accident.

[Original Signed]

By: Deborah A.P. Hersman
Chairman