Aviation Investigation Final Report

Location:	Honolulu, Hawaii	**Accident Number:**	DCA21FA174
Date & Time:	July 2, 2021, Local	**Registration:**	N810TA
Aircraft:	Boeing 737-275C	**Aircraft Damage:**	Destroyed
Defining Event:	Loss of engine power (partial)	**Injuries:**	1 Serious, 1 Minor
Flight Conducted Under:	Part 121: Air carrier - Non-scheduled		

Analysis

Transair flight 810, a Title 14 *Code of Federal Regulations* Part 121 cargo flight, experienced a partial loss of power involving the right engine shortly after takeoff and a water ditching in the Pacific Ocean about 11.5 minutes later. This analysis summarizes the accident and evaluates (1) the right engine partial loss of power, (2) the captain's communications with air traffic control (ATC) and the first officer's left and right engine thrust reductions, (3) the first officer's misidentification of the affected engine and the captain's failure to verify the information, (4) checklist performance, and (5) survival factors. Maintenance was not a factor in this accident.

The flight data recorder (FDR) showed that, when the initial thrust was set for takeoff, the engine pressure ratios (EPR) for the left and right engines were 2.00 and 1.97, respectively. Shortly after rotation, the cockpit voice recorder (CVR) recorded a “thud” and the sound of a low-frequency vibration. The captain (the pilot monitoring at the time) and the first officer (the pilot flying) reported that they heard a “whoosh” and a “pop,” respectively, at that time. As the airplane climbed through an altitude of about 390 ft while at an airspeed of 155 knots, the right EPR decreased to 1.43 during a 2-second period. The airplane then yawed to the right; the first officer countered the yaw with appropriate left rudder pedal inputs. The CVR showed that the captain and the first officer correctly determined that the No. 2 (right) engine had lost thrust within 5 seconds of hearing the thud sound.

After moving the flaps to the UP position, the captain reduced thrust to maximum continuous thrust, causing the left EPR to decrease from 1.96 to 1.91 while the airplane was in a climb. (The right EPR remained at 1.43). The captain reported that he did not move the thrust levers again until after he became the pilot flying. The first officer stated that, after the airplane leveled off at an altitude of about 2,000 ft, he reduced thrust on both engines. FDR data showed that thrust was incrementally reduced to near flight idle (1.05 EPR on the left engine and then 1.09 EPR on the right engine) and that airspeed decreased from about 250 to 210 knots. (A decrease in airspeed to 210 knots was consistent with the operator's simulator guide procedures for a single-engine failure after the takeoff decision speed [V_1]. The simulator guide, which supplemented information in the company's flight crew training manual, contained the most recent operator guidance for single-engine failure training at the time of the accident.)

The captain was unaware of the first officer's thrust changes because he was busy contacting the controller about the emergency. The captain told the controller, "we've lost an engine," but he had declared the emergency to the controller twice before this point, as discussed later in this analysis.

The captain instructed the first officer to maintain a target speed of 220 knots (which the captain thought would be "easy on the running engine"), a target altitude of 2,000 ft, and a target heading of 240°. (About 52 seconds earlier, the controller had issued the 240° heading instruction to another airplane on the same radio frequency.) About 3 minutes 14 seconds after the right engine loss of thrust occurred, the captain assumed control of the airplane; at that time, the airplane's airspeed was 224 knots and heading was 242°, but the airplane's altitude had decreased from about 2,100 ft (the maximum altitude that the airplane reached during the flight) to 1,690 ft. The captain increased the airplane's pitch to 9°; the airplane's altitude then increased to 1,878 ft, but the airspeed decreased to 196 knots.

The captain subsequently stated, "let's see what is the problem...which one...what's going on with the gauges," and "who has the E-G-T [exhaust gas temperature]?" The first officer stated that the left engine was "gone" and "so we have number two" (the right engine), thus misidentifying the affected engine. The captain accepted the first officer's assessment and did not take action to verify the information. Afterward, the EPR level on the right engine began to increase in response to the captain advancing the right thrust lever so that the airplane could maintain airspeed and altitude. Right EPR increased and decreased several times during the rest of the flight (coinciding with crew comments regarding the EGT on the right engine and low airspeed) while the left EPR remained near flight idle.

The first officer asked the captain if they "should head back toward the airport" before the airplane traveled "too far away," and the captain responded that the airplane would stay within 15 miles of the airport. During a postaccident interview, the captain stated that, because there was no fire and an engine "was running," he intended to have the airplane climb to 2,000 ft and stay within 15 miles of the airport to avoid traffic and have time to address the engine issue. The captain also stated that he had been criticized by the company chief pilot for returning to the airport without completing the required abnormal checklist for a previous in-flight emergency. Although the captain's decision resulted in the accident airplane flying farther away from the airport and farther over the ocean at night, the captain's decision was reasonable for a single-engine failure event.

The captain directed the first officer to begin the Engine Failure or Shutdown checklist and stated that he would continue handling the radios. The first officer began to read aloud the conditions for executing the Engine Failure or Shutdown checklist but then stopped to tell the captain that the right EGT was at the “red line” and that thrust should be reduced on the right engine. The captain then decided that the airplane should return to the airport and contacted the controller to request vectors.

The flight crew continued to express concern about the right engine. The first officer stated, “just have to watch this though…the number two.” The captain asked the first officer to check the EGT for the right engine, and the first officer responded that it was “beyond max.” Afterward, the captain told the first officer to continue with the Engine Failure or Shutdown checklist and finish as much as possible. The first officer resumed reading aloud the conditions for performing the checklist but then stopped to state, “we have to fly the airplane though,” because the airplane was continuing to lose altitude and airspeed. The captain replied “okay.” As a result, the flight crew did not perform key steps of the checklist, including identifying, confirming, and shutting down the affected (right) engine.

The first officer told the captain that the airplane was losing altitude; at that time, the airplane’s altitude was 592 ft, and its airspeed was 160 knots. The captain agreed to select flaps 1 (which the first officer had previously suggested likely because the airplane was slowing). The CVR then recorded the first enhanced ground proximity warning system (EGPWS) annunciation (500 ft above ground level); various EGPWS callouts and alerts continued to be annunciated through the remainder of the flight. The captain then told the controller that “we’ve lost number one [left] engine…there’s a chance we’re gonna lose the other engine too it’s running very hot….we’re pretty low on the speed it doesn't look good out here.” Also, the captain mentioned that the controller should notify the US Coast Guard (USCG) because he was anticipating a water ditching in the Pacific Ocean.

Because of the high temperature readings on the right engine, the flight crew thought, at this point in the flight, that a dual-engine failure was imminent. During a postaccident interview, the captain stated that his priority at that time was figuring out how the airplane could stay in the air and return safely to the airport. The captain also stated that he attempted to resolve the airplane’s deteriorating energy state by advancing the right engine thrust lever. However, with the left engine remaining near flight idle, the right engine was not producing sufficient thrust to enable the airplane to maintain altitude or climb.

The captain’s communication with the controller continued, and the first officer stated, “fly the airplane please.” The controller asked if the airport was in sight, and the captain then asked the first officer whether he could see the airport. The first officer responded “pull up we’re low” to the captain and “negative” to the controller; the captain was likely unable to respond to the controller because he was trying to control the airplane.

The captain asked the first officer about the EGT for the right engine; the first officer replied “hot…way over.” The captain then asked about, and the controller responded by providing, the location of the closest airport. Afterward, the CVR recorded a sound similar to the stick shaker, which continued intermittently through the rest of the flight. The CVR then recorded sounds consistent with water impact.

The aircraft performance study for this accident found that the airplane had adequate total engine thrust available to climb, accelerate, and maintain altitude both before and after the rapid decrease in right EPR to 1.43. However, as the left EPR decreased and remained below a level of 1.2 (which occurred about 35 seconds after the airplane leveled off at 2,000 ft and while the EPR on the right engine was about 1.4), total engine thrust decreased to the point that the airplane transitioned to and remained at a low-energy state (that is, low total engine thrust, low airspeed, and low altitude). The flight crew relied exclusively on thrust from the damaged right engine as thrust on the left engine remained near flight idle. With this engine power configuration, the flight crew could not arrest the airplane's descent, and the airplane was unable to maintain altitude, accelerate, or climb because the flight crew did not take the corrective action of adding left engine thrust, which was available.

Right Engine Loss of Thrust and Left Engine Pressure Ratio Decrease

The rotational signatures observed during postaccident examination of both engines indicated that the right engine was rotating at a much faster speed at impact than the left engine. The indications showing low rotation of the left engine core at impact were consistent with the engine operating near flight idle at that time. Postaccident examination of the left engine found no anomalies that would have caused the reduced thrust on that engine.

The teardown of the right engine showed that two high-pressure turbine stage 1 blades were missing their outer spans and that both had failed from a stress rupture fracture due to oxidation and corrosion of the internal blade lightening (weight-reduction) holes, which resulted in a loss of load-bearing cross-section. The blade failures caused downstream (secondary) damage to the low-pressure turbine, resulting in a loss of thrust, which would have been presented to the flight crew as a decrease in EPR on the right engine (along with the thud sound recorded on the CVR and the yaw to the right).

Postaccident examination of the high-pressure turbine stage 1 right engine blades also revealed that they had been exposed to temperatures beyond the blades' normal operating range, resulting in microstructure changes to the blade material. According to flight crew postaccident interviews as well as CVR evidence, the right EGT was at the top of the gauge (at or above the red line). Also, the operator's *Boeing 737 Aircraft Operations Manual* stated that the maximum continuous EGT for the airplane's engines was 540°C, but the EGT gauge was found in the wreckage indicating 700°C. Thus, the overtemperature damage on the right engine blades likely occurred during the accident flight when the engine was operated at elevated temperatures.

Notification to Controller About Emergency and Engine Thrust Reductions

The captain first declared an emergency to the controller about 36 seconds after the CVR recorded the thud sound; he also advised the controller to stand by. The controller responded with a routine departure clearance; thus, the controller likely did not hear or understand the captain's transmission. About 7 seconds later, the captain again declared an emergency and advised the controller to stand by. During the 30 seconds that followed, the captain reminded the first officer to fly the airplane on a heading of 220° and level off at 2,000 ft.

The controller again provided routine instructions to the flight crew about 33 seconds after the captain's second transmission about the emergency. The captain then declared an emergency (for the third time) and stated that the airplane lost an engine and was on a 220° heading. The controller responded, "say again heading two four zero." Immediately after issuing this instruction, the controller informed the captain that the heading was intended for another airplane. The captain did not hear, understand, or remember this transmission because he later instructed the first officer to fly the airplane on a 240° heading.

The controller then cleared the accident airplane for a visual approach to the airport, and the captain informed the controller that he and the first officer had to perform a checklist and would let her know when they were ready to return to the airport. The controller then asked the captain to keep her advised.

The process of declaring the emergency to ATC took 1 minute 53 seconds. During a postaccident interview, the captain stated that his communications with the controller "became a project" and that "it took a while for ATC to know what was going on" regarding the emergency. The captain added that those communications "took too much of [his] time away from the cockpit." Although frequency congestion impeded the captain's efforts to declare an emergency to ATC, the captain could have entered squawk code 7700 (indicating an emergency situation) into the transponder and deferred further radio communications until after the first officer stabilized the airplane in level flight.

In addition, about 25 seconds after the previous exchange between the controller and captain ended, the controller asked for more information about the emergency, including which engine was affected. The operator's simulator guide stated that, after declaring an emergency involving a single-engine failure after V_1, the captain could provide additional information to ATC when time permitted. Because further communication with ATC was not a priority at that time, the captain responded appropriately to the controller by stating that he would provide the information later.

The simulator guide also stated that, after declaring an emergency to ATC, selecting flaps to the UP position, reducing thrust, and establishing the airplane's climb at 210 knots, the pilot flying was to fly, navigate, and communicate, and the pilot monitoring was to "reconfirm" the failure. However, much of the captain's time by this point in the flight was spent listening and responding to ATC transmissions. Thus, communications between the captain and controller after the onset of the emergency caused interruptions that delayed the flight crew's efforts to address the emergency situation.

