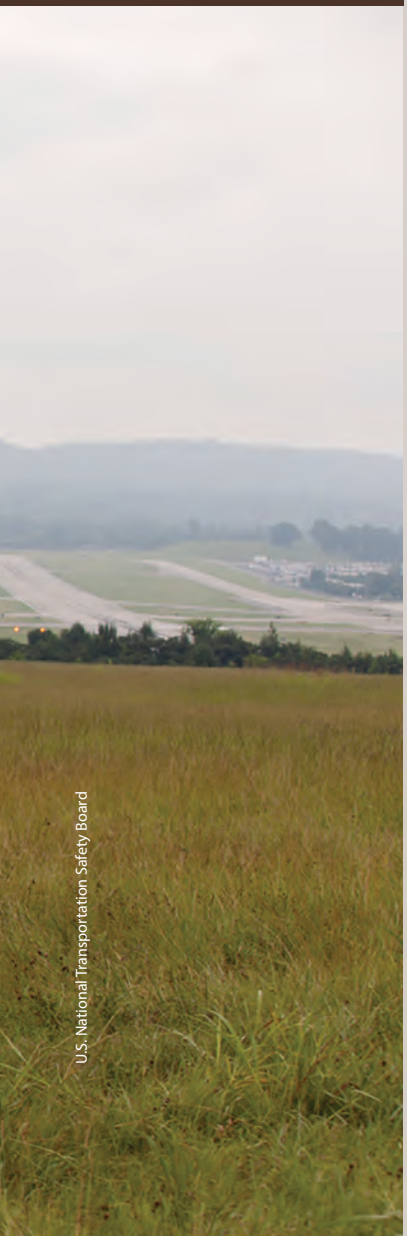
False Expectations

BY MARK LACAGNINA

The pilots were looking out the windshield, anticipating visual contact with the runway, when the A300 descended below minimums at Birmingham.



U.S. National Transportation Safety Board

Relying on the reported weather conditions at the airport, the flight crew expected to break out of the clouds 1,000 ft above ground level (AGL) while conducting a late-night nonprecision approach. They did not realize that the bases of the clouds along the approach path were lower than those over the airport.

Concentrating on gaining sight of the runway, the pilots allowed the Airbus A300-600 freighter to descend below the minimum descent altitude for the approach. They finally caught sight of the runway about two seconds before the airplane struck the ground near Birmingham (Alabama, U.S.)–Shuttlesworth International Airport at 0447 local time on Aug. 14, 2013. Both pilots were killed, and the airplane was destroyed by the impact and subsequent fire.

In its final report, the U.S. National Transportation Safety Board (NTSB) said that the probable causes of the accident were "the flight crew's continuation of an unstabilized approach and their failure to monitor the aircraft's altitude during the approach."

The NTSB determined that fatigue played a major role in the accident (see "Sooo Tired," *ASW,* 11/14, p. 17) and that the crew's improper programming of the flight management system to achieve descent at a constant angle on final approach, the captain's failure to inform the first officer when he switched from the autopilot profile mode to the vertical speed mode, and the first officer's failure to make required altitude callouts also were contributing factors.

'Substandard Elements'

The A300 was being operated as UPS Flight 1354, a scheduled cargo flight to Birmingham from Louisville, Kentucky.

The captain, the pilot flying, was 58. He flew for a regional airline and for a major airline as a Boeing 727 flight engineer and first officer before being hired by UPS as a 727 flight engineer in 1990. He upgraded as a 727 first officer in 1994.

"UPS records indicate that the captain attempted to upgrade to Boeing 757 captain twice — in July 2000 and September 2002 — but voluntarily withdrew from training during classroom instruction, returning to the position of 727 first officer on both occasions," the report said. He upgraded as an A300 first officer in 2004 and as an A300 captain in 2009.

"Although the captain reported 8,600 hours of total flight time on his most recent first-class medical application, no documentation of that time was available," the report said. "A review of UPS records indicated that the captain had about 6,406 hours total flight time at UPS, of which 3,265 hours were in the A300."

UPS records revealed several instances in which the captain displayed substandard performance while conducting nonprecision instrument approaches during recurrent training. "The captain's poor performance during the accident flight was consistent with past performance deficiencies … during training," the report said.

The first officer, 37, flew for corporate and regional aircraft operators before being hired by UPS as a 727 flight engineer in 2006. She then upgraded as a first officer in the 757, 747-400 and A300. "According to UPS records … the first officer had about 4,721 hours of total flight time, including 403 hours as second-in-command in the A300," the report said.

Lack of Communication

Investigators determined that the flight crew likely was not aware before departing from Louisville of two critical factors relating to their arrival at Birmingham: the main runway would be closed, and a precision approach would not be available.

The report attributed this absence of awareness in part to a lack of communication between the pilots and the dispatcher at Louisville. The dispatcher did not point out salient information about the weather conditions at Birmingham or about the runway and approaches available at the airport at the estimated time of arrival. The pilots did not seek the dispatcher's input.

The flight release paperwork provided to the flight crew included a notice to airmen (NOTAM) stating that the main runway at

Birmingham — Runway 06/24, which has an instrument landing system (ILS) approach — would be closed from 0400 to 0500 for maintenance of the runway edge lights.

"Because the flight's scheduled arrival time was 0451, only the shorter Runway 18, with a nonprecision approach, was available to the crew," the report said. Runway 18 is 7,099 ft (2,164 m) long and has a localizer approach and a global positioning system (GPS) approach.

"The investigation could not confirm whether the flight crewmembers became aware of the NOTAM during their paperwork review," the report said.

Moreover, the Jeppesen charts the crew was using indicated erroneously that the localizer approach was not authorized at night, and the forecast weather conditions at Birmingham indicated that the ceiling would be below the minimum descent altitude for the GPS approach.

"As a result, the flight may have had to divert to its alternate of Hartsfield–Jackson Atlanta [Georgia, U.S.] International Airport … or hold until the longer runway opened," the report said. "However, the dispatcher did not discuss this possibility or remind the flight crew that Runway 06/24 would reopen about 0500."

"The NTSB concludes that the dispatcher of UPS Flight 1354 should have alerted the flight crew to the limited options for arrival at [Birmingham], especially that Runway 18 was the only available runway, because doing so would have further helped the pilots … evaluate all available options."

The dispatcher told investigators that he generally did not, and was not required to, talk with pilots. "He indicated that he typically only spoke with pilots when they initiated the conversation," the report said.

The investigation determined that the flight crew was not aware before departing from Louisville that Runway 06 and, consequently, the ILS approach would not be available when they reached Birmingham.

A 9-minute delay of the departure, which either the captain or the dispatcher was authorized to make, would have changed the expected arrival time to coincide with the runway's scheduled reopening time. However, neither the captain nor the dispatcher apparently considered changing the scheduled departure time.

'It Figures'

Shortly after the A300 departed from Louisville at 0503 (0403 Birmingham time), air traffic control (ATC) cleared the crew to navigate directly to the Birmingham airport and to climb to Flight Level (FL) 280 (approximately 28,000 ft).

Nearing Birmingham, the first officer listened to the automatic terminal information service (ATIS) broadcast, which stated that the winds were calm, visibility was 10 mi (16 km), the ceilings were broken at 1,000 ft and overcast at 7,000 ft, the localizer approach to Runway 18 was in use and that Runway 06/24 was closed. (No information about when the runway was scheduled to be reopened was included in the broadcast.)

