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DCA00MA006

National Transportation Safety Board

Washington, DC 20594

Aircraft Accident Brief

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Boeing 767-366ER, SU-GAP
60 Miles South of Nantucket, Massachusetts
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Aircraft Accident Brief

Accident Number:	DCA00MA006
Operator/Flight Number:	EgyptAir flight 990
Aircraft and Registration:	Boeing 767-366ER, SU-GAP
Location:	60 miles south of Nantucket, Massachusetts
Date:	October 31, 1999
Adopted On:	March 13, 2002

FACTUAL

On October 31, 1999, about 0152 eastern standard time (EST), EgyptAir flight 990, a Boeing 767-366ER (767), SU-GAP, crashed into the Atlantic Ocean about 60 miles south of Nantucket, Massachusetts. EgyptAir flight 990 was being operated under the provisions of *Egyptian Civil Aviation Regulations* (ECAR) Part 121 and U.S. 14 *Code of Federal Regulations* Part 129 as a scheduled, international flight from John F. Kennedy International Airport (JFK), New York, New York, to Cairo International Airport, Cairo, Egypt.[1] The flight departed JFK about 0120, with 4 flight crewmembers, 10 flight attendants, and 203 passengers on board. All 217 people on board were killed, and the airplane was destroyed. Visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules (IFR) flight plan.

[1] Under the provisions of Annex 13 to the Convention on International Civil Aviation, the investigation of an airplane crash occurring in international waters falls under the jurisdiction of the airplane's country of registry (in this case, Egypt). At the request of the Egyptian Government, the National Transportation Safety Board assumed full responsibility for the investigation. Parties to the investigation included the Federal Aviation Administration (FAA), Boeing Aircraft Company, and Pratt & Whitney (P&W) Aircraft Engines. The Egyptian Civil Aviation Authority (ECAA) designated an accredited representative to the investigation on behalf of the Egyptian Government. EgyptAir provided a technical advisor to the ECAA and the investigation. The Federal Bureau of Investigation (FBI) also assisted in the investigation. The National Oceanic and Atmospheric Administration, U.S. Navy, and U.S. Coast Guard assisted in the search and recovery operations.

HISTORY OF FLIGHT

On October 30, 1999, the accident airplane departed Los Angeles International Airport (LAX), Los Angeles, California, as EgyptAir flight 990, destined for Cairo, with a scheduled intermediate stop at JFK. EgyptAir flight 990 landed at JFK about 2348 eastern daylight time (EDT)[2] and arrived at the gate about 0010 EDT on October 31, 1999.

Because of the 10-hour scheduled en route flight time from JFK to Cairo, ECAR Part 121, Subpart Q, required that the accident flight have two designated flight crews (each crew consisting of a captain and first officer). According to the EgyptAir flight dispatcher who accompanied the two accident flight crews from their hotel in New York City to the airport, they departed the hotel about 2330 EDT on October 30 and arrived at JFK about 40 minutes later, about the same time as the airplane, inbound from LAX, arrived at the terminal gate.

According to air traffic control (ATC) records, by 0101, the pilots of EgyptAir flight 990 had requested, received, and correctly read back an IFR clearance from ATC. ATC transcripts further indicated that between about 0112 and 0116, air traffic controllers issued a series of taxi instructions to EgyptAir flight 990. At 0117:56, the pilots advised the local controller that they were holding short of the departure runway (runway 22 right [22R]) and that they were ready for takeoff. The local controller instructed EgyptAir flight 990 to taxi into position and hold on runway 22R and, at 0119:22, cleared the accident flight for takeoff. The first officer acknowledged the takeoff clearance, and, about 0120, the airplane lifted off runway 22R.