While the captain was communicating with the controller, the first officer, as the pilot flying, incrementally reduced left and then right engine thrust to near flight idle so that the airplane could slow down after leveling off. The first officer stated that he had been trained in the simulator to move the thrust levers together until the crew was ready to confirm the affected engine. Thus, the first officer's decision to independently move the left and then the right thrust lever was inappropriate.

When the captain turned his attention back to the airplane after communicating with the controller, both engines were near flight idle (the EPR was 1.05 and 1.12 for the left and right engine, respectively), and the airspeed was 227 knots and decreasing. The captain commanded a speed of 220 knots and then announced that he was taking control of the airplane. FDR data indicated that the captain did not promptly increase thrust after the airspeed subsequently dropped below the 220-knot target speed. During a postaccident interview, the captain stated that he was unaware that the first officer had reduced left engine thrust to near flight idle. The captain's lack of awareness of the first officer's thrust reductions played a role in his handling of the in-flight emergency, as discussed in the next section.

Misidentification of the Affected Engine and Failure to Verify

About 4 minutes elapsed between the time of the flight crew's correct identification of the right engine as the affected engine and the first officer's incorrect assessment about the left engine. This amount of time played a role in the first officer's misidentification of the left engine as the affected engine. The first officer had a high workload during that time; as the pilot flying, he had to (among other things) closely monitor basic flight parameters and fly the airplane to achieve the target airspeed, altitude, and heading. The first officer was also dealing with interruptions due to the interspersing of various operational tasks. Although the first officer had previously verbalized that the right engine had lost power, the first officer's workload demands left few opportunities for him to commit that information to memory. In addition, after the airplane had leveled off and the left and right EPR had been reduced to near flight idle, no adverse yaw (the primary cue indicating that the right engine was affected) was occurring, and the engine indications were ambiguous because both were producing low thrust (with the EPR on the left and right engines at 1.05 and 1.12, respectively).

Although thrust was low on both engines, the first officer might have thought that the left engine was affected because its EPR level was lower than that for the right engine. For that to be the case, the first officer would have had to have forgotten his earlier actions of pulling back the power on the left (operational) engine and then the right (damaged) engine to reduce airspeed.

The National Transportation Safety Board (NTSB) considered whether the first officer's use of prescription medications played a role in (1) forgetting his and the captain's initial correct diagnosis and his movement of the left thrust lever (along with the right thrust lever) to reduce airspeed and (2) asserting erroneously that the left engine was the affected engine. The NTSB's analysis of the potential side effects of these medications found that the use of these medications likely did not play a role in the accident.

The NTSB also considered whether the first officer's errors were due to fatigue. Even though the errors that the first officer made were consistent with the effects of fatigue, the evidence supporting fatigue was inconclusive. Stress is also known to degrade cognitive functions such as working memory, attention, and reasoning, and it provides an alternate explanation for the first officer's actions. The loss of right engine thrust at a low altitude over the ocean at night was a surprising and stressful event, especially for the first officer as the pilot flying at the time of the engine event.

The captain initially questioned the first officer's assessment, stating "number one is gone?", but then accepted the assessment and stated, "so we have number two." At that time, no salient cue was available to indicate which engine was affected (due to the reduced thrust on both engines and the lack of adverse yaw). During a postaccident interview, the captain remembered his initial assessment that the right engine was affected but stated that he had assumed that the first officer had a better understanding of the engines' status because he was flying the airplane when the captain was communicating the emergency to ATC.

The captain had confidence in the first officer's assessment of the affected engine based on their flight experience together; during a postaccident interview, the captain stated that the first officer "never makes a mistake." Nevertheless, the captain did not take any action to verify the first officer's assessment about the left engine, such as advancing the thrust lever for the left engine to determine whether an increase in thrust occurred. The operator's simulator guide stated that pilots should be alert for changes indicating that thrust was being reduced on the incorrect (operational) engine. However, the crew did not notice the reduction in adverse yaw that resulted from the first officer's reduction of thrust on the left engine. Subsequently, the reductions in thrust on the left and right engines (which the first officer made to reduce airspeed) meant that there would be no noticeable indications that would have reinforced the idea to the crewmembers that the left engine was affected, as they determined initially.

If the captain had thought to test the thrust on the left engine by advancing the left thrust lever, the flight crew would likely have noticed an increase in left engine thrust, a yaw to the right, and engine sounds indicating that the left engine was capable of producing normal power. The captain could also have simultaneously advanced both thrust levers and observed the left engine producing more thrust. However, neither flight crewmember suggested that the captain perform these actions, and neither of these potential diagnostic steps was included in the operator's Engine Failure or Shutdown checklist.

Further, the Engine Failure and Shutdown checklist would not have helped the captain sort out the situation because the checklist appeared to assume that the airplane would be experiencing ongoing asymmetric thrust, which was not the case at this point in the accident flight. The checklist did not consider the possibility that a flight crew would need to delay checklist execution until after completing steps in an operator's single-engine departure procedure, such as leveling off at a low altitude and reducing thrust on both engines. Because there was no longer a clear sign of which engine had failed and the crew had forgotten its earlier determination that the right engine had lost power, critical thinking was required for the

crew to devise diagnostic steps to confirm the affected engine. However, each pilot's thinking was degraded by high workload and stress.
The operator's simulator guide stated that, for a single-engine failure after V_1, "the Captain, if not currently the PM [pilot monitoring], may (and most times should) elect to become the PM and run the…checklist." Remaining in the pilot monitoring role (which was recommended but not required) would have preserved more of the captain's mental resources to correctly diagnose and respond to the engine issue. The captain's decision to assume the pilot flying role before reconfirming the engine issue increased his workload and decreased his ability to perceive and evaluate key information, such as the positioning of the thrust levers, the performance of the engines, and changes in the airplane's energy state. Thus, the captain's decision to take control of the airplane also decreased his ability to manage the crew's response to the abnormal situation.

In addition, the captain's lack of awareness of the left engine's low commanded thrust level, along with the subsequent deterioration of the airplane's energy state throughout the rest of the flight, played a role in his (1) failure to verify the first officer's (incorrect) assertion about the left engine and (2) inability to detect the crew's misidentification of the affected engine and cognitively reframe the situation. The NTSB considered whether fatigue played a role in the captain's errors, but the evidence was inconclusive. These errors were likely the result of the captain's high workload and stress. Research indicates that, under conditions of high workload and stress, "crews are vulnerable to missing important cues related to their situation and are likely to experience difficulty pulling together disparate pieces of information and making sense of them," especially when "some of that information is incomplete, ambiguous, or contradictory." (Burian, B.K., Barshi, I., and Dismukes, K., 2005).

The captain's high workload increased further due to his decision to continue handling ATC radio communications, which occurred frequently on an ongoing basis throughout the flight. It is possible that the captain decided to maintain control of the radios based on information that he learned during the operator's crew resource management (CRM) training. Specifically, the operator's initial CRM training included a video that presented the circumstances of the September 2007 accident involving American Airlines flight 1400, including the distraction that radio communications caused the pilot monitoring while he attempted to execute the appropriate abnormal checklist. Thus, the captain of the Transair accident airplane might have thought that, by relieving the first officer of the responsibility of handling the radios, the first officer could focus his attention on performing the Engine Failure or Shutdown checklist (which is further discussed in the next section).

The captain's ability to properly respond to the emergency was further diminished toward the end of the flight when he thought that the airplane could have a dual-engine failure, as demonstrated by his transmissions to the controller stating, "we might lose the other engine too" and, 2 minutes 19 seconds later, "there's a chance we're gonna lose the other engine too." After the crewmembers noticed that the right engine was overheating, their attention became primarily focused on monitoring basic flight instruments and controlling the airplane. The crew’s communications and behavior during this latter portion of the flight were consistent with stress-related attentional narrowing, which restricts a person’s perceptions to the most salient cues and results in rigid thinking by reducing the number of alternatives that are considered (Stokes, A., and Kite, K.,1994). Attentional narrowing diminished the crew’s ability to understand and control the abnormal situation. As a result, the flight crew became fixated on monitoring the right EGT as well as basic flight parameters while manipulating only the right engine thrust lever.

Checklist Performance

The captain was aware that numerous steps in the operator’s Boeing 737-200 Engine Failure or Shutdown checklist were expected to be performed before the airplane could return to the airport. The previous criticism that the captain received from the company’s chief pilot for his handling of an earlier in-flight emergency (during which he returned to the airport without completing a required checklist) likely added pressure to the already-demanding situation of troubleshooting an engine issue while flying at a low altitude over the ocean at night.

The Engine Failure or Shutdown checklist defined three conditions that warranted the use of that checklist: an engine failure, an engine flameout, or another checklist that directed an engine shutdown. The checklist had 11 reference items, none of which were memory items. The Engine Failure or Shutdown checklist required pilots to confirm that the thrust lever for the affected engine was selected, move that thrust lever to the idle position, and shut down the corresponding engine. However, the checklist was not designed to help the crew identify the affected engine. Further, the operator’s simulator guide stated that the primary indications of an engine failure were a yawing moment and the rudder input required to counteract it, but neither was present at the time that the checklist was initiated. Thus, the simulator guidance did not reflect realistic operational conditions because it did not account for the possibility of a partial loss of thrust or a possible need to level off and reduce thrust on both engines before completing the checklist.

The captain called for the Engine Failure or Shutdown checklist about 4 minutes 26 seconds after the first indication of an engine problem. The captain’s communications with ATC after the onset of the emergency (as well as the need to assist the first officer in executing various aspects of the single-engine departure procedure) distracted the captain and precluded him from calling for the checklist sooner. The operator does not require its pilots to conduct the checklist immediately after an engine issue is detected. However, if the checklist had been started earlier in the accident sequence (that is, when adverse yaw was occurring or the EPR indications clearly showed which engine was producing lower thrust), and if fewer intervening distractions had occurred, the first officer might have recalled that he had reduced engine thrust to decrease the airplane’s speed, and both crewmembers might have recalled their initial (correct) diagnosis of the affected engine.

The first officer stated that he had accomplished “maybe a third or less” of the checklist, but the CVR showed that he had only read aloud the conditions for performing the checklist. The first officer further stated that he stopped the checklist (for the first time) because of the high EGT on the right engine (which he described as “beyond max”). Afterward, the captain stated that they should head toward the airport, which the first officer suggested about 1 minute earlier (before he started reading aloud the conditions for performing the checklist). The captain then asked the first officer to set up the instrument landing system approach, and the captain contacted the controller to let her know that the airplane was ready to return.

About 1 minute 35 seconds after the first officer informed the captain about the high EGT on the right engine, the captain instructed the first officer to “see what you can do in the checklist finish as much as possible.” About 15 seconds later, the first officer resumed reading aloud the conditions for performing the checklist but then stopped (for the second time) to state “we have to fly the airplane though” because the airplane was “slowing” or “low” and he thought that the captain was not focused on flying the airplane. Although the first officer likely thought that it was appropriate to focus on resolving the symptoms of the abnormal situation (the high EGT on the right engine and the airplane’s decreasing energy state) instead of performing the checklist, the first officer’s comments caused the crew’s attention to be directed away from confirming which engine was affected.

After the first officer advised the captain to focus on flying the airplane, the captain stated “okay” and did not redirect the first officer to continue the checklist. During a postaccident interview, the captain stated that, when he saw that the EPR for the right engine was decreasing and that there was “nothing coming out” of the left engine, he thought that performing the checklist would be “useless” because both engines had “already shut themselves down.” It is possible that performing the checklist’s third item, “AFFECTED ENGINE…CONFIRM…CLOSE” might have prompted the crew to shut down the incorrect (left) engine, which would not have prevented this accident. However, it is also possible that performing this checklist item might have led the crew to reconsider the source of the engine issue and the correct cause of the airplane’s deteriorating energy state. Thus, as a result of the flight crewmembers’ stress-related attention tunneling (which led to their thinking that a dual-engine failure was occurring and fixation on the right EGT and basic flight parameters), they neglected to perform a checklist item that might have alerted them about their misidentification of the affected engine.