The ATIS information was based in part on meteorological observations from a routine aviation weather report (METAR) issued at 0353. Although the METAR included remarks that the ceiling varied between 600 ft and 1,300 ft AGL, the remarks were not included in the ATIS broadcast.

The report noted that although the U.S. Federal Aviation Administration

(FAA) requires ATC personnel to include "pertinent remarks" in ATIS broadcasts, the agency provides limited guidance on what information is pertinent. "If the flight crewmembers had been aware of the variable ceilings reported on the 0353 METAR, they may not have expected to break out of the clouds at 1,000 ft AGL," the report said.

After copying the ATIS information, the first officer told the captain, "They're saying six and two-four is closed. They're doing the localizer to one eight."

The captain replied, "Localizer one eight, it figures."

"I know, especially since we're a little heavy," the first officer said.

The report said these comments indicate that the pilots were not aware before hearing the ATIS broadcast that Runway 06/24 would be closed and that the ILS would be unavailable.

A UPS A300 check airman told investigators that although pilots receive annual training on nonprecision approaches, they rarely conduct them during line operations. "In most cases, a UPS pilot's only opportunity to practice nonprecision approaches would likely occur once a year during recurrent training," the report said. "An unintended consequence of the operational preference for precision approaches is that pilots have lost proficiency with the unique procedures associated with infrequently conducted nonprecision approaches."

'Meaningless' Path

The localizer approach to Runway 18 at Birmingham includes an initial approach fix called "COLIG"; a final approach fix, "BASKN"; and a step-down fix, "IMTOY," between the final approach fix and the missed approach point. The minimum crossing altitudes are 2,300 ft at BASKN and 1,380 ft at IMTOY; and the minimum descent altitude (MDA) is 1,200 ft (Figure 1).

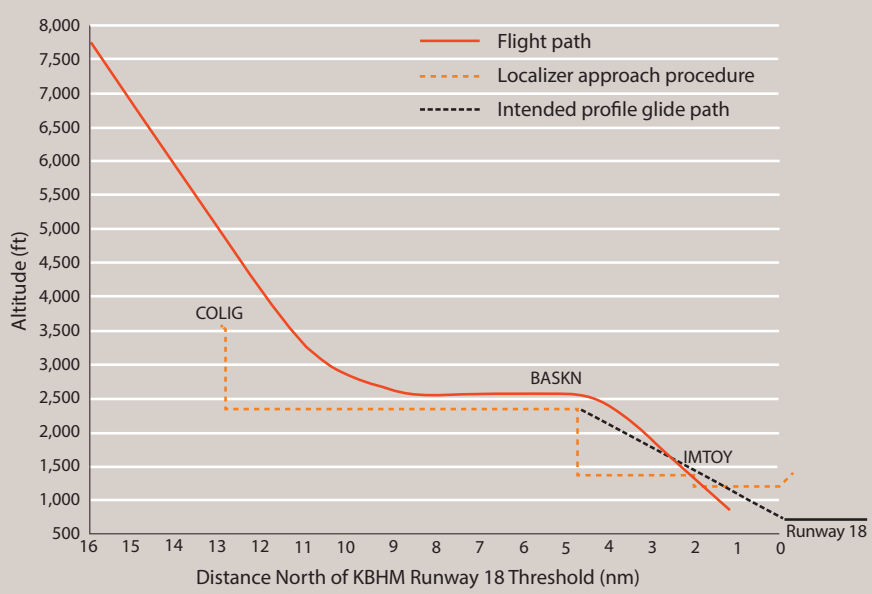
Because consecutive descents and level-offs are required after BASKN and after IMTOY, this is considered a step-down, or "dive and drive" approach. To illustrate the drawbacks of such approaches, the report cited FAA Advisory Circular 120-108, *Continuous Descent Final Approach*, which says, "Stepdowns flown without a constant descent will require multiple thrust, pitch and altitude adjustments inside the final approach fix (FAF). These adjustments increase pilot workload and potential errors during a critical phase of flight."

To avoid this, the pilots planned and briefed for a "profile approach," also called a "continuous descent final approach," which would enable descent at a constant angle (3.28 degrees in this case, as shown on the approach chart) after the FAF.

To prepare for the profile approach, the first officer attempted to program the flight management computer (FMC) to generate the 3.28-degree glide path from 2,300 ft at the final approach fix to the MDA, 1,200 ft. Investigators found, however, that she did not program the FMC correctly for the profile approach: The waypoints for the en route portion of the flight were not cleared from the flight plan before the approach fixes were entered.

The approach fixes, beginning with COLIG, were entered after the last waypoint in the en route flight plan, "KBHM," the airport identifier. As a result, the FMC flight plan remained sequenced for a course direct to the Birmingham airport.

A300 Flight Path



DA/MDA = decision altitude/minimum descent altitude; KBHM = Birmingham-Shuttlesworth International Airport

Source: Adapted from U.S. National Transportation Safety Board report by Jennifer Moore

Figure 1

A fire engulfed the aft fuselage and wings after the A300 struck trees and crashed in a gulley.

U.S. National Transportation Safety Board

"The FMC constructed a glide path for the approach using the 3.28-degree angle and the total length of all the navigation legs in the FMC, including the improper direct-to-KBHM leg," the report said. "Because this length was unrealistically long, the altitude of the glide path was unrealistically high for the airplane's actual distance from the runway, rendering the glide path meaningless."

Distraction

At 0433, the crew was cleared to descend to FL 240. Shortly thereafter, ATC told the crew that they could descend at their discretion to 11,000 ft. The first officer replied that they were beginning the descent to the lower altitude.

The A300 was level at 11,000 ft at 0441 when the first officer requested a lower altitude. The Birmingham approach controller cleared the crew to descend to 3,000 ft.

The cockpit voice recorder (CVR) captured several comments by the pilots that reflected their concern about the lack of approach options and their perception that ATC had kept the airplane high on arrival. For example, the captain said, "Diving for the airport. Unbelievable."

The airplane was 11 nm (20 km) from BASKN, the FAF, and descending through 6,900 ft at 0443 when the approach controller told the crew to maintain 2,500 ft until established on the localizer and cleared them to conduct the localizer approach to Runway 18.

The airplane was established on the localizer course when it leveled off at 2,500 ft about 4 nm (7 km) from the FAF. "Because the approach was still sequenced for a direct-to-KBHM course, the airplane continued flying toward BASKN at 2,500 ft and did not capture the desired profile glide path," the report said.

The report said that the pilots' nonpertinent conversation about the lack of approach options and being left high on the approach likely distracted them from detecting several cues showing that the profile approach had not been programmed properly. The FMC flight plan page displayed the message "F-PLAN DISCONTINUITY" between the KBHM and COLIG waypoints. The navigation displays showed an unusual flight path trajectory, vertical deviation indicators pegged at the top of their scales and discrepancies in the displayed distances.

Although the crew could have descended to 2,300 ft after intercepting the localizer course, they maintained 2,500 ft. Thus, the airplane was 200 ft high when it crossed BASKN. Because the autopilot had not captured the profile glide path, as expected, the captain switched from the autopilot profile mode to the vertical speed mode and selected a descent rate of 700 fpm to effect a descent to the MDA.