Shortly after liftoff, the pilots of EgyptAir flight 990 contacted New York Terminal Radar Approach (and departure) Control (TRACON). New York TRACON issued a series of climb instructions and, at 0126:04, instructed the flight to climb to flight level (FL) 230[3] and contact New York Air Route Traffic Control Center (ARTCC). According to ATC and cockpit voice recorder (CVR) records, at 0135:52, New York ARTCC instructed EgyptAir flight 990 to climb to FL 330 and proceed directly to DOVEY intersection.[4]

According to the CVR transcript,[5] about 0140 (20 minutes after takeoff), as the airplane was climbing to its assigned altitude, the relief first officer suggested that he relieve the command first officer at the controls,[6] stating, "I'm not going to sleep at all. I might come and sit for two hours, and then…," indicating that he wanted to fly his portion of the trip at that time. The command first officer stated, "But I…I slept. I slept," and the

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[2] At 0200 EDT on October 31, 1999, local time in the eastern United States changed from 0200 EDT to 0100 EST. Unless otherwise indicated, all times in this document are EST, based on a 24-hour clock.

[3] FL 230 is 23,000 feet mean sea level (msl), based on an altimeter setting of 29.92 inches of mercury.

[4] This clearance resulted in EgyptAir flight 990 passing through a type of special-use airspace referred to as a "warning area." New York ARTCC and U.S. Navy records indicated that the warning area was not in use by the U.S. Navy at the time of the accident. For additional information, see the Air Traffic Control Group Chairman's Factual Report and its attachments.

[5] A complete, English-language transcript of the CVR is attached to this report.

relief first officer stated, "You mean you're not going to get up? You will get up, go and get some rest and come back." The command first officer then stated, "You should have told me, you should have told me this, Captain [relief first officer's surname].[7] You should have said, '[command first officer's first name]…I will work first.' Just leave me a message. Now I am going to sit beside you. I mean, now, I'll sit by you on the seat. I am not sleepy. Take your time sleeping and when you wake up, whenever you wake up, come back, Captain."

The relief first officer then stated, "I'll come either way…come work the last few hours, and that's all." The command first officer responded, "No…that's not the point, it's not like that, if you want to sit here, there's no problem." The relief first officer stated, "I'll come back to you, I mean, I will eat and come back, all right?" The command first officer responded, "Fine, look here, sir. Why don't you come so that…you want them to bring your dinner here, and I'll go to sleep [in the cabin]?" The relief first officer stated, "That's good." The command first officer then stated to the command captain, "With your permission, Captain?"

At 0140:56, the CVR recorded the sound of the cockpit door operating. About 1 second later, the command first officer stated in a soft voice, "Do you see how he does whatever he pleases?" At 0141:09, the command first officer stated, "No, he does whatever he pleases. Some days he doesn't work at all." At 0141:51, the CVR again recorded the sound of the cockpit door operating. Sounds recorded during the next minute by the CVR (including a whirring sound similar to an electric seat motor operating, a clicking sound similar to a seat belt operating, and some conversation) indicated that the command first officer vacated and the relief first officer moved into the first officer's seat.

Flight data recorder (FDR) and radar data indicated that the airplane leveled at its assigned altitude of FL 330 at 0144:27. At 0147:19, New York ARTCC instructed EgyptAir flight 990 to change radio frequencies for better communication coverage. The command captain of EgyptAir flight 990 acknowledged and reported on the new frequency at 0147:39.[8]

At 0147:55, the relief first officer stated, "Look, here's the new first officer's pen. Give it to him please. God spare you,"[9] and, at 0147:58, someone responded, "yeah."

[6] When two flight crews are used, EgyptAir designates one crew as the command flight crew and the other as the relief flight crew. Although EgyptAir has no written or formal procedures for command/relief flight crew transitions, postaccident interviews with EgyptAir flight crewmembers indicated that the command and relief flight crews typically agreed upon transfer-of-control procedures for a flight before departure. The interviews indicated that the most common procedure involved the command flight crew flying the airplane for the first 3 or 4 hours of the flight, then the relief flight crew assuming control until about 1 to 2 hours before landing. The command flight crew would then resume control of the airplane and complete the flight.

[7] Postaccident interviews with several EgyptAir pilots indicated that the relief first officer was often addressed as "captain" as a title of respect because he had instructed many of the EgyptAir pilots at the Egyptian flight training institute before he was hired by EgyptAir.