The operator’s CRM training emphasized the importance of using checklists to manage abnormal situations and defend against error. During the accident flight, the captain and the first officer demonstrated ineffective CRM. Specifically, the captain did not ensure that the first officer, after his interjections while reading the conditions of the Engine Failure or Shutdown checklist, continued performing the checklist so that the affected engine could be confirmed. In addition, the captain demonstrated difficulties with task prioritization (an aspect of workload management) and leadership because, as pilot-in-command, he did not ensure that the checklist was accomplished, and he was distracted by lower-priority tasks, such as communicating with ATC. As a result, the flight crew was unable to coordinate an effective response to the emergency situation.

Emergency Response

The controller contacted the USCG Joint Rescue Coordination Center, which was responsible for coordinating US search and rescue activities in the Pacific Ocean, to report that the accident airplane was in the water. An aircraft rescue and firefighting (ARFF) rescue boat and a USCG helicopter from Barbers Point Air Station launched about 0200 and 0218, respectively.

The USCG helicopter arrived on scene about 0230 and located the accident airplane and crew. The captain was hanging onto the floating tail section of the airplane, and the first officer was on top of floating debris. The captain was struggling to stay afloat after the tail began to sink, and he was hoisted from the water to the helicopter with the assistance of a rescue diver. The diver then re-entered the water and swam with the first officer to the ARFF rescue boat, which had arrived on scene about 0240. The first officer received medical care once aboard the rescue boat.

The helicopter transported the captain directly to a local hospital. The rescue boat encountered high surf and low visibility while traveling back to the ARFF station, arriving about 0406. The first officer was then taken to the hospital; his delayed arrival there did not affect the treatment of his injuries, which were minor. Thus, the search and rescue operation was timely and effective.

Survival Factors

The captain and the first officer were wearing their restraints, including their shoulder harnesses, at the time of the accident. According to the first officer, his upper torso moved forward during impact, and his right shoulder rolled forward, downward, and to the left, which caused his body to twist so that he was facing to the left. The first officer's head then moved downward, and the top of his head struck something in front of him, resulting in a minor head injury that did not impede his evacuation from the airplane.

Postaccident examination of the first officer's seat found that the seatback had collapsed. Subsequent examination by the NTSB's Materials Laboratory determined that the seatback collapse was due to the fracture of a jack nut that was part of a jackscrew assembly. The jack nut fractured in overstress due to loads that exceeded its load-bearing capacity.

The accident airplane model was certificated in December 1967, and the first officer's seat was manufactured in September 1984. The seat complied with Technical Standard Order (TSO)-C39A, which was issued in February 1972. The TSO required the seat to meet a static load requirement of 9 G forward and 6 G downward. The loads that the first officer's seat sustained during the ditching could not be determined from the available evidence for this investigation.

Newer seating systems are required to meet higher loads during certification. Specifically, crewmembers and passenger seating systems certificated under Title 14 *Code of Federal Regulations* Part 25 must currently meet, among other criteria, a dynamic requirement of 16 G forward and 14 G downward. These dynamic requirements apply to newly designed airplanes certificated after 1988 and all Part 25 airplanes manufactured after 2009, except for those that do not carry passengers for hire (including cargo-only airplanes, such as the accident airplane). According to the Federal Aviation Administration (FAA), four cargo 737-200 airplanes were registered in the United States as of November 2022, but the available evidence for this investigation did not indicate whether those airplanes were in active use.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The flight crewmembers' misidentification of the damaged engine (after leveling off the airplane and reducing thrust) and their use of only the damaged engine for thrust during the remainder of the flight, resulting in an unintentional descent and forced ditching in the Pacific Ocean. Contributing to the accident were the flight crew's ineffective crew resource management, high workload, and stress.

Findings

Aircraft	Turbine section - Damaged/degraded
Personnel issues	Identification/recognition - Flight crew
Personnel issues	Use of checklist - Flight crew
Personnel issues	Task overload - Flight crew
Personnel issues	CRM/MRM techniques - Flight crew
Personnel issues	Incorrect action performance - Flight crew

Factual Information

History of Flight

Initial climb	Loss of engine power (partial) (Defining event)
Enroute	Ditching

On July 2, 2021, about 0145 Hawaii-Aleutian standard time, Rhoades Aviation flight 810, dba Transair flight 810, a Boeing 737-200, N810TA, experienced an engine anomaly shortly after takeoff from Daniel K. Inouye International Airport (HNL), Honolulu, Hawaii, and was subsequently ditched into Mamala Bay (in the Pacific Ocean), about 5.5 miles southwest of HNL. The captain sustained serious injuries, the first officer sustained minor injuries, and the airplane was destroyed. The flight was operating under Title 14 *Code of Federal Regulations* Part 121 as a cargo flight from HNL to Kahului International Airport (OGG), Kahului, Hawaii.

The flight crew arrived at Rhoades Aviation's flight-following office at HNL by 0015 for the flight to OGG, which was scheduled to depart at 0100. The flight was the first of the day's six planned flight legs for the captain and first officer. According to postaccident interviews, the flight crew discussed the weather for the flight and other related information. The captain then determined the performance limitations of the airplane and provided that information to the flight follower, who in turn provided the information to the cargo load manager. The flight crewmembers monitored cargo-loading activities, and the cargo load supervisor gave the crewmembers the weight and balance paperwork.

The first officer conducted a preflight external inspection of the airplane. He found dried fluid that appeared to have leaked onto the right main landing gear. The first officer reported his findings to the captain, who examined the area with a mechanic. They determined that no active leak was occurring, the landing gear hydraulic reservoir had an appropriate amount of fluid, and the dried fluid was not a concern.

According to the CVR, the flight crew completed the Before Engine Start checklist at 0119:33 and the Engine Start checklist at 0120:01. During a postaccident interview, the captain stated that both engines started normally. At 0123:08, the tower controller cleared the airplane to taxi to runway 8R; the flight crew reported that the airplane left the gate behind schedule because of delays with cargo loading. The flight crew began the Taxi checklist at 0124:45, and the captain recalled that the engine indications looked normal at that time. After taxiing the airplane onto the runway, the first officer recalled that he brought up the power to an EPR level of 1.4 and then asked the captain to set the thrust. The captain adjusted the thrust until the EPR indications were at the carats (an EPR level of 2.01).

At 0132:20, the controller cleared the airplane for takeoff, and the first officer, who was the pilot flying, acknowledged the clearance. (The captain was the pilot monitoring.) At 0132:44, the flight crew completed the Before Takeoff checklist. The captain recalled that, during the takeoff roll, the EGT indications for both engines were at the line between the green (normal) and the yellow (caution) ranges on the displays. (The yellow range on the EGT display indicates temperatures between 520°C and 590°C; according to the Boeing 737 *Aircraft Operations Manual*, the maximum continuous EGT was 540°C.) During a postaccident interview, the captain stated that he had seen that EGT position during previous takeoffs and thus considered it to be normal.

According to the FDR, the engines were advanced to takeoff power starting at 0133:08, and both engines stabilized at an EPR consistent with takeoff; specifically, the No. 1 (left) engine was at 2.00 EPR, and the No. 2 (right) engine was at 1.97 EPR. According to the CVR, at 0133:13, the captain stated, “engines stable.” Between 0133:35 and 0133:46, the captain made the standard takeoff callouts, including “V_1,” “rotate,” “V_2” (takeoff safety speed), and “positive rate,” and the first officer made the callout “gear up.” The airplane flew a heading of 080°.

At 0133:52, the CVR recorded the sound of a “thud.” Starting about 2.5 seconds later, the CVR recorded the sound of a low-frequency vibration, the first officer stating an expletive, the captain stating “lost (an) engine,” and both pilots noting that the right engine had lost power. FDR data showed that, as the airplane climbed through an altitude of about 390 ft mean sea level (all altitudes in this report are mean sea level unless stated otherwise) while the airplane was at an airspeed of 155 knots, the EPR for the right engine dropped suddenly to 1.43; the EPR for the left engine remained at a level of about 2.00. (The only engine parameter that the accident FDR recorded was EPR.) The left rudder pedal then moved to a position consistent with the application of about 5.5° of left rudder. During postaccident interviews, the crewmembers recalled that the airplane yawed to the right and that the first officer corrected the yaw with the left rudder pedal. In addition, when the loss of thrust on the right engine occurred, the airplane banked 2° to the left; immediately afterward, the airplane banked 3° to the right.

About 0134:22, the captain stated, “I’ll give you flaps up,” and the first officer acknowledged this statement. During a postaccident interview, the captain stated that, after setting the flaps, he reduced thrust to maximum continuous thrust. FDR data showed that, during a 2.6-second period ending about 0134:28, the EPR for the left engine decreased from 1.96 to 1.91.

The captain’s initial notification to the controller about the emergency occurred at 0134:29; at the end of that transmission, the captain stated, “stand by.” The controller responded with a routine departure instruction, after which the captain again declared an emergency and repeated “stand by.” The captain then told the first officer that the airplane should climb to and level off at 2,000 ft (the airplane was at an altitude of 1,200 ft at that time) and fly a 220° heading. At 0135:16, the controller again provided the flight crew with routine instructions. One second later, the airplane reached its maximum altitude of 2,107 ft. Also at that time, the EPR on the left engine began incrementally decreasing from 1.91 to 1.83, 1.53, and 1.23 during the next 1 minute 17 seconds.

At 0135:35, the captain told the controller about the emergency for the third time, stating, “we’ve lost an engine…we are on a two twenty heading…maintaining two thousand [ft]…declaring emergency.” About that time, the airplane’s airspeed reached a maximum of about 252 knots. After this transmission, the CVR recorded the controller stating, “say again heading two four zero.” Immediately after issuing this instruction, the controller informed the captain that the heading was intended for another airplane on the same radio frequency. At 0135:55, the controller cleared the airplane for a visual approach to runway 4R at HNL and stated that the airplane could turn toward the airport. The captain responded, “we’re gonna have to run a checklist” and “we’ll let you know when we’re ready to come into the airport.” At 0136:08, the controller asked the flight crew to keep her advised, and the captain acknowledged the transmission. The exchange between the captain and the controller ended at 0136:22.

While that exchange was occurring, the EPR for the left engine decreased to 1.05 (at 0135:56), which was consistent with a power level near flight idle. The EPR for the left engine remained at this level for the remainder of the flight; 8 seconds later, the EPR for the right engine began to decrease below a level of about 1.4. At 0136:20, the airplane began to descend from 2,000 ft, reaching an altitude of 1,659 ft before beginning to climb again. At 0136:34, the captain stated, “two forty heading.” About 13 seconds later, the controller requested more information about the flight, including which engine was affected, and the captain responded, “we'll give you all that in a little bit.”

At 0137:06, the captain stated that the airplane should maintain an airspeed of 220 knots. During a postaccident interview, the captain stated that the 220-knot airspeed would be “easy on the running engine.” FDR data showed that, at 0137:09, the EPR for the right engine reached 1.09, which was also consistent with a power level near flight idle.

At 0137:13, the captain announced his intention to take control of the airplane, which the first officer acknowledged. FDR data showed that the airplane’s altitude at the time was 1,690 ft and that its airspeed was 224 knots. At 0137:36, the captain stated, “let's trim this up at two thousand [ft]”; at that time, the airplane’s altitude was 1,878 ft and airspeed was 196 knots. Four seconds later, the captain stated, “let’s see what is the problem…which one…what’s going on with the gauges,” and “who has the E-G-T?” The first officer stated, “it looks like the number one [engine].”About that time, the EPR on the left and right engines was 1.05 and 1.12, respectively. At 0137:54, the captain asked, “number one is gone?” The first officer replied that the left engine was “gone” and that “we have number two”; at 0137:58, the captain repeated “we have number two” and stated “okay.” Between 0137:59 and 0138:10, the right EPR level (which had been slowly increasing after reaching a level of 1.09) increased quickly from 1.12 to 1.18.

At 0138:16, the first officer asked, "should we head back toward the airport…before we get too far away?" The captain responded that the airplane would stay within 15 miles of the airport. During a postaccident interview, the captain recalled that he intended to climb the airplane to 2,000 ft and stay 15 miles from HNL to avoid traffic and have time to address the engine issue. He also recalled that there was no need to rush because there was no fire and an engine "was running."

The captain called for the "engine failure shutdown checklist" and then stated, "I have the radios." At 0138:43, the captain notified the controller that the airplane could turn to the right toward the airport but that he was not yet ready to land, and the controller provided instructions for the airplane to fly a 250° heading, which the captain acknowledged. At 0138:56, the right EPR reached 1.22. Two seconds later, the first officer stated, "engine failure engine flameout or another checklist directs an engine failure." This information was consistent with the conditions for executing the Engine Failure or Shutdown checklist (see the Organizational and Management Information section of this report.) The first officer then stated, "we're red line here" and "we should pull the right [thrust lever] back a little bit."

At 0139:10, the captain stated that the airplane should head toward HNL, and the first officer agreed. The captain then instructed the first officer to set up the airplane for the instrument landing system approach to runway 4R. At 0139:18 and 0139:24, the captain informed the controller that the airplane was ready to proceed toward the airport and that he did not have the airport in sight, respectively. At 0139:46, the captain requested vectors straight to the airport and informed the controller that "we might lose the other engine too."

At 0139:56, the EPR on the right engine began to decrease from 1.22. At 0140:05, the first officer stated, "just have to watch this…the number two [engine]." At 0140:10, the right EPR reached 1.18. One second later, the airplane's altitude and airspeed were 1,050 ft and 157 knots, respectively, and the CVR recorded sounds lasting 1.8 seconds that might have been associated with the stick shaker. The captain stated something similar to "what's this" and then "we can't keep going down," and the first officer noted that the airplane was descending.

Between 0140:12 and 0140:27, the right EPR increased from 1.18 to 1.37, the airplane's airspeed increased to 172 knots and altitude decreased to 680 ft, and the first officer stated, "we're descending" and "we have to climb." At 0140:30, the captain asked the first officer to check that the airplane was "cleaned up"; at that time, the airplane began to slowly climb from 632 ft. The first officer stated that the flaps were up, and he started to report the status of the speedbrakes when the captain stated, "how is the EGT?" The first officer replied, "it's beyond max." The airplane's airspeed began to drop below 170 knots, and the right EPR decreased from 1.37 to 1.33 during a 2-second period.

At 0140:41, the captain stated, "we're barely holding altitude…see what you can do in the checklist finish as much as possible." By 0140:48, the airplane's airspeed had decreased to 165 knots, and its altitude began to descend from 682 ft. Five seconds later, the first officer resumed the checklist by stating, "airframe vibrations abnormal engines exist." Step 1 of the

Engine Failure or Shutdown checklist prompted flight crews to determine whether they should continue with this checklist or instead use the Engine Fire or Engine Severe Damage or Separation checklist. The first officer continued, “it says do the engine shutdown only when flight conditions” but interrupted this thought to state, “we have to fly the airplane though.” At that time, the airplane’s airspeed was 159 knots and altitude was 614 ft. The captain replied, “okay.”

At 0141:10, the first officer stated, “we’re losing altitude”; at that time, the airplane was at an altitude of 592 ft and an airspeed of 160 knots. Between 0141:14 and 0141:17, the right EPR increased from 1.33 to 1.36. About 3 seconds later, the controller instructed the crew to fly a heading of 050°; the first officer acknowledged this instruction at 0141:22. Starting at 0141:46, the first officer asked the captain whether the flaps 1 setting should be used, and the captain responded “not yet.” The first officer then stated that the airplane was “very slow,” to which the captain responded, “shoot…okay flaps one.”

At 0141:58 and 0142:00, the CVR recorded the EGPWS annunciations “five hundred [feet above ground level]” and “too low gear,” respectively. At 0142:05, the captain told the controller, “we’ve lost [the] number one engine…we’re coming straight to the airport…we’re gonna need the fire department there’s a chance we’re gonna lose the other engine too it’s running very hot.” The captain further stated, “we’re pretty low on the speed it doesn’t look good out here…you might want to let the Coast Guard know as well.”

Afterward, the captain informed the controller that the airplane had no hazardous material and about 2 hours of fuel and that he and the first officer were the only occupants aboard. In between those transmissions, the first officer stated, “fly the airplane please,” which was followed by the EGPWS annunciations “too low terrain,” “too low gear,” and “terrain terrain.” At 0142:45, the captain asked the first officer if he had the airport in sight, which was followed by the EGPWS annunciation “pull up” and the first officer’s statement, “pull up we’re low.” The EGPWS annunciations continued throughout the rest of the flight.

At 0142:50, the controller asked whether the crew had the airport in sight, and the first officer stated “negative.” The controller informed the flight crew about a low-altitude alert for the airplane and asked whether the airplane was able to climb. The first officer again stated “negative.” Between 0142:58 and 0143:02, the right EPR increased from 1.33 to 1.45 and remained between 1.45 and 1.47 for the rest of the flight.

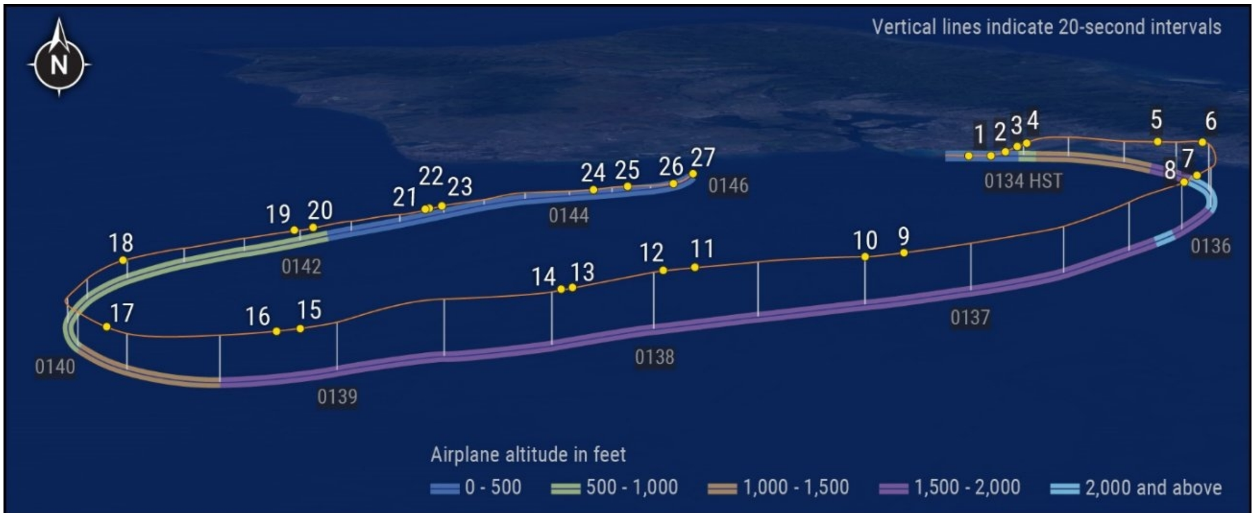
Between 0143:00 and 0143:06, the controller stated that the airplane should proceed directly to the airport on a heading of 060° and cleared the airplane to land on any airport runway. At 0143:24, the captain told the controller that the airplane “cannot maintain altitude.” Between 0143:35 and 0143:41, the first officer stated, “pull back we've got a climb” and “pull back to the stick shaker,” and the captain stated, “shoot three hundred feet.”

At 0143:45, the captain asked the first officer about the EGT, and he stated that it was “hot” and “way over.” At 0144:11, the controller asked if the crew wanted to land at Kalaeloa-

Rodgers Airport (JRF), Kapolei, Hawaii, and the first officer responded, “we’d like the closest airport runway please.” The controller stated that JRF was 3 miles north of the airplane’s position at the time and then provided a heading of 310°. At 0144:28, the CVR recorded sounds similar to the stick shaker, which continued intermittently throughout the remainder of the flight.

At 0144:52, the captain stated “you have control” twice, and the first officer responded “okay.” The captain then stated, “this is the water we [will be] in the water,” and the cockpit area microphone recorded sounds of heavy breathing. At 0145:11, the captain announced “we’re in the water” twice, and the CVR recorded sounds consistent with impact at 0145:17. FDR data showed that, at water impact, the EPR for the left engine was still 1.05 and that the EPR for the right engine was 1.46.

Figure 1 shows the airplane’s flightpath along with key transmissions and events. Figure 2 shows the EPR values during the flight. Figure 3 shows the location of the EPR gauges in the cockpit of the accident airplane. The evacuation and emergency response are discussed in the Survival Aspects section of this report.



1. Standard takeoff callouts
2. Sound of "thud" followed by low-frequency vibration
3. Capt.: "lost (an) engine"
4. Capt. and F/O: "Number two"
5. Capt. directs F/O to climb to 2,000 ft and level off
6. Capt. declares emergency (third time)
7. Left EPR reaches and remains at a level near flight idle
8. Airplane cleared for approach to HNL
9. Capt. states intention to become pilot flying
10. Airspeed decreases and remains below crew's target speed
11. F/O misidentifies affected engine as "number one"
12. Capt. acknowledges and states "so we have number two"
13. F/O asks if airplane should head toward airport
14. Capt. states "we'll stay within fifteen" and directs F/O to perform checklist
15. F/O stops checklist to state "we're red line here"
16. Capt. states airplane should return to airport
17. Capt. to controller: "might lose the other engine too"
18. F/O stops checklist to state "we have to fly the airplane though"
19. EGPWS annunciations begin and continue intermittently
20. Capt. to controller: "we're pretty low on the speed…let the Coast Guard know"
21. F/O tells controller airport not in sight
22. Controller informs crew of low-altitude alert
23. F/O tells controller airplane cannot climb
24. Controller offers crew JRF as landing option
25. Sounds similar to stick shaker begin and continue intermittently
26. Capt.: "we [will be] in the water"
27. Sounds consistent with impact

Figure 1. Airplane flightpath with pertinent transmissions and events overlaid.

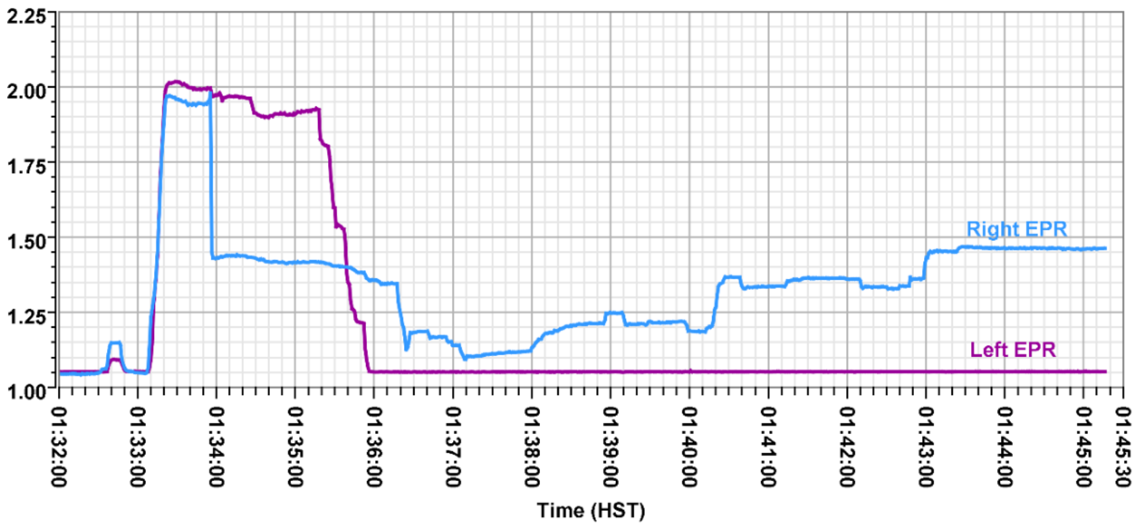


Figure 2. Left and right EPR values during the accident flight.

Note: The EPR decrease on the left engine between 0135:00 and 0136:00 (in purple) occurred between events 6 and 7 in figure 1.

Figure 3. EPR gauges on the accident airplane's center instrument panel (Source: Transair).

Note: This photograph was taken in March 2016.

Postaccident Interviews with Flight Crew

The NTSB interviewed the accident captain and first officer a few days after the accident. The investigation subsequently determined that the left engine was capable of producing normal thrust during the accident flight; as a result, the NTSB conducted follow-up interviews with the accident flight crew 8 months later (March 2022).

The captain stated that he heard a "whoosh" sound immediately after his gear-up callout. The captain also stated that he noticed that the EPR indication for each engine was "about two tick marks" below where he had set power on the EPR gauge. (One tick mark on the EPR gauge was equivalent to 0.02 EPR.) The captain thought that power had been lost on the left engine but stated that the EPR for the right engine was a "few ticks lower" than that for the left engine. The captain further stated that "the noise, the yaw and the roll, and the fact that the EPR was lower than what [he] had set, led [him] to believe that the problem [was with] number 2" when the engine issue occurred.

The first officer stated that he heard a "pop" sound about the time that the landing gear retracted and that the sound emanated from the left engine area. The first officer also stated that, after the pop sound, "all the gauges on the left side, the Number 1 just dropped." The first officer recalled "very clearly that [his] initial thought was we've lost the number one engine." In addition, he recalled that the airplane was subsequently "pulling to the left," so he thought that the left engine "wasn't producing thrust."

The captain stated that his communications with ATC about the emergency "became a project" and that "it took a while for ATC to know what was going on." The captain also stated that initially he had difficulty hearing radio transmissions from ATC because "everybody [was] stepping over everybody." The captain added that ATC communications "took too much of [his] time away from the cockpit."

The captain also stated that, after setting maximum continuous thrust as the pilot monitoring, he did not move either thrust lever until after he became the pilot flying. The captain could not recall the lever positions when he took control of the airplane, but the captain noted that the first officer could adjust the thrust levers as he wanted when he was the pilot flying.

The first officer stated that, after the airplane leveled off at an altitude of about 2,000 ft, he reduced thrust on both engines. The first officer also stated that, for an engine failure at V_1, the procedure is to move both levers together until the affected engine is identified. The first officer further stated that "our training is [such that] we don't fly on one thrust lever until we have identified which engine. And we don't do that until after we level off."

The captain recalled that the first officer later informed him that the airplane had lost power on the left engine. The captain indicated that he trusted the first officer's assessment because the captain had "flown with [the first officer] so many times" and "he never makes a mistake." The captain explained that, after the first officer mentioned the left engine, he "didn't pay attention to [the] number 1 engine" because his "focus was on the engine running, which was number 2." Further, the captain recalled that the EPR level for the left engine "was down" and "was not going to sustain flight."

The first officer stated that he got through "maybe a third or less" of the Engine Failure or Shutdown checklist because, at that point in the flight, he became concerned that the airplane was "low" and "slowing." The first officer had also become concerned that the captain "wasn't focused on flying the airplane." According to the first officer, he did not get to the step in the checklist that stated, "thrust lever, affected engine, confirm close," and he could not recall the position of the left thrust lever. The first officer further stated that he should have continued the checklist but that "the number one rule is you fly the airplane first…everything [else] comes after that."

The captain recalled that the first officer read a few lines from the Engine Failure or Shutdown checklist. The captain also stated that, when he saw that the EPR for the right engine was decreasing and that there was “nothing coming out” of the left engine, he thought that performing the checklist would be “useless” at that point. The captain explained that both engines “already shut themselves down” and that his primary focus was staying airborne and figuring out how to return to the airport “without power.”

The captain added that, after he saw the EPR for the right engine and the airspeed dropping, he pushed the right thrust lever to the forward stop (where it remained for the rest of the flight), but the airspeed continued to decrease. The captain stated that he did not consider pushing the left thrust lever forward because he was “wrestling” the stick shaker and “trying to get the wings level.” In addition, both pilots stated that, after the transfer of control from the first officer to the captain (about 0137), the captain retained control of the airplane through the end of the flight.

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	58,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	5-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	February 4, 2021
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	June 9, 2021
Flight Time:	(Estimated) 15781 hours (Total, all aircraft), 871 hours (Total, this make and model), 10600 hours (Pilot In Command, all aircraft), 140 hours (Last 90 days, all aircraft), 46 hours (Last 30 days, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Private	**Age:**	50,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):		**Restraint Used:**	5-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):		**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	June 22, 2021
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	June 16, 2020
Flight Time:	(Estimated) 5272 hours (Total, all aircraft), 908 hours (Total, this make and model), 247 hours (Pilot In Command, all aircraft), 93 hours (Last 90 days, all aircraft), 6 hours (Last 30 days, all aircraft)		

The Captain

The captain’s first-class medical certificate included the limitation that he must wear corrective lenses, and the captain stated that he was wearing his glasses during the accident flight. The captain’s work schedule at Rhoades Aviation for the 3 days before the accident flight is shown in the table below.

Table. Captain's 72-hour work history.

Date	Start time	End time	Flight time	No. of legs
June 29, 2021	0015	0730	3 hours 26 minutes	6
June 30, 2021	0015	1202	5 hours 17 minutes	8
July 1, 2021	0015	0723	3 hours 32 minutes	6

The captain stated that the nature of his job resulted in an unpredictable sleep pattern. The captain could not recall how much sleep he obtained in the days before the accident, but the captain reported that he obtained some sleep each day and did not feel sleep deprived when he arrived at work for the accident flight. The captain also stated that he might have obtained rest between his work shifts from June 29 to July 1. On June 29, he had a sleep opportunity between 1000 and 2000; on June 30, he had a sleep opportunity between 1500 and 2100; on July 1, he had a sleep opportunity between 1000 and 2000.

The captain reported that he had experienced about five engine failures while working at Rhoades Aviation. One such failure occurred about 3 to 4 months before the accident. During that flight, the captain heard a “pow” sound while the airplane was climbing through 700 ft and noted an issue with the left engine, so he decided to immediately return to the airport. The captain reported that the company chief pilot criticized him for returning to the airport without performing the relevant abnormal checklist. The captain promised the chief pilot that he would perform the relevant checklist if he were involved in another emergency. The captain also stated that he had performed seven precautionary or emergency landings while working for the company.

The First Officer

The first officer was also an attorney who did legal work (when he was not flying) during weekdays and part of the day on Saturdays. The first officer did not log any flight time during the 72 hours before the accident. The first officer’s second-class medical certificate included the limitation that he must wear corrective lenses, and the first officer stated that he needed to wear a corrective lens only in his right eye and that he was wearing the corrective lens during the accident flight.

The first officer reported that he normally went to sleep between 2200 and 2300 and awoke between 0600 and 0700. He thought that his sleep pattern on June 29 and 30 was consistent with his normal schedule. On June 29, he worked on manual revisions for Rhoades Aviation. On June 30 and the morning of July 1, he did legal work. The first officer then rested between 1400 and 2330 for his upcoming flight (the accident flight). He could not recall when he fell asleep but stated that his quality of sleep was good.

The first officer stated that he had experienced an in-flight engine failure while working for another air carrier (from 1991 to 1995) and that the event airplane landed safely. The first officer also stated that he had not experienced another in-flight engine failure until the accident flight.

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	**Registration:**	N810TA
Model/Series:	737-275C	**Aircraft Category:**	Airplane
Year of Manufacture:	1975	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	21116
Landing Gear Type:	Retractable - Tricycle	**Seats:**	4
Date/Type of Last Inspection:	June 9, 2021 Continuous airworthiness	**Certified Max Gross Wt.:**	119500 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo jet
Airframe Total Time:	27788.5 Hrs at time of accident	**Engine Manufacturer:**	P & W
ELT:	C126 installed, activated, aided in locating accident	**Engine Model/Series:**	JT8D-9A
Registered Owner:	RHOADES AVIATION INC	**Rated Power:**	14500 Lbs thrust
Operator:	RHOADES AVIATION INC	**Operating Certificate(s) Held:**	Flag carrier (121), Supplemental
Operator Does Business As:	Transair	**Operator Designator Code:**	JRAA

The airplane was owned and operated by several different companies before Rhoades Aviation purchased it on December 23, 2014. Rhodes Aviation registered the airplane with the FAA on January 23, 2015, and the airplane was added to the company's operations specifications on February 2, 2015. According to company records, the airplane had accumulated 72,871 total hours and 69,446 total cycles before the accident flight.

The airplane was powered by two Pratt & Whitney JT8D-9A turbofan engines, which were installed on the accident airplane on October 28 (left) and September 20, 2019 (right). The left engine was manufactured on June 24, 1971, and had accumulated 32,305 total hours and 33,670 total cycles. The right engine was manufactured on January 10, 1968, and had accumulated 70,827 total hours and 101,368 total cycles. After their last shop visit, the left and right engines were returned to service on September 19 and April 5, 2019, respectively, and they accumulated 1,055 hours and 2,085 cycles through the date of the accident.

The JT8D-9A engine has a six-stage low-pressure compressor driven by a three-stage low-pressure turbine, a seven-stage high-pressure compressor driven by a single-stage high-pressure turbine, and a can-annular combustor. Both engine rotors turn in the clockwise direction (as viewed aft of the engine looking forward). The high-pressure compressor, combustion chamber, and high-pressure turbine are collectively referred to as the engine core.

All required inspections and maintenance checks listed in the Rhoades Aviation aircraft inspection program were completed for the airplane. The airplane underwent a routine daily check on July 1, 2021, and no discrepancies were identified. All reviewed items in the airplane logbooks from January 1, 2020, to July 1, 2021, were properly signed off and closed. No minimum equipment list items for the airplane were open at the time of the accident. A review of time-limit component reports for the airframe, engines, and auxiliary power unit revealed no discrepancies. A review of the FAA’s service difficulty report database showed three reports that pertained to the accident airplane; the most recent report (related to the failure of the left engine at 2,000 ft) occurred about 2.5 years before the accident.

A previous Rhoades Aviation chief inspector (who resigned from that position 6 weeks before the accident) recalled “chronic” maintenance writeups for issues related to the accident airplane’s EGT and fuel indications but could not remember specific details about those issues. The company’s director of maintenance stated that he was unaware of any flight crew reports about high EGT indications on the accident airplane. The director of maintenance further stated that an engine trend monitoring report for the accident airplane’s engines, which the company received 2 days before the accident, showed “everything normal.”

The airplane’s basic empty weight as of April 19, 2021, was 59,720 pounds. The accident flight was estimated to have a basic operating weight of 60,160 pounds, which included the standard weight for two flight crewmembers and their bags. The accident flight was loaded with 19,897 pounds of cargo and 14,000 pounds of fuel. The airplane’s takeoff weight was 93,557 pounds, which was below the airplane’s maximum takeoff weight of 119,500 pounds.

Transair stated that, on the day of the accident, the accident airplane was fueled from the same fuel truck as another airplane in the company’s fleet (N809TA). A fuel sample taken from N809TA’s sump tank on July 3, 2021, showed that the fuel met specifications.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Night
Observation Facility, Elevation:	PHNL	**Distance from Accident Site:**	7 Nautical Miles
Observation Time:	00:53 Local	**Direction from Accident Site:**	250°
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	13 knots /	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	70°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	30.04 inches Hg	**Temperature/Dew Point:**	26°C / 18°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Honolulu, HI (PHNL)	**Type of Flight Plan Filed:**	IFR
Destination:	Kahului, HI (PHOG)	**Type of Clearance:**	IFR
Departure Time:	01:23 Local	**Type of Airspace:**	Class B

Airport Information

Airport:	HNL PHNL	**Runway Surface Type:**	
Airport Elevation:	13 ft msl	**Runway Surface Condition:**	
Runway Used:		**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	1 Serious, 1 Minor	**Aircraft Damage:**	Destroyed
Passenger Injuries:	N/A	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Serious, 1 Minor	**Latitude, Longitude:**	21.1639,-158.01313

The airplane’s forward fuselage section separated from the rest of the airplane near the leading edge of the wing. Most of the fuselage structure below the main cabin and cockpit floor separated from the forward fuselage. The separated structure below the floor was crushed and torn. The aft fuselage lower section was damaged, and portions of belly skin had separated from the airplane. The four cargo containers remained in the aft fuselage. Most of the cargo was waterlogged.

Both wings remained attached to the fuselage, and the inboard and outboard flaps, ailerons, and spoilers remained attached to the wings. The left and right engines separated from their respective wings. The left and right main landing gear were in the retracted position when the airplane was lifted from the water after the accident. (See the Additional Information section of this report for details about the search and recovery of the wreckage.)

The empennage was mostly intact with the horizontal stabilizer, elevators, and trim tabs remaining in their installed positions. The left and right elevators were undamaged. The vertical stabilizer and the rudder remained in their installed positions and were mostly undamaged.

The center instrument panel showed that the EPRs for the left and right engines were about 1.0 and 1.6, respectively. The panel also showed that the EGTs for the left and right engines were 70 (indicating 700°C) and less than 0, respectively.

Postaccident Examination of Left Engine

The left engine showed no indications of fire, uncontainment, or case rupture. The pressure ratio bleed control valve remained installed. The turbine exhaust case EGT and EPR probes were full length.

The low-pressure compressor stage 1 through 4 blades were full length. Two of the stage 5 blades had fractured; the rest were full length. Sections of the stage 5 and 6 blades were bent opposite the direction of rotation. The compressor intermediate case exhibited a deep inward dent by these blades. Most of the high-pressure compressor stage 7 blades were bent opposite the direction of rotation; four of these blades were fractured and deformed. The stage 12 and 13 blades were also bent opposite the direction of rotation.

The fuel pump and fuel control unit from only the left engine were examined and tested. No anomalies were found that would have prevented normal engine operation.

Postaccident Examination of Right Engine

The right engine showed no indications of fire, uncontainment, or case rupture. The pressure ratio bleed control valve remained attached to the engine. The turbine exhaust case EGT and EPR probes were full length.

The low-pressure compressor blades in stages 2 through 6 were bent opposite the direction of rotation, as were the high-pressure compressor blades in stages 7 through 13. The high-pressure turbine disk was intact, and all stage 1 blades and blade retention rivets were secure. The outer spans of two high-pressure turbine stage 1 blades were missing. The high-pressure turbine stage 1 blades were numbered clockwise from 1 to 80, with the trailing fractured blade designated as blade No. 1 and the leading fractured blade designated as blade No. 6, as shown in figure 4. The liberated portions of the blades were not recovered.

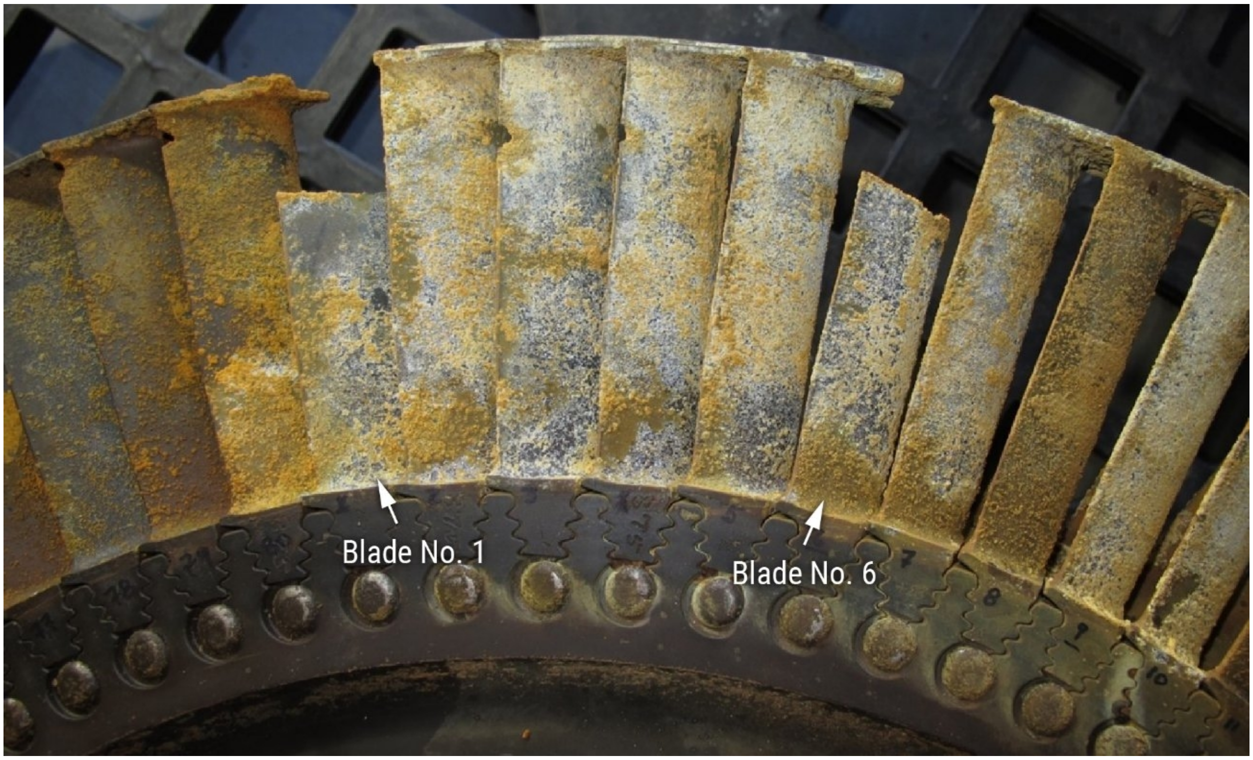


Figure 4. Fractured blades on the right engine high-pressure turbine.

Blade Nos. 1 and 6 were fractured transversely about 2.4 and 2.7 inches, respectively, above the platform trailing edge. Blade Nos. 3, 4, 79, and 80 exhibited trailing-edge outer diameter impact damage toward the outer span. Other blade trailing edges showed varying damage with missing material up to 0.04 inches radially. The blade fracture surfaces were heavily coated with ocean deposits.

The low-pressure turbine stage 2 and 3 blades exhibited outer span fractures. Up to 3 inches of outer span material was missing from the stage 4 blades.

Metallurgical Examination of Right Engine High-Pressure Turbine Blades

The two fractured high-pressure turbine blades (Nos. 1 and 6) were examined at Pratt & Whitney's Materials and Processes Engineering Lab in East Hartford, Connecticut. The examination determined that the blades failed by stress rupture resulting from a loss of load-bearing material due to oxidation and corrosion. The oxidation occurred around the blades' internal lightening (weight-reduction) holes and had significantly reduced each blade's load-bearing cross-section. The fracture through the oxidized regions exhibited comparatively flat features, consistent with brittle fracture. The fracture across the remaining load-bearing blade material either exhibited a rough (intergranular) texture, which was consistent with stress rupture, or was covered by ocean deposits.

In addition, the examination found microstructure changes to the blade material on four high-pressure turbine stage 2 blades, which was consistent with exposure to temperatures beyond the blades' normal operating range.

Flight recorders

The accident airplane was equipped with an Allied Signal (now Honeywell) solid-state universal FDR. The FDR recorded 18 parameters in accordance with federal requirements.

Defects in the rubber RTV sealant surrounding the memory module were found; these defects resulted from the way that the sealant was applied and cured at the time that the FDR was manufactured. The RTV sealant is designed to protect the unit's internal memory boards from water damage and corrosion, but the defects allowed sea water to flood the boards as the airplane wreckage sank. Despite the manufacturing defects in the sealant, data from the accident flight were successfully recovered.

The accident airplane was also equipped with a Honeywell 6022 solid-state CVR, which, according to federal requirements, recorded at least the last 2 hours of the airplane's operation. Specifically, the CVR contained a two-channel recording of the last 2 hours of operation and a separate three-channel recording of the last 30 minutes of operation. The 2-hour portion of the recording comprised one channel that combined three audio panel sources and a second channel that contained the cockpit area microphone source. The 30-minute portion of the recording contained three channels of audio information for each flight crewmember and a cockpit observer.

The CVR had a similar manufacturing defect in the RTV sealant for the internal memory boards, which resulted in water intrusion that led to corrosion; this corrosion rendered the 30-minute recordings unusable. The 2-hour CVR channels were unaffected and were able to be successfully downloaded.

Medical and Pathological Information

According to postaccident medical records, the captain was placed on a ventilator after arriving at the hospital and was diagnosed with aspiration with respiratory failure. His hospital-administered urine drug screen and blood alcohol level were both negative. Toxicology testing performed by the FAA was positive for a medication given at the hospital that was related to the captain’s treatment. The captain was hospitalized for 2 days and then discharged.

The first officer was diagnosed with a scalp laceration, blunt head trauma, cervical strain, and aspiration pneumonitis. His hospital-administered urine drug screen and blood alcohol level were both negative. His Department of Transportation postaccident urine drug screen, which was performed 18 hours after the accident, was negative. Toxicology testing performed by the FAA was positive for four prescription medications. The first officer was discharged from the hospital about 12 hours after he arrived.

Survival Aspects

Evacuation

The flight crew reported that the airplane came to a quick stop after impacting the water. The captain looked out his left-side cockpit window and saw water halfway up the window. Both he and the first officer could feel the airplane sinking. The captain opened his window, and water began rushing in. The captain released his restraints (including his shoulder harnesses) and evacuated the airplane through the window. (The captain’s window was found fully open and unbroken.) The captain reported no problems releasing his restraints or opening the window. The captain left everything behind and did not reach for a flotation device because he was focused on getting out of the airplane. The captain recalled that he evacuated the airplane after the first officer.

Once in the water, the captain decided to swim along the left side of the airplane to try to find structure to hold onto because waves were coming over him. The captain found nothing to hold onto, so he swam to the tail section, which was floating. The captain used the automatic direction finder antenna to hoist himself onto the right side of the vertical fin. The waves knocked him off a few times, and each time he swam back to the tail, climbed back up, and held on. The captain remembered seeing a helicopter making a few passes overhead, and the last thing that he remembered was struggling to stay afloat after a wave knocked him off the tail. His next memory was waking up in the hospital.

The first officer stated that, during the impact, his upper torso moved forward as his right shoulder moved forward, downward, and to the left, causing his body to twist. The first officer's head then moved downward (with his face turned to the left), and the top of his head struck something in front of him. The first officer opened his right-side window and had no problem releasing his restraints (including his shoulder harnesses). He evacuated the airplane through his window. (The first officer's window was found unbroken and partially open before wreckage recovery efforts, which resulted in the window moving to the fully open position.)

Once outside the cockpit, the first officer saw that the airplane had broken into two pieces, and he stayed with the nose section. The first officer saw the captain swim to the tail section but then lost sight of him. Both flight crewmembers called each other's names and heard the other's reply, so they both knew that the other was still above the water. The first officer recalled that the airplane nose then started to sink. About that time, he noticed a large wooden pallet nearby and climbed upon that, which enabled him to see the tail section with the captain on top.

The first officer recalled hearing a helicopter and seeing it make three large circles around the wreckage area. On the fourth pass, the helicopter crew saw the first officer and shined the spotlight on him. The first officer signaled that the captain was on the tail section because he was concerned that the tail might sink. The helicopter then moved to a position over the tail to rescue the captain. A boat from HNL ARFF arrived to rescue the first officer. The first officer stated that someone in the boat bandaged his head to stop the bleeding caused by his injury. The first officer was found without a flotation device.