However, the captain did not call out his actions, which deviated from the briefed approach plan, and the first officer, who was completing the "Before Landing" checklist, did not notice the mode change for several seconds.

The report said that the captain apparently had become confused about the airplane's height, possibly because he misinterpreted the full-scale deflection of the vertical deviation indicators. He commented, "We're like way high … or higher," before increasing the descent rate to 1,000 fpm and then to 1,500 fpm.

The A300 was descending at 1,500 fpm when the first officer made the required callout at 1,000 ft above airport elevation. "The flight

crew did not monitor the descent rate and continued to fly the airplane with a vertical descent rate of 1,500 ft per minute below 1,000 ft above ground level, which was contrary to standard operating procedures, resulting in an unstabilized approach that should have necessitated a go-around," the report said.

After the first officer made the 1,000-ft callout, the captain responded, "All right, DA [decision altitude] is twelve hundred."

However, "neither pilot appeared to be aware of the airplane's altitude after the first officer's 1,000-ft callout," the report said. "Neither pilot made the required callouts regarding approaching and reaching the minimum descent altitude."

The investigation concluded that the crew's expectation of seeing the airport environment after reaching the altitude corresponding to the reported 1,000-ft cloud base distracted them from their duties of monitoring the approach.

High Sink Rate

The report said that both pilots likely were looking out the windshield during the final seconds of the approach. "The captain did not arrest the rate of descent as the airplane approached and then descended through the minimum descent altitude, even though he had commented that 'DA is twelve hundred' only 11 seconds earlier," the report said.

When the A300 descended through 1,200 ft, the CVR captured the first officer saying, "It wouldn't happen to be actual," and the sound of a chuckle.

The captain responded, "Oh, I know."

Shortly thereafter, as the airplane descended through 1,000 ft (about 250 ft AGL), the Enhanced Ground Proximity Warning System (EGPWS) generated a "sink rate" caution alert.

The EGPWS warning apparently prompted the captain to reduce the descent rate from 1,500 fpm to 600 fpm. About 3 seconds later, he announced that he had the runway in sight. The first officer said that she also had the runway in sight.

"About 2 seconds after reporting the runway in sight, the captain further reduced the commanded vertical speed [to 400 fpm], but the airplane was still descending rapidly on a trajectory that was about 1 nautical mile [2 km] short of the runway," the report said.

Five seconds after the pilots caught sight of the runway, the CVR captured the sound of the airplane striking trees, followed by an EGPWS caution alert of "too low terrain."

"The airplane struck more trees, a power pole and power lines before it impacted downsloping terrain in a large gulley north of the Runway 18 threshold," the report said. "The debris path continued to the bottom of the gulley and up the adjacent side."

Dormant Alerts

Investigators found that the EGPWS in the A300 had not been updated with available software that would have enabled the system to provide alerts earlier during the approach. For example, the "too low terrain" alert would have been generated 6.5 seconds earlier and 150 ft higher.

Tests conducted in a flight simulator showed that aggressive manual control inputs applied promptly after the earlier alert would have been effective in avoiding impact with the terrain.

"Although simulator results indicate that the updated EGPWS software could have avoided terrain if the CFIT [controlled flight into terrain] maneuver had been executed within 2.4 seconds of the earlier 'too low terrain' alert, it was not possible to determine whether the pilots would have, in fact, performed that maneuver or performed it in time to avoid terrain," the report said.

Investigators also found that UPS had not activated several altitude alerts that the A300s in its fleet were capable of generating. The alerts included a 500-ft callout by the EGPWS and aural alerts at 400 ft and at published approach minimums by the flight warning computer. The latter would have provided an automatic callout of "minimums" 20 seconds before the airplane struck terrain.

"Although it cannot be known how the accident crew would have responded to these alerts had they been activated, in general the alerts can provide a beneficial reminder to pilots about the airplane's altitude above terrain," the report said.

The NTSB issued numerous recommendations based on the findings of the investigation. Among them were that the FAA should require operators to reinforce the need for open communication between pilots and dispatchers, require pilots to rebrief approaches after any changes to the initial plan, and require operators to activate automated "minimums" alerts. The safety board also called on the FAA to provide further guidance on what pertinent remarks must be included in ATIS broadcasts.

This article is based on NTSB Accident Report AAR-14/02, "Crash During a Nighttime Nonprecision Instrument Approach to Landing, UPS Flight 1354, Airbus A300-600, N155UP, Birmingham, Alabama, August 14, 2013." The report is available at <ntsb.gov/investigations/reports.html>.

Inadequate monitoring of the flight instruments and misuse of the 777's autoflight system led to a collision with a seawall at San Francisco.

Mismanaged Descent

BY MARK LACAGNINA

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The indicated airspeed was on target, and the approach path lights showed that the airplane was just slightly high as it descended below 500 ft, the point at which the stability of a visual approach typically is judged. These indications were deceptive, however, and the flight crew did not recognize that the airspeed was decreasing rapidly and that the airplane would soon descend below the 3-degree glidepath.

There were other signs that the approach was not stabilized: The thrust levers were at idle (the engines were not spooled up properly), and the descent rate was higher than it should have been.

By the time the crew realized that a missed approach was in order, it was too late. "The airplane did not have the performance capability to accomplish a go-around," the U.S. National Transportation Safety Board (NTSB) said in its report on the subsequent accident.

The Asiana Airlines Boeing 777-200ER clipped a seawall bordering Runway 28L at San Francisco International Airport, slid down the runway as it shed parts and became airborne again momentarily before coming to a stop in flames off the side of the runway.

Three of the 291 passengers were killed, and 40 passengers, eight of the 12 flight attendants and one of the four flight crewmembers were seriously injured in the accident, which occurred the morning of July 6, 2013.

The NTSB concluded that the probable cause of the accident was "the flight crew's mismanagement of the airplane's descent during the visual approach, the PF's [pilot flying's] unintended deactivation of automatic airspeed control, the flight crew's inadequate monitoring of airspeed, and the flight crew's delayed execution of a go-around after they became aware that the airplane was below acceptable glidepath and airspeed tolerances."

The report said that factors contributing to the accident were: "(1) the complexities of the autothrottle and autopilot/flight director systems that were inadequately described in Boeing documentation and Asiana's pilot training, which increased the likelihood of mode error; (2) the flight crew's nonstandard communication and coordination regarding the use of the autothrottle and autopilot/flight director systems; (3) the PF's inadequate training on the planning and execution of visual approaches; (4) the PM [pilot monitoring]/instructor pilot's inadequate supervision of the PF; and (5) flight crew fatigue, which likely degraded their performance."

New Roles

The 777 was being operated as Asiana Airlines Flight 214, a scheduled passenger flight from Seoul, South Korea, with an estimated time en route to San Francisco of 10 hours and 24 minutes.

An instructor pilot and a trainee captain comprised the primary flight crew, backed up by a relief captain and first officer. The instructor pilot was the pilot-in-command (PIC) of the flight. He occupied the right seat and served as the PM during the takeoff from Seoul and the approach to San Francisco; the trainee captain was in the left seat and was the PF. Both pilots were relatively inexperienced in their flight roles.