[8] This was the last transmission to ATC from the accident airplane. Although some irregularities in ATC handling were noted during the investigation, they were not relevant to the accident. For additional information, see the Air Traffic Control Group Chairman's Factual Report and its attachments and addenda.

At 0148:03, the command captain stated, “Excuse me, [nickname for relief first officer], while I take a quick trip to the toilet…before it gets crowded. While they are eating, and I’ll be back to you.” While the command captain was speaking, the relief first officer responded, “Go ahead please,” and the CVR recorded the sound of an electric seat motor as the captain maneuvered to leave his seat and the cockpit. At 0148:18.55, the CVR recorded a sound similar to the cockpit door operating.

At 0148:30, about 11 seconds after the captain left the cockpit, the CVR recorded an unintelligible comment.[10] Ten seconds later (about 0148:40), the relief first officer stated quietly, “I rely on God.”[11] There were no sounds or events recorded by the flight recorders that would indicate that an airplane anomaly or other unusual circumstance preceded the relief first officer’s statement, “I rely on God.”

At 0149:18, the CVR recorded the sound of an electric seat motor. FDR data indicated that, at 0149:45 (27 seconds later), the autopilot was disconnected.[12] Aside from the very slight movement of both elevators (the left elevator moved from about a 0.7° to about a 0.5° nose-up deflection, and the right elevator moved from about a 0.35° nose-up to about a 0.3° nose-down deflection)[13] and the airplane’s corresponding slight nose-down pitch change, which were recorded within the first second after autopilot disconnect, and a very slow (0.5° per second) left roll rate, the airplane remained essentially in level flight about FL 330 for about 8 seconds after the autopilot was disconnected. At 0149:48, the relief first officer again stated quietly, “I rely on God.” At 0149:53, the throttle levers were moved from their cruise power setting to idle, and, at 0149:54, the FDR recorded an abrupt nose-down elevator movement and a very slight movement of the inboard ailerons. Subsequently, the airplane began to rapidly pitch nose down and descend.

[9] The context of this statement indicates that the relief first officer was talking to the command first officer and that the “new first officer” to whom the relief first officer was referring was a pilot who had been in the cockpit earlier in the flight and who was seated in the cabin at the time of this statement. (According to the Cockpit Voice Recorder Group Chairman’s Factual Report, an Arabic-speaking member of the Cockpit Voice Recorder Group identified the voices of six flight crewmembers and one flight attendant recorded in the cockpit at various times during the accident flight.)

[10] According to the CVR transcript, “the five Arabic speaking members of the [CVR] group concur that they do not recognize this as an Arabic word, words, or phrase. The entire group agrees that three syllables are heard and the accent is on the second syllable. Four Arabic speaking group members believe that they heard words similar to ‘control it.’ One English speaking member believes that he heard a word similar to ‘hydraulic.’ The five other members believe that the word(s) were unintelligible.” For additional information regarding the computer analysis of this comment, see the section titled, “Cockpit Voice Recorder.”

[11] This phrase (recorded on the CVR in Arabic as “Tawakkalt Ala Allah”) was originally interpreted to mean “I place my fate in the hands of God.” The interpretation of this Arabic statement was later amended to “I rely on God.” According to an EgyptAir and ECAA presentation to Safety Board staff on April 28, 2000, this phrase “is very often used by the Egyptian layman in day to day activities to ask God’s assistance for the task at hand.”

[12] No autopilot disconnect warning tone was heard on the CVR recording. According to the system design, an autopilot disconnect warning is generated unless the autopilot is disconnected manually, either by clicking the control yoke-mounted autopilot disconnect switch twice within 0.5 second or by moving the autopilot switch on the instrument panel.

Between 0149:57 and 0150:05, the relief first officer quietly repeated, "I rely on God," seven additional times.[14] During this time, as a result of the nose-down elevator movement, the airplane's load factor[15] decreased from about 1 to about 0.2 G.[16] Between 0150:04 and 0150:05 (about 10 to 11 seconds after the initial nose-down movement of the elevators), the FDR recorded additional, slightly larger inboard aileron movements, and the elevators started moving further in the nose-down direction. Immediately after the FDR recorded the increased nose-down elevator movement, the CVR recorded the sounds of the captain asking loudly (beginning at 0150:06), "What's happening? What's happening?," as he returned to the cockpit.