Emergency Response

About 0145 the USCG Joint Rescue Coordination Center in Honolulu received initial notification about a downed airplane 2 nautical miles south of HNL. (The USCG Joint Rescue Coordination Center was responsible for coordinating US aviation and maritime search and rescue activities in the Pacific Ocean.) Two minutes later, the USCG received the first emergency locator transmitter alert from the airplane, indicating that it was located 2 nautical miles southeast of JRF.

The Joint Rescue Coordination Center notified HNL ARFF personnel (about 0147) and USCG Air Station Barbers Point personnel (about 0148) about the downed airplane. HNL ARFF launched a rescue boat about 0200, and Air Station Barbers Point launched an MH-65 Dolphin helicopter about 0218. The ARFF station was located about 2.8 nautical miles northwest of the airplane's coordinates, and the helicopter flew to the airplane's last known position.

About 0230, personnel aboard the helicopter arrived at the accident site (which they identified by a fuel slick and debris on the water) and subsequently located both flight crewmembers on floating debris. About 0240, the HNL ARFF rescue boat arrived on scene; the boat had been delayed because of high surf and low visibility. A rescue diver aboard the helicopter was hoisted downward and assisted the captain, who was struggling to stay afloat after the tail began to sink. The diver and the captain were hoisted back to the helicopter, and then the diver entered the water again to help the first officer. The diver assessed the first officer's condition and decided to swim with the first officer on the floating debris to the ARFF rescue boat. They reached the boat about 0251.

The helicopter departed the scene about 0259, and the ARFF rescue boat departed the scene about 0302. The helicopter arrived at a local hospital with the captain about 0305. The ARFF rescue boat encountered high surf and low visibility while traveling to the HNL ARFF station dock. About 0406, the first officer was transported to the hospital by an ambulance that had been positioned at the ARFF station.

Flight Crew Seats

The captain's and the first officer's seats were manufactured by IPECO. The captain's seat (on the left side of the cockpit) had a manufacture date of May 25, 1990, and was designed to comply with TSO-39b, Aircraft Seats and Berths, dated April 17, 1987. The first officer's seat (on the right side of the cockpit) had a manufacture date of September 9, 1984, and was designed to comply with TSO-39a, dated February 24, 1972. (The difference between these TSOs involved the incorporation of fire-blocking material that met the requirements of 14 *Code of Federal Regulations* 25.853(c), which became effective November 26, 1984.) Both TSO-39a and -39b required the seats to meet a static load requirement of 9 G forward and 6 G downward.

The captain's seat was intact and secured to the seat tracks, which were fastened to a box structure that attached to the floor. The box seat structure, seat cushions, and seat pan were not damaged. The bungees underneath the seat and the threaded rod and spring (which were used to adjust the seatback angle) remained intact. The storage area below the seat pan was not damaged.

The first officer's seat was intact and secured to the seat tracks. The seatback had rotated forward and collapsed, as shown in figure 7. The seat cushions and seat pan were not damaged, but the stowage compartment below the seat was damaged. The left bungee was broken with one-half missing; the right bungee was connected, but the elastic was broken in multiple places. The threaded rod and spring were fractured at the forward end.

Figure 7. First officer's seat in cockpit after recovery.

The seatback for the first officer's seat was designed with a jackscrew mechanism that adjusted the seatback position. The jackscrew was mounted to the underside of the seat. The base of the screw was connected to the base of the seatback with a hinge pin, and a jack nut inside a housing was located on the underside of the seat pan. A compression spring and sleeve were installed over the jackscrew, and the free end of the screw was passed through the nut assembly. The spring used residual compression to push the jackscrew aft, which would cause the seatback to move forward. To move the seatback aft, the occupant would use body weight to push against the seatback, which would result in forward movement of the jackscrew. The rotation of the nut, and thus the seatback position, would become locked by a latch mechanism that could be engaged or disengaged by the seat occupant.

The first officer's seat was examined by the NTSB Materials Laboratory to determine the condition of the components that controlled the seatback position. Examination of the nut assembly revealed that the jack nut was fractured in the transverse plane between large- and small-diameter sections of the nut. The latch was found in the locked position. The latch tip showed no apparent deformation, and the nut slot (for receiving the latch) appeared to be aligned with the locking slot in the housing.

Teardown of the nut assembly revealed that the jack nut had fractured in overstress. The threads on the large-diameter portion of the nut (which contained the slots for engaging with the latch) exhibited a stripped appearance, whereas the threads on the small-diameter portion of the nut did not appear stripped. Examination with a stereomicroscope revealed no apparent progressive cracking features.

Tests and Research

An aircraft performance study was performed as part of this accident investigation. The objectives of the study were to (1) quantify the Boeing 737-200 airplane's expected climb performance capability with one engine inoperative (OEI), (2) evaluate the accident airplane's climb performance after the rapid reduction in right EPR, and (3) determine if the accident airplane's motion, in response to EPR changes, configuration changes, and flight control inputs, was consistent with the behavior of a nominal 737-200.

Boeing developed takeoff and climb performance data and OEI maximum takeoff thrust and maximum continuous thrust performance data for its 737-200 *Airplane Flight Manual* (AFM). For this study, Boeing engineering staff calculated baseline takeoff and climb performance for a 737-200 equipped with Pratt & Whitney JT8D-9 engines and determined the OEI-expected and the accident airplane-demonstrated climb performance. The Pratt & Whitney JT8D-9A engine model was unavailable, so the JT8D-9 engine model was used to support calculations for this study. The data used in the study assumed that the landing gear was retracted, the airplane was flying at a constant airspeed with a neutral control wheel, and the OEI thrust asymmetry was trimmed with rudder. According to these data, a 737-200 with JT8D-9 engines would have adequate OEI performance capability to climb or maintain altitude with the accident airplane's (1) altitude range (0 to about 2,000 ft), (2) loading conditions (a takeoff weight of 93,557 pounds), (3) flight conditions from takeoff to water impact (including a 26°C outside air temperature), and (4) flap and gear configurations.

After the right engine rapid EPR reduction shortly after takeoff (with no change to the left EPR), the flight crew and the accident airplane demonstrated the ability to climb to 1,000 ft, accelerate, climb to 2,000 ft, and maintain altitude. When the left EPR was reduced below 1.2 (which occurred between 0135:52 and 0135:53), the airplane's total engine thrust was less than the thrust required for the airplane to maintain altitude with the flight conditions, flight control inputs, EPR values for the left and right engines, and flap configurations during the remainder of the flight. (The left EPR continued to decrease, reaching 1.05 at 0135:56 and remaining at that level for the rest of the flight.)

Boeing used its 737-200 integrated airplane simulation model to conduct a simulation of the accident flight. As part of this effort, Boeing modeled the following segments of the accident flight: takeoff ground roll and initial climb; right EPR rapid reduction and airplane climb and level-off; sequential left EPR reductions; the right banked turn from a heading of 240° to 260° (which began about 0138:13) followed by the left banked turn to a heading of 240° (which began about 0138:36); deceleration with flaps up; and deceleration with the flaps 1 configuration.

Pratt & Whitney provided baseline JT8D-9 engine model data for each engine during the accident flight based on FDR airspeed, pressure altitude, and left and right EPR data. The following engine parameters were then calculated for each engine: N1 (speed of low-pressure spool), N2 (speed of high-pressure spool), net thrust, EGT, fuel flow, and nominal engine power lever angle. Pratt & Whitney also developed engineering models to account for (1) the engine thrust increments resulting from the installation of an AvAero hush kit (for noise abatement) on each engine in May 2004, (2) in-service engine deterioration based on data recorded during the cruise segments of preceding flights that the accident airplane accomplished, and (3) estimated thrust degradation to the right engine based on the damage observed in the recovered high- and low-pressure turbines.

According to the Boeing 737-200 airframe and Pratt & Whitney JT8D-9 engine simulation models, the accident airplane's motion (in response to EPR changes, configuration changes, and flight control inputs) was generally consistent with the behavior of the nominal 737-200 airplane/engine/flight controls simulation model and the Pratt & Whitney-calculated engine thrust profile for each engine.

Organizational and Management Information

Rhoades Aviation

According to FAA documentation, in May 2012, Rhoades Aviation began operating Boeing 737 airplanes under Part 121 as a supplemental cargo-only operation doing business as Transair.

At the time of the accident, Rhoades Aviation had five 737-200 airplanes and 230 employees, 24 of which were pilots.

Continuous Analysis and Surveillance System

According to Rhoades Aviation's *General Maintenance Manual* (dated February 25, 2014), the primary function of the CASS program was to ensure that the company's airplanes were airworthy, safe, and reliable and that the company's maintenance and inspection programs met or exceeded all regulatory requirements. The company's CASS program had the following primary functional areas:

? monitoring a maintenance program's effectiveness;
? monitoring a maintenance program's performance/execution;
? developing and implementing corrective actions for maintenance program deficiencies identified during the surveillance, investigation, and analysis processes; and
? following up to ensure that the corrective actions were effective.

Monthly CASS meetings were held, and findings from the program were presented by Rhoades Aviation's chief inspector, who was responsible for the company's CASS program. The meetings included the FAA principal inspectors for the company. The NTSB reviewed the CASS meeting reports from July 2020 to June 2021 and found that the June 2021 CASS report included four components that had failed at least three times during the preceding month. One of these components, the right engine fuel quantity system, was first identified several months earlier. The June 2021 CASS report also showed that Rhoades Aviation was tracking maintenance issues related to the traffic collision avoidance system, right engine thrust reverser system, and left engine fuel heat valve light.

The Rhoades Aviation chief inspector at the time of the accident had been hired 2 weeks before the accident. The previous chief inspector began working for the company in February 2019 as a part-time mechanic, left the company at some point later, and returned in July 2019 as the company's chief inspector. He resigned from that position in May 2021 because of the stress associated with the position but remained with the company. In addition to managing the CASS program, his main responsibilities as chief inspector included ensuring that required inspections were performed and overseeing a records manager, records clerk, and a nondestructive testing inspector. In addition, he was helping the company with its responses to FAA inquiries about maintenance issues.

The previous chief inspector stated that he did not have the staffing to effectively handle all his responsibilities and that he did not have the time or the related experience to review the CASS data and perform trend analyses. The previous chief inspector asked company management to hire a CASS manager and an additional inspector, but the positions were not filled before the chief inspector resigned because the company had difficulty finding qualified applicants.

Company Manuals and Checklists

Review of Rhoades Aviation's most recent revision of its *General Maintenance Manual* found that several of the manual's references and procedures no longer applied or were inaccurate. The company's director of maintenance was responsible for the manual procedures.

The Rhoades Aviation *Boeing 737 Aircraft Operations Manual* discussed the effect of an engine failure after V_1. The manual stated the following:

> *An engine failure at or after V1 initially affects yaw much like a crosswind effect. Vibration and noise from the affected engine may be apparent and the onset of the yaw may be rapid. The airplane heading is the best indicator of the correct rudder pedal input. To counter the thrust asymmetry due to an engine failure, stop the yaw with rudder.*

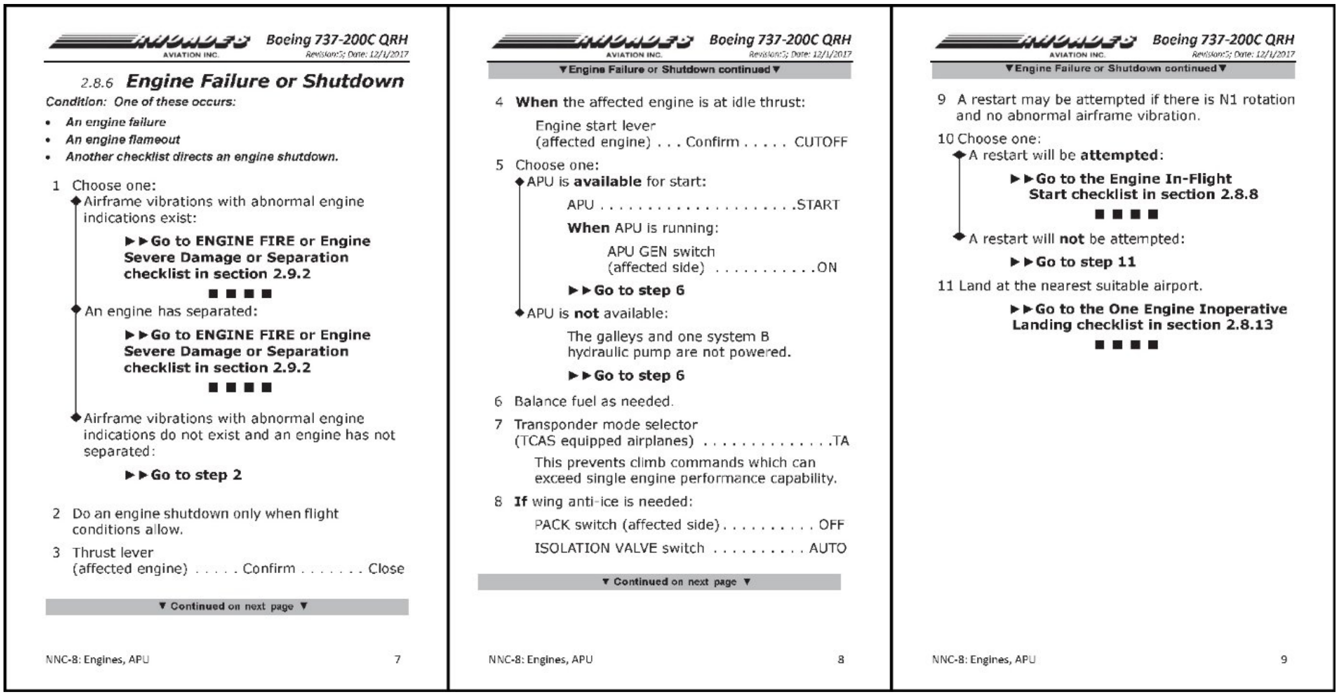
The manual provided the following technique for an in-flight engine shutdown:

> *Any time an engine shutdown is required in flight, good crew coordination is essential. Airplane incidents have turned into airplane accidents as a result of the flight crew shutting down the incorrect engine.*
>
> *When the flight path is under complete control, the crew should proceed with a deliberate, systematic process that identifies the correct engine and ensures that the operating engine is not shut down. Do not rush through the shutdown checklist, even for a fire indication.*
>
> *The following technique is an example that could be used:*
>
> *The PF…verbally coordinates confirmation of the affected engine with the PM and then slowly retards the thrust lever of the engine that will be shutdown* [sic].
>
> *Coordinate activation of the start lever as follows:*
>
> - *PM places a hand on and verbally identifies the start lever for the engine that will be shutdown* [sic]
> - *PF verbally confirms that the PM has identified the correct start lever*
> - *PM moves the start lever to cutoff*

The Rhoades Aviation *Boeing 737-200C Quick Reference Handbook* (QRH) provided the following guidance about non-normal checklist usage:

> *Non-normal checklist use starts when the airplane flight path and configuration are correctly established…. Usually, time is available to assess the situation before corrective action is started. All actions must then be coordinated under the Captain's supervision and done in a deliberate, systematic manner.*

The QRH included the Engine Failure or Shutdown checklist, as shown in figure 8. The QRH stated that “the word ‘Confirm’ is added to checklist items when both crewmembers must verbally agree before action is taken.” The QRH also stated that, “during an inflight non-normal situation, verbal confirmation is required” for several items, including movement of an engine thrust lever.



Boeing 737-200C QRH
AVIATION INC.
Revision:5; Date: 12/1/2017

2.8.6 **Engine Failure or Shutdown**

Condition: One of these occurs:

- *An engine failure*
- *An engine flameout*
- *Another checklist directs an engine shutdown.*

1 Choose one:

- Airframe vibrations with abnormal engine indications exist:

  ►►Go to ENGINE FIRE or Engine Severe Damage or Separation checklist in section 2.9.2

  ■■■■

- An engine has separated:

  ►►Go to ENGINE FIRE or Engine Severe Damage or Separation checklist in section 2.9.2

  ■■■■

- Airframe vibrations with abnormal engine indications do not exist and an engine has not separated:

  ►►Go to step 2

2 Do an engine shutdown only when flight conditions allow.

3 Thrust lever (affected engine) . . . . . Confirm . . . . Close

▼ Continued on next page ▼

NNC-8: Engines, APU 7

Boeing 737-200C QRH
AVIATION INC.
Revision:5; Date: 12/1/2017

▼Engine Failure or Shutdown continued▼

4 **When** the affected engine is at idle thrust:

Engine start lever (affected engine) . . . Confirm . . . . . CUTOFF

5 Choose one:

- APU is **available** for start:

  APU . . . . .START

  When APU is running:

  APU GEN switch (affected side) . . . . .ON

  ►►Go to step 6

- APU is **not** available:

  The galleys and one system B hydraulic pump are not powered.

  ►►Go to step 6

6 Balance fuel as needed.

7 Transponder mode selector (TCAS equipped airplanes) . . . . .TA

This prevents climb commands which can exceed single engine performance capability.

8 **If** wing anti-ice is needed:

PACK switch (affected side) . . . . OFF

ISOLATION VALVE switch . . . . AUTO

▼ Continued on next page ▼

NNC-8: Engines, APU 8

Boeing 737-200C QRH
AVIATION INC.
Revision:5; Date: 12/1/2017

▼Engine Failure or Shutdown continued▼

9 A restart may be attempted if there is N1 rotation and no abnormal airframe vibration.

10 Choose one:

- A restart will be **attempted**:

  ►►Go to the Engine In-Flight Start checklist in section 2.8.8

  ■■■■

- A restart will **not** be attempted:

  ►►Go to step 11

11 Land at the nearest suitable airport.

►►Go to the One Engine Inoperative Landing checklist in section 2.8.13

■■■■

NNC-8: Engines, APU 9

Figure 8. Engine Failure or Shutdown checklist (Source: Rhoades Aviation).

The Rhoades Aviation simulator guide, which supplemented information in the operator’s flight crew training manual, contained the most recent company guidance for training at the time of the accident. The simulator guide, which contained memory items, provided procedures to follow with an engine failure after the V_1 callout. According to the simulator guide, both pilots should announce the engine failure, which (1) the pilot flying would primarily recognize from a yawing moment and the rudder input required to counteract it and (2) the pilot monitoring would primarily recognize from a yawing moment and the engine gauges. The simulator guide stated that the pilot monitoring should declare an emergency to ATC and provide “initial intentions (such as heading & altitude).” The guide also stated that, when time permits, the pilot flying should “advise ATC of level of impairment, assistance required, souls-onboard, [and] fuel-on-board (in pounds).”

The simulator guide further stated that, after declaring the emergency, selecting flaps to the UP position, reducing thrust, and establishing the airplane in a climb at 210 knots, the pilot flying was to fly, navigate, and communicate, and the pilot monitoring was to “call out or reconfirm” the affected engine. The guide indicated that “the Captain, if not currently the PM, may (and most times should) elect to become the PM and run the QRH checklist.” In addition, the guide mentioned that both pilots should “be alert for aircraft yawing and changes in engine gauges & engine noise that could indicate that thrust is being reduced on the incorrect engine (operating engine).”

Crew Resource Management Training

According to FAA Advisory Circular 120-51E, CRM is “the application of team management concepts in the flight deck environment.” In 1998, the FAA began requiring Part 121 air carriers to provide FAA-approved initial and recurrent CRM training to flight crews.

The Rhoades Aviation *Aircrew Training Manual* indicated that the objective of the company’s CRM training was “to increase the efficiency with which flight personnel perform by focusing on communication skills, teamwork, task allocation, and decision making.” The manual stated that the instruction methods used in the company’s CRM training included lectures, audio-visual programs, multimedia presentations, overhead projections, and printed handouts and that CRM exercises would be introduced in flight training.

Rhoades Aviation’s initial CRM training consisted of 6 hours of instruction and included videos about the history of CRM, complacency, threat and error management, and four accidents that involved a lack of CRM. One of those accidents was American Airlines flight 1400, a McDonnell Douglas DC-9-82, which experienced an in-flight left engine fire during the departure climb from St. Louis Lambert International Airport, St. Louis, Missouri, in September 2007. The video for this accident explained that American Airlines’ policy was for the pilot flying to handle the radios while flying the airplane and for the pilot monitoring to execute the appropriate checklist. The flight 1400 first officer (who was the pilot monitoring) continued to control the radios while attempting to execute the engine fire checklist. The flight 1400 captain did not recognize that multiple ATC radio calls were delaying the execution of the checklist, and he directed the first officer to take control of the airplane before critical checklist steps were performed, such as cutting off fuel flow to the affected engine, causing the engine fire to continue. The video emphasized the importance of task prioritization and workload management, adherence to standard operating procedures, and good leadership when confronted with abnormal situations. The captain’s and the first officer’s initial CRM training occurred in 2019.

Rhoades Aviation’s recurrent and upgrade CRM training consisted of 2 hours instruction and included topics such as current CRM-related findings, the mission of CRM training, performance markers, and team building and maintenance. The captain’s and the first officer’s most recent recurrent CRM training occurred on May 7, 2021, and August 5, 2020, respectively.

Training materials and records from Rhoades Aviation showed that the captain and the first officer’s CRM training addressed the importance of CRM in abnormal situations. This training discussed thorough preparation and planning, the use of briefings, task prioritization, workload management, the use of checklists and standard operating procedures to prevent errors, and clear communications. The captain also received CRM training on the importance of effective leadership.

Federal Aviation Administration Oversight

FAA oversight for Rhoades Aviation was provided by a team at the Honolulu certificate management office. The team included a front-line manager and principal operations, maintenance, and avionics inspectors. The front-line manager stated that all the principal inspectors were “new to the certificate” and that the operator was “understaffed a lot of the time” and did not have “enough help to do what they need to do and to fix manuals.”

Before the accident, the FAA issued several letters of investigation to Rhoades Aviation. The FAA provides letters of investigation for suspected violations of the *Federal Aviation Regulations*. According to the FAA, a letter of investigation “serves the dual purposes of notifying an apparent violator that he or she is under investigation for a possible violation and providing an opportunity for the apparent violator to tell his or her side of the story.” Most of the issues in the letters of investigation addressed Rhoades Aviation’s operations specifications; aircraft inspection program (the issues were unrelated to engine maintenance); maintenance manual revisions; and processes, policies, and procedures.

Additional Information

The search for the airplane began on the day after the accident, July 3, 2021. The aft fuselage was located on July 7 about 0.13 miles north-northwest of the last recorded FAA automatic dependent surveillance-broadcast data point. The aft fuselage (with both wings and the tail still attached, as shown in figure 5) was found on a sloped area of the seafloor with the forward end at a depth of about 340 ft and the tail at a depth of about 363 ft. On July 8, several more parts of the airplane were located, including the forward fuselage (see figure 6), engine cores, thrust reversers, inlet cowls, and nose landing gear. The water depths where these structures were located ranged from 354 to 437 ft. The debris field was about 0.12 miles long (north-south) and about 0.10 miles wide (east-west). All major portions of the airplane were identified in the debris field.

Figure 5. Aft fuselage (Source: Sea Engineering Inc.).

Figure 6. Forward fuselage (Source: Sea Engineering Inc.).

Planning for the wreckage recovery included awarding a contract to recover the wreckage; consulting and coordinating with the State of Hawaii, the USCG, and other federal agencies; and developing and finalizing a recovery plan. Wreckage recovery operations began on October 12 and concluded on November 2, 2021.

Administrative Information

Investigator In Charge (IIC):	Silva, Sathya
Additional Participating Persons:	Patrick Lusch; FAA Jacob Zeiger; The Boeing Co; WA Doug Zabawa; Pratt and Whitney Orlando Debrum; Transair; HI Sarah Owens; NATCA
Original Publish Date:	June 15, 2023
Last Revision Date:	
Investigation Class:	Class 2
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=103407