The trainee captain, 45, had 9,684 flight hours, including 3,729 hours as PIC. He had no previous flight experience when he was hired by Asiana as a cadet pilot in 1994. He served as a first officer in 737s and 747s before upgrading as a 737 captain in 2005. He transitioned as an Airbus A320 captain in 2007 and began transition training to become a 777 captain in March 2013. By the end of May, he had completed ground training, flight simulator training and line-oriented flight training in the 777.

"He began flying the 777 with an IP [instructor pilot] as part of his required initial OE [operating experience] on June 16, 2013," the report said. He had logged eight flight legs and 33.5 flight hours with IPs. "All of the approaches the PF had previously flown during OE were ILS [instrument landing system] approaches, and there was no requirement to perform visual approaches during OE," the report said.

Investigators received mixed feedback when they interviewed three IPs who had flown with the trainee captain. One said his overall performance

was above average. Another said that "nothing stood out" about his performance. The third IP said that the trainee captain had not performed well. "He said the PF was not well organized or prepared, conducted inadequate briefings, poorly monitored the operation and deviated from multiple standard operating procedures," the report said.

The IP told investigators that he provided "extensive counseling" but "worried that the PF was not taking his feedback seriously." However, the IP said that he was not overly concerned because he knew that the trainee captain had to complete more OE flights. (Korean aviation regulations required 20 flight legs and 60 flight hours of OE.)

The IP who served as the PIC and PM on Flight 214 was 49 and had 12,307 flight hours, including 9,045 hours as PIC and 3,208 hours in 777s. He served as a Korean air force pilot before joining Asiana in 1996. He flew as a 767 first officer and captain before transitioning as a 777 captain in 2008.

"He underwent 777 IP training in May and June 2013 and became qualified as an IP on June 12, 2013," the report said. The captain who conducted the IP's final check flight said that he was "very calm, followed the procedures correctly, had professional knowledge of the flight and had good capability and skill as an instructor." Flight 214 was the PIC's first as an acting IP.

Visual Approach

The relief pilots took over about four hours into the flight, allowing the primary crew to rest for about five hours. When the trainee captain and IP resumed their posts, the airplane was less than two hours from San Francisco.

Visual meteorological conditions prevailed at the destination, and visual approaches to Runway 28L and 28R were in progress. The automatic terminal information service noted that the glideslopes for the ILS approaches to these runways were out of service.

The relief captain already had programmed the ILS approach to Runway 28L in the flight management system. Expecting vectors for a visual approach to 28L, the trainee captain (the PF) planned to use the ILS localizer to maintain the lateral path to the runway and the automatic flight control system (the autopilot/flight director and autothrottle systems) to manage the vertical profile. The calculated reference landing speed (V_{REF}) was 132 kt.

The airplane was nearing the airport at 1112 San Francisco time when the relief first officer returned to the flight deck and occupied the center jump seat. He served as an observer during the approach and landing.

As expected, Northern California Approach Control provided the crew with radar vectors for a straight-in approach to Runway 28L. At 1121, the approach controller asked the crew if they had the airport in sight. The PM (the instructor pilot) replied that the runway was in sight, and the controller issued clearance for a visual approach.

At the time, the airplane was descending through 6,300 ft at 210 kt. The autothrottle system was in the "HOLD" mode, and the autopilot was in the "FLCH SPD" (flight level change speed) pitch mode and in the "HDG SEL" (heading select) roll mode.

With these modes selected, the autopilot would hold the heading that the crew selected on the mode control panel (MCP) and would command changes in elevator position, effectively adjusting the airplane's pitch attitude, to maintain the airspeed selected on the MCP (210 kt in this case). Vertical speed would be maintained with thrust; in this case, with the autothrottle system on "HOLD," the thrust levers would remain in their current positions until manually moved by one of the pilots.

The PF announced, "I am intercepting the localizer," and selected the "LOC" mode, which causes the autopilot to capture and track the localizer course. The selected altitude was changed to 3,100 ft, which corresponded with the minimum altitude for crossing a step-down fix just outside the final approach fix for the published localizer approach procedure.

Drifting High

The 777 was descending through 5,300 ft at about 210 kt when it intercepted the localizer course 15 nm (28 km) from the runway threshold. The PM said, "Let's descend slowly to one thousand eight hundred feet," which was the published minimum altitude for crossing the final approach fix, 5.4 nm (10.0 km) from the threshold.

The PF replied, "Yes, sir, I will set to one thousand eight hundred," and set 1,800 ft in the altitude selector.

The approach controller then told the crew to reduce their airspeed to 180 kt and to maintain that speed until they were 5 nm (9 km) from the airport. The PM read back the instruction, and the PF changed the selected airspeed to 180 kt.

The reduction in the selected airspeed caused the autopilot to increase the airplane's pitch attitude to maintain that speed. As a result, the descent rate decreased to 300 fpm. "The PF did not appear to promptly recognize that the airplane was drifting above the desired glidepath," the report said, noting that the deviation would have been shown graphically on the pilots' navigation displays.

The airplane was descending through 4,300 ft about 12 nm (22 km)

from the runway when the PF changed the autopilot pitch mode from "FLCH SPD" to "VS" (vertical speed), selected a vertical speed of 1,000 fpm and selected the autothrottle speed ("SPD") mode. "The airplane's vertical speed began to increase toward the target value," the report said. "However, a descent rate of 1,000 fpm was not high enough to maintain, let alone recapture, the desired glidepath, so the airplane continued to drift above it."

The airplane was descending through 3,400 ft about 9 nm (17 km) from the runway when the pilot called for the landing gear to be extended. The additional drag from the landing gear would have facilitated deceleration, the report said, but the crew did not use the speed brakes or select a higher flap setting (flaps 20 at this point), either of which would have helped in managing the descent.

'It's Too High?'

Apparently referring to the airplane's height (900 ft) above the desired glidepath, the PM said, "This seems a little high." After a few seconds, the PF replied, "Do you mean it's too high? … I will descend more," and changed the selected vertical speed from 1,000 fpm to 1,500 fpm.

"This exchange was followed by 21 seconds of no communication between the pilots as the airplane's descent rate increased and the airplane drew closer to the desired glidepath," the report said.

However, the PF changed the selected vertical speed back to 1,000 fpm when the airplane was about 6 nm (11 km) from the runway, descending through 2,600 ft at 178 kt — and still well above the desired glidepath.

"By examining the altitude and distance to the runway, both of which were displayed on the instrument panel, and applying the well-known rule of thumb that a 3-degree glidepath requires about 300 ft of altitude loss per nautical mile, the pilots could have quickly estimated that they were still several hundred feet high," the report said. "The flight crew needed to continue descending the airplane at more than 1,000 fpm to return to the desired glidepath.

"The crew's action indicated a lack of awareness of the airplane's position relative to the desired glidepath and of cues in the cockpit that could have alerted them to this. As a result of this lack of awareness and their early reversion to a descent rate of 1,000 fpm, the airplane remained high."

The airplane crossed the final approach fix at 2,250 ft — 450 ft high. The crew selected flaps 20, and the PF set 150 kt in the airspeed selector. He also entered 3,000 ft, the published missed approach altitude, in the altitude selector.

At the time, indicated airspeed was about 4 kt higher than the maximum speed for selection of flaps 30, which would have allowed a steeper descent while maintaining the selected airspeed. "Clearly, the airplane's excess altitude increased the difficulty of achieving a stabilized approach," the report said.

The report noted that when Boeing test pilots later attempted to conduct an approach from this point in a flight simulator, they had difficulty achieving a stabilized approach before reaching 500 ft above ground level (AGL). "In fact, they found it impossible to do so without exceeding maximum descent rates published in Asiana's FOM [flight operations manual]," the report said.

Mode Confusion

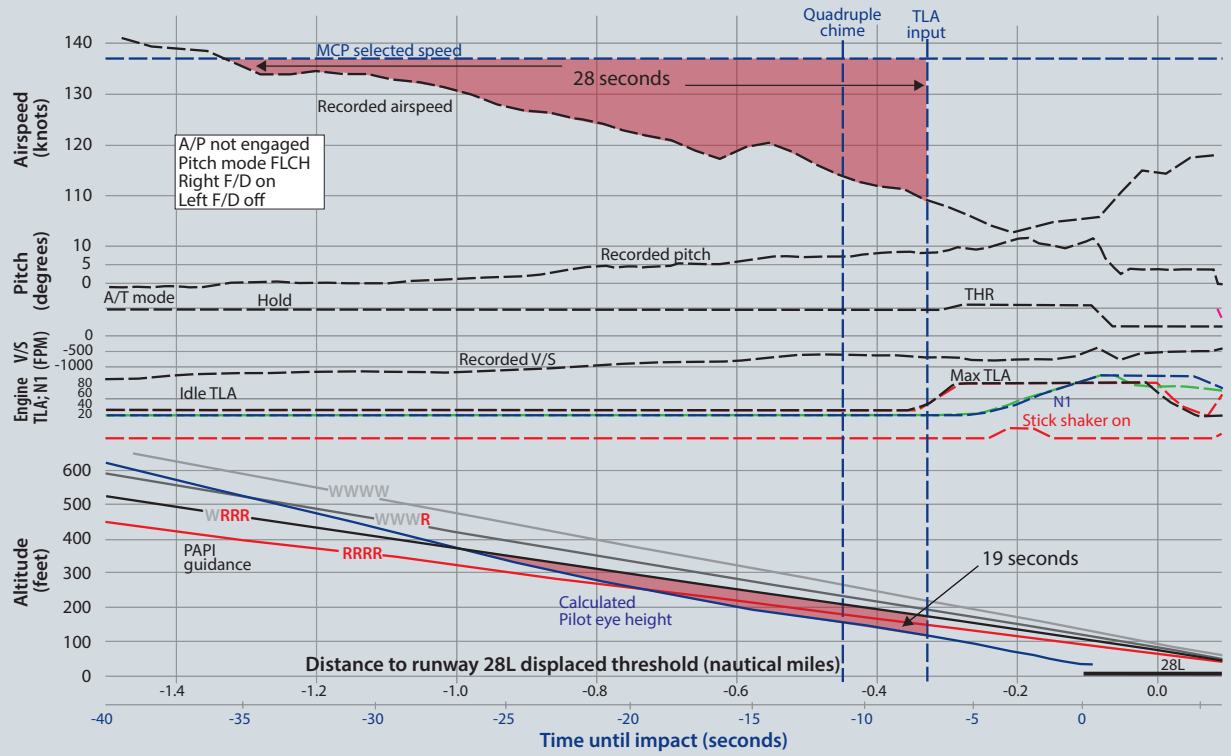
"The flight crew's difficulty in managing the airplane's vertical path continued as the approach progressed" beyond the final approach fix, the report said. Aware of the need to lose the excess altitude, the PF changed back from the "VS" mode to the "FLCH SPD" mode, believing that this would increase the descent rate.

Instead, however, selection of the flight change speed mode at this point caused the autopilot to command an increase in pitch to slow the airplane to the selected airspeed, 150 kt. Simultaneously, the autothrottle system responded, as designed, by entering the thrust mode and moving the thrust levers forward to attain the selected altitude, 3,000 ft.

The PF reacted to the unexpected pitch-up by disengaging the autopilot,

National Transportation Safety Board

Profile View of the Last 40 Seconds of Asiana Airlines Flight 214



A/P = autopilot; A/T = autothrottle; F/D = flight director; FLCH = flight level change; FPM = feet per minute; MCP = mode control panel; N1 = engine low pressure spool speed; PAPI = precision approach path indicator; THR = thrust; TLA = throttle lever angle; V/S = vertical speed

Source: National Transportation Safety Board

Figure 1

moving the thrust levers to idle and manually pitching the airplane nose-down. The manual change in thrust lever position caused the autothrottle system to enter the "HOLD" mode, which effectively disengaged the system. Neither the pilots nor the observer noticed this mode change. "This is not surprising in light of human factors research demonstrating that pilots frequently do not notice mode changes on the FMA [flight mode annunciator], especially those that are unexpected," the report said.

The report noted that the PF had not announced any of the mode changes he had made, which reduced the ability of the PM and the observer to cross-check and monitor his actions.

The airplane was descending through 1,300 ft at 165 kt and 1,000 fpm when the PM said "speed." The PF replied, "Target speed one three seven" (V_{REF} plus 5 kt) and selected 137 kt on the MCP. The PM then said, "It's high," and the PF responded by manually increasing the descent rate.

"By this point, the flight crew should have been able to clearly see the precision approach path indicator (PAPI) lights," the report said. "The PAPI indication would have been four white lights, showing that the airplane was significantly above the PAPI glidepath angle of 2.98 degrees."

The observer called out "sink rate, sir" three times as the descent rate increased to 1,500 fpm and then to 1,800 fpm. He later told investigators that he made the callouts because Asiana required that the descent rate be no more than 1,000 fpm below 1,000 ft. "He further stated that the PF and PM were slow to respond to his sink rate callouts, but they did respond, and the sink rate decreased," the report said.

Decision Time

Indicated airspeed was 137 kt when the airplane descended at 1,200 fpm through a radio altitude of 500 ft about 1.3 nm (2.4 km) from the runway. The thrust levers were still at idle, and the engines were at 24 percent N1 (low-pressure spool speed). The PAPI lights showed the airplane to be slightly above the 3-degree glidepath.

"Although, at 500 ft, the airplane met some of Asiana's stabilized approach criteria … (including being on target airspeed, in the landing

configuration and on the correct flight path), it failed to satisfy other criteria," the report said. "It was descending at greater than 1,000 fpm, and the thrust setting was not appropriate (it should have been about 56 percent N1 speed).

"Because the approach was not stabilized at 500 ft AGL, the flight crew should have conducted a go-around. Either the pilots did not notice that these parameters exceeded stabilized approach criteria or they believed that the deviations were minor and could easily be corrected. In either case, the crew's decision to press ahead was not unusual, as industry statistics indicate about 97 percent of unstable approaches are continued to landing."

As the airplane descended below 500 ft, the PM said, "Landing checklist complete, cleared to land … on glidepath, sir." The PF replied "check."

Red Lights

About five seconds later, all the PAPI lights turned red, indicating that the airplane was significantly below the glidepath. At this point, the 777 was 219 ft over San Francisco Bay and 0.7 nm (1.3 km) from the runway, descending at 900 fpm and about 130 kt.

"Both the airspeed indication, which was more than 5 knots below target approach speed, and a PAPI indication of four red lights required a go-around, but the flight crew continued the increasingly unstabilized approach," the report said.

The PM, referring either to the airspeed or the airplane's position below the glidepath, said, "It's low." The PF, still under the impression that the autothrottle system would adjust thrust to maintain the target airspeed, apparently took the PM's callout as referring to the glidepath; and he responded by pulling back the control column. The pitch attitude increased from 5 degrees to 7.5 degrees, and airspeed decreased further.

Aural and visual master warnings were generated when airspeed decreased to 120 kt. When airspeed dropped to 114 kt, the PM called out "speed" and moved the thrust levers forward. Airspeed continued to decrease, however, and the stick shaker (stall warning) activated at 103 kt.

"At this time, the airplane was about 0.35 nm [0.65 km] from the runway at 39 ft RA [radio altitude], the descent rate was about 700 fpm, the N1 speeds for both engines were increasing through about 50 percent, and the pitch attitude reached about 12 degrees nose-up," the report said. "The airspeed then began to increase."

The PM called out "go around," and the PF responded. At this point, however, the airplane lacked the performance capability to accomplish a go-around, the report said. The main landing gear and aft lower fuselage struck the seawall about three seconds later, at 1128 local time.

"Video from airport surveillance cameras showed that following the initial impact, the tail of the airplane separated, the airplane slid along the runway, and the rear of the fuselage lifted up, tilting the airplane into about a 30-degree nose-down angle," the report said. "The airplane pivoted counterclockwise about 330 degrees before impacting a second time and coming to rest off the left side of the runway, about 2,400 ft [732 m] from the initial seawall impact point."

The 777 was destroyed by the impact and subsequent fire. Two of the three passengers who died in the accident had been ejected from the airplane after it struck the seawall. In addition to the fatalities and serious injuries, 134 passengers, two flight attendants, the relief first officer and the PM sustained minor injuries; 114 passengers, two flight attendants and the relief captain were not hurt.

'Faulty Mental Models'

"In postaccident interviews, the PF made several statements that indicated he had an inaccurate understanding of some aspects of the airplane's autoflight system," the report said. For example, as demonstrated during the approach to San Francisco, he believed that the autothrottle system was "always working" and would maintain the selected airspeed even after a manual change of thrust lever setting with the autoflight system in the "FLCH SPD" mode.

Interviews with other Asiana pilots and instructors revealed similar misunderstandings. Investigators also found deficiencies in Boeing's documentation of the autoflight system and in the airline's training on the system.

Moreover, the report cited human factors research showing that due to the complexity of autoflight systems and subsystems in airplanes such as the 777, "faulty mental models" of how they work are fairly common among pilots.

Improvement of 777 autoflight system training was among the specific recommendations included in the NTSB report (*ASW*, 9/14, p. 8). The safety board also called for an expert panel to be convened to evaluate methods of training pilots on automated systems and to identify the most effective training methods.

This article is based on NTSB Accident Report AAR-14/01, "Descent Below Visual Glidepath and Impact With Seawall; Asiana Airlines Flight 214; Boeing 777-200ER, HL7742; San Francisco, California; July 6, 2013." The report is available at <ntsb.gov/investigations/reports.html>. The report provides an in-depth examination of cabin safety issues involved in the accident; those issues will be discussed in the November AeroSafety World.

NTSB's analysis of how occupants fared after Asiana Airlines Flight 214 collided with a seawall points to research opportunities.

BY WAYNE ROSENKRANS

Survival Factors

Sensing that the Boeing 777-200ER was about to impact the bay on its final approach to San Francisco International Airport, one of the flight attendants watched the water surface move closer through the window in door L2 (left side, second door from the nose) adjacent to his "A position" jump seat. Suddenly, he yelled for the flight attendant facing him — his "B position" colleague at the same door — to brace for impact. No warning had come from the flight deck.

Several other flight attendants realized, too, that the airplane was traveling or descending too quickly relative to the water surface. Then the airplane pitched up in an odd way, and they felt the first impact, similar to a hard landing, which one of them perceived as being quickly followed by a "crushing sensation." A seawall in front of the Runway 28L threshold had just sheared away the landing gear, part of the lower fuselage and the tail.

Among these details, the U.S. National Transportation Safety Board's (NTSB's) final report on the July 6, 2013, accident also said that the crew of Asiana Airlines Flight 214 perceived the crash sequence and, in some cases, suffered injuries in ways that varied depending on their seat locations (see "Research Directions," p. 16) and other factors.

A previous *AeroSafety World* article (*ASW,* 10/14, p. 14) summarized the probable cause and contributing factors in the crash, detailing the sequence of preceding events involving the flight crew. The final report essentially found that — in addition to the aircraft design meeting current U.S. standards for airworthiness and crash survivability (*ASW,* 4/14, p. 37) — the evacuation of the airplane and the aircraft rescue and fire fighting (ARFF) response proved to be critical, positive factors enabling the survival of 99 percent of occupants.

"Three of the 291 passengers were fatally injured; 40 passengers, eight of the 12 flight attendants and one of the four flight crewmembers received serious injuries," the report said. "The other 248 passengers, four flight attendants and three flight crewmembers received minor injuries or were not injured."

Crash Experiences

"The initial impact with the seawall occurred at 1127:50. … Some flight attendants stated that the first impact was followed by a sensation of lifting off again. Others reported being thrown against their restraints or that the airplane was shaking or rolling," the report said. "The flight attendants reported a second impact that was much more severe than the first. …. Most of the flight attendants reported items flying throughout the cabin and oxygen masks and ceiling panels falling down."

Video images recorded by airport surveillance cameras helped investigators to document the order of the airplane's momentary lifting and pivoting motions, then a sliding deceleration — all resulting in complex patterns of injuries or absence of injury. "When the main landing gear and the aft fuselage struck the seawall, the tail of the airplane broke off at the aft pressure bulkhead," the report said. "The airplane

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slid along the runway, lifted partially into the air [tilting the airplane into about a 30-degree nose-down angle], spun about 330 degrees, and impacted the ground a final time [coming to rest off the left side of the runway, about 2,400 ft (732 m) from the initial seawall impact point … about 1128:06.26 local time].

"The impact forces, which exceeded certification limits, resulted in the inflation of two slide/rafts within the cabin, injuring and temporarily trapping two flight attendants. Six occupants were ejected from the airplane during the impact sequence: two of the three fatally injured passengers and four of the seriously injured flight attendants. The four flight attendants were wearing their restraints but were ejected due to the destruction of the aft galley where they were seated. The two ejected passengers (one of whom was later rolled over by two firefighting vehicles) were not wearing their seatbelts and would likely have remained in the cabin and survived if they had been wearing their seatbelts."

Mapping of the crash site (Figure 1, p. 14) showed that some major airplane components had come to rest between the seawall and the runway numbers, including the vertical stabilizer, the left and right horizontal stabilizers, and left and right main landing gear components. The left engine safely separated as per design specifications and came to rest about 600 ft (183 m) north of the main wreckage on a grassy area right of Runway 28L. The right engine safely separated but came to rest against the right side of the fuselage.

Evacuation Difficulties

Fuselage, door and slide/raft damage; debilitating injuries of some occupants; passenger entrapment by damaged cabin equipment; the slide/rafts that did not deploy normally because of door sill position or that inflated inside the cabin; and fire and smoke impeded some occupants when the airplane came to a stop about 16 seconds after initial impact. The oil-fed fire began within the right engine pressed against the fuselage and then destroyed sections of the airplane before being suppressed by ARFF personnel. The airplane's fuel tanks were not breached or involved in the postcrash fire.

The NTSB report contains selected evacuation vignettes and descriptions of occupant ejections. "Based on their injuries, the locations where they were found, and the statements of first responders, the four aft flight attendants were ejected out of the ruptured tail of the airplane during the airplane's slide down the runway," the report said.

When the airplane stopped sliding, flight attendant L2A, who had yelled for his colleague to brace for impact, directed passengers to remain seated while he assessed the postcrash situation for less than 93 seconds. He heard the flight attendant assigned to jump seat R2A screaming for help (Figure 2, p. 15). "Her legs had been pinned against the galley next to her jump seat by the inflated slide/raft, and she could not free them," the report said. "He went over to her to try to assist but was unsuccessful in freeing her. He saw fire and smoke outside the door 2R window

and determined that they needed to evacuate. … He initiated an evacuation [entirely on his own], and 98 percent of the passengers successfully self-evacuated."

About 20 seconds after the airplane stopped moving, the captain, who was the pilot monitoring (PM), spent one minute and 11 seconds attempting unsuccessfully to obtain the airport tower controller's assessment of the condition of the airplane, which was temporarily enveloped in dust. The airport tower controller heard these radio transmissions, but, except for the aircraft call sign, they were unintelligible, so the controller repeatedly said only that ARFF vehicles were responding. "When the PM understood emergency vehicles were responding, he read and accomplished the evacuation checklist. … Once the initial steps of the checklist were completed, he issued an evacuation order." The cabin manager later told investigators that when she heard an unidentified voice (L2A) announce the command "Evacuate!" she opened door 1L and began to direct passengers onto the slide/raft at that door.

The flight attendant assigned to door/jump seat R1 was initially unconscious and trapped in her jump seat by an inflated slide/raft. She was freed by the efforts of her husband (a passenger), the cabin manager and another flight attendant and then was assisted in exiting down the door 1L slide/raft. The legs of flight attendant R2A, who was conscious, remained trapped although she had unfastened her restraint and fallen to the floor.

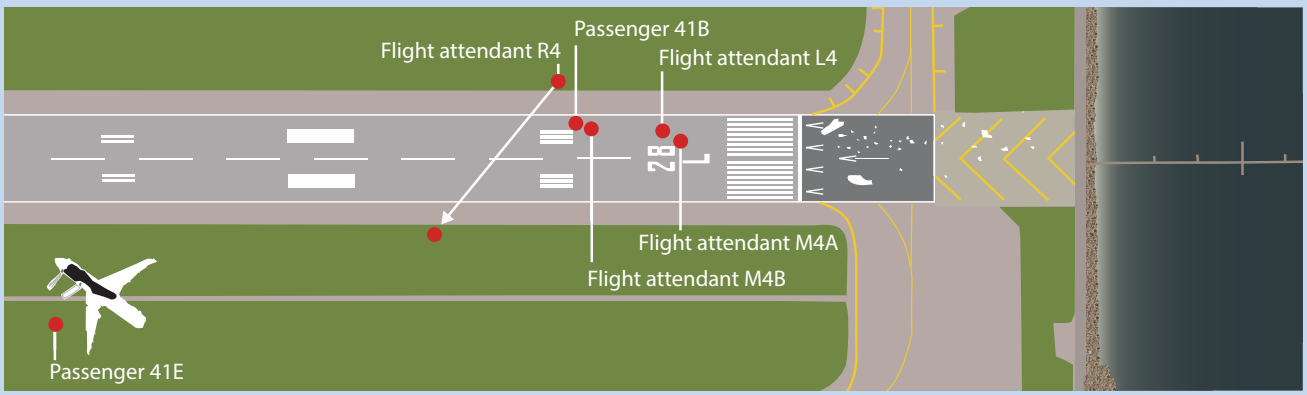
"Several flight attendants and at least one member of the flight crew helped her," the report said, and they used a knife from the galley and had knives provided by emergency responders to puncture the slide/raft and free the trapped flight attendant. The relief first officer tried to extinguish an interior fire while "the remaining flight attendants and flight crew in the front of the airplane evacuated from either door 1L or door 2L."

Only one of the six flight attendants in the rear half of the airplane, who later said she had lost consciousness for a few seconds after impact, was physically able to take part in conducting the evacuation. She was assigned to door/jump seat L3. She told investigators that she had been unable to open door L3 or to command the evacuation of her zone by interphone handset.

A passenger, meanwhile, had opened door 3R and was directing passengers out that door, and from near her jump seat, flight attendant L3 directed evacuating passengers to exit via door 2L and door 3R. The flight attendant responsible for door 3R had been thrown to the floor and seriously injured despite her fastened jump seat restraint, and a passenger helped her exit from her assigned door.

"When all of the ambulatory passengers in her area had evacuated, flight attendant L3 noticed that several passengers were not evacuating," the report said. "She commanded them to evacuate but realized that some passengers were trapped. She went to the back of the airplane and tried to help extricate them until firefighters arrived, but she was forced to evacuate because of the smoke and difficulty breathing. … As the fire spread into the fuselage, firefighters entered the airplane and extricated five passengers (one of whom later died) who were injured and unable to evacuate. … Once outside, the uninjured flight attendants performed various duties, such as gathering passengers together, attending to injured

Positions of Flight 214 Occupants Found Outside the Aircraft



Source: U.S. National Transportation Safety Board

Figure 1

passengers and crewmembers, and notifying responders that the four flight attendants who had been seated in the aft galley area were missing."

How Fatalities Occurred

A deceased 16-year-old female passenger, who had been assigned to seat 41B but reportedly occupied seat 41D for landing, was found on the right side of the runway about midway between the seawall and the main wreckage, the report said. A deceased 16-year-old female passenger, who had been in seat 41E, was found about 30 ft (9 m) in front of the airplane's left wing and about 50 ft from the left side of the fuselage. A 15-year-old female passenger, who had been in seat 42A, "was taken to the hospital from the scene and died six days after the accident," the report said.

Eight flight attendants who were able to provide oral or written statements to NTSB investigators described a normal flight and normal performance of their cabin safety duties in preparation for landing. "They reported that they performed their seatbelt compliance checks and that at least two flight attendants (the cabin manager and flight attendant L2A) checked [the aftmost, travel class zone]," the report said.

"The three passengers who sustained fatal injuries were part of a school group traveling from China to the United States to attend summer camp," the report said, and three surviving students who had been seated near those fatally injured described the circumstances to NTSB investigators. "They reported that their fatally injured friend [occupying seat 41B was] covered by a blanket at the time of landing. They did not know if she was wearing her seatbelt. They also reported that [another] fatally injured friend … was seated in her assigned seat [41E] and was not wearing her seatbelt at the time of landing."

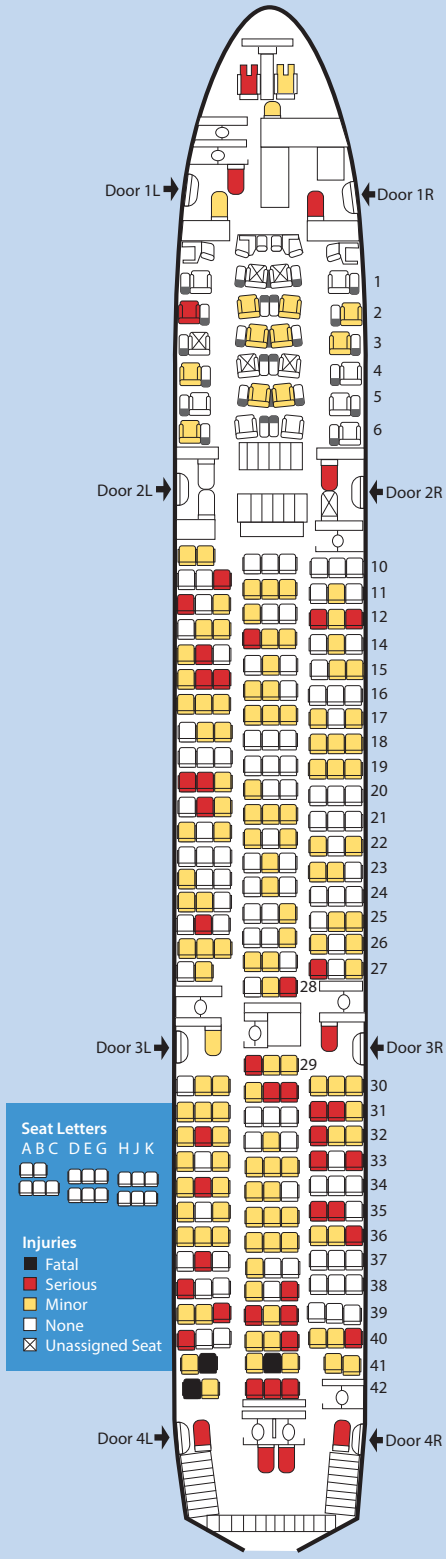
The students said that they did not know the seating/seatbelt status of the third fatally injured student, but one of them said that a flight attendant (L2A) had come through the cabin for the prelanding check and specifically had reminded her to fasten her seatbelt. A nearby passenger corroborated that the cabin crew had been especially attentive to the student group before landing and had enforced all cabin safety rules.

One student told interviewers that two of the deceased friends' seats were empty when the aircraft came to a stop, the report said, noting, "All three students believed that their friends, passengers 41B and 41E, were ejected from the airplane during the impact. … The NTSB concludes that [two of the] passengers … were unrestrained for landing and ejected through the ruptured tail of the airplane at different times during the impact sequence."

ARFF Operations

The control tower alerted most ARFF units and other emergency responders at 1128:00, about 10 seconds after the airplane collided with the seawall. Highlights from more comprehensive details in the NTSB's report include discussion of the response time; the actions taken to rescue the last group of passengers; finding/accounting for deceased passengers and assisting injured

Flight 214 Occupant Injuries



Source: U.S. National Transportation Safety Board

Figure 2

Research Directions

The U.S. National Transportation Safety Board's (NTSB's) final report on Asiana Airlines Flight 214 called for survival factors–related research into factors that, in some cases, were possibly unique given the unusual dynamic forces and other circumstances.

- **Injury potential from significant lateral forces, as opposed to longitudinal forces, in airplane crashes.** The research objective would be to improve understanding of what caused high thoracic spinal injuries to some occupants of Flight 214. "In this accident, the dynamics were such that occupants were thrown forward and experienced a significant lateral force to the left during the impact sequence," the report said.
- **Adequacy of slide/raft inertia load–certification testing.** Slide/rafts in this case were subjected to impact-sequence forces much greater than those currently established for their performance certification. NTSB recommended that mitigation of overload failures of the slide/raft release mechanisms be considered in relation to data yielded by this investigation.
- **Improvements to ARFF response capabilities.** These would cover issues identified in command assignment, fuselage skin–piercing guidance, a U.S. Federal Aviation Administration (FAA) requirement for minimum staffing level, interoperability of radio frequencies between the airport-based aircraft rescue and fire fighting (ARFF) and non-ARFF/backup fire fighting companies, timely emergency medical supply bus deployment, vehicle operation to avoid striking or rolling over ground casualties (which occurred in this accident to passenger 41E) and FAA oversight of the timely implementation of local procedure manuals. "Although no additional injuries or loss of life could be attributed to the fire attack supervisor's lack of ARFF training [and consequent decisions], it demonstrates the potential strategic and tactical challenges associated with having non–ARFF trained personnel in positions of command at an airplane accident," the report said regarding two of those issues. Vehicles equipped with high-reach extendable turrets and skin-piercing nozzles were not used optimally in the initial Flight 214 fire attack, according to NTSB, indicating a need for updated consensus in the U.S. ARFF community about whether piercing should begin even before all occupants are known to have evacuated the airplane.

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flight attendants ejected from the moving aircraft; and fire suppression.

When the first emergency response vehicle, occupied by one airfield security officer, reached the scene, passengers had been coming down the slide/rafts at doors 1L and 2L for about 25 seconds. The San Francisco Fire Department's first ARFF vehicle arrived at the aircraft at 1131:11 and began to apply foam to the visible fire in the right engine, the report said. The second of seven ARFF vehicles arrived and applied extinguishing agent to the fire about 37 seconds later. "Within about 20 seconds of [the second vehicle's] arrival, most passengers had finished evacuating from doors 1L and 2L," the report said.

During the rescue phase of their response, firefighters searched the smoke-hazy cabin, extinguished the interior fire spreading from the right engine and found an estimated four to six passengers unable to self-evacuate — some pinned beneath seats — while a flight attendant and other passengers stayed with them.

Firefighters and airport police officers, who entered through the tail section opening, removed these passengers from the airplane. "At 1138:37, [the first] three firefighters climbed the 2L slide/raft … and entered the cabin," the report said regarding the elapsed time. "Based on information from multiple sources, it is likely that the last passenger was extricated from the back of the airplane about 1147." The fire was brought under control at 1218:30 after simultaneous, elevated attacks by two ARFF vehicles equipped for fuselage skin piercing and aerial application of extinguishing agents.

After a person was seen walking across the runway toward the aircraft at 1149:41 (Figure 1) from the position where flight attendant jump seat R4 later was found, and was assisted by passengers who had evacuated, the ARFF responders conducted a search of the entire debris field between the seawall and the airplane wreckage.

The distribution of occupants with serious injuries prompted an inquiry into three patterns of injury seen, using the associated medical records. The report said, "The 40 passengers with serious injuries were primarily located in the aft cabin. … Twenty-four passengers and five flight attendants sustained spinal injuries. The passengers with spinal injuries were also primarily located in the aft cabin, with 20 of the 24 passengers (83 percent) with spinal injuries located in C-zone [the aftmost section]."

This article is based on NTSB Accident Report AAR-14/01, "Descent Below Visual Glidepath and Impact With Seawall; Asiana Airlines Flight 214; Boeing 777-200ER, HL7742; San Francisco, California; July 6, 2013." The report is available at <ntsb.gov/investigations/reports.html>.