The airplane's load factor decreased further as a result of the increased nose-down elevator deflection, reaching negative G loads (about -0.2 G) between 0150:06 and 0150:07. During this time (and while the captain was still speaking [at 0150:07]), the relief first officer stated for the tenth time, "I rely on God." Additionally, the CVR transcript indicated that beginning at 0150:07, the CVR recorded the "sound of numerous thumps and clinks," which continued for about 15 seconds.

According to the CVR and FDR data, at 0150:08, as the airplane exceeded its maximum operating airspeed (0.86 Mach), a master warning alarm began to sound. (The warning continued until the FDR and CVR stopped recording at 0150:36.64 and 0150:38.47, respectively.)[17] Also at 0150:08, the relief first officer stated quietly for the eleventh and final time, "I rely on God," and the captain repeated his question, "What's happening?" At 0150:15, the captain again asked, "What's happening, [relief first officer's first name]? What's happening?" At this time, as the airplane was descending through about 27,300 feet msl, the FDR recorded both elevator surfaces beginning to move in the nose-up direction. Shortly thereafter, the airplane's rate of descent began to decrease.[18] At 0150:21, about 6 seconds after the airplane's rate of descent began to decrease, the left and right elevator surfaces began to move in opposite directions; the left

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[13] Throughout the FDR data for the accident airplane (including data recorded during uneventful portions of the accident flight and during previous flights and ground operations), small (less than 1°) differences between the left and right elevator surface positions were observed. The left and right elevator surface movements were consistent (that is, moved in the same direction about the same time) where these offsets were observed. According to Boeing, there are several factors that could result in differences between the left and right elevator surfaces, including rigging of the elevator control system, tolerances within the system's temperature compensation rods, routing differences between the left and right elevator control cables, friction distribution within the system, the accuracy of the sensors used to measure elevator position, and differences in FDR sampling times for the left and right elevator parameters.

[14] Although earlier statements made by the relief first officer were recorded by the hot microphone at the first officer's position, the "I rely on God" statements were not, which was consistent with these statements being spoken relatively quietly. For additional information, see the section titled, "Audio Information Recorded by First Officer's Hot Microphone."

[15] An airplane's normal load factor is approximately perpendicular to the airplane's wings. Although the terms "vertical load factor," "vertical acceleration," and "normal load factor" are often used interchangeably, for the purposes of this document, the term "load factor" is used.

[16] A G is a unit of measurement of force on a body undergoing acceleration as a multiple of its weight. The normal load factor for an airplane in straight and level flight is about 1 G. As the load factor decreases from 1 G, objects would become increasingly weightless, and at 0 G, those objects would float. At load factors less than 0 G (negative G), loose objects would float toward the ceiling, and, at -1 G, those objects would accelerate toward the ceiling.

surface continued to move in the nose-up direction, and the right surface reversed its motion and moved in the nose-down direction.

The FDR data indicated that the engine start lever switches for both engines moved from the run to the cutoff position between 0150:21 and 0150:23.[19] Between 0150:24 and 0150:27, the throttle levers moved from their idle position to full throttle, the speedbrake handle moved to its fully deployed position, and the left elevator surface moved from a 3º nose-up to a 1º nose-up position, then back to a 3º nose-up position.[20] During this time, the CVR recorded the captain asking, "What is this? What is this? Did you shut the engine(s)?" Also, at 0150:26.55, the captain stated, "Get away in the engines,"[21] and, at 0150:28.85, the captain stated, "shut the engines." At 0150:29.66, the relief first officer stated, "It's shut."

Between 0150:31 and 0150:37, the captain repeatedly stated, "Pull with me." However, the FDR data indicated that the elevator surfaces remained in a split condition (with the left surface commanding nose up and the right surface commanding nose down) until the FDR and CVR stopped recording at 0150:36.64 and 0150:38.47, respectively. (The last transponder [secondary radar] return from the accident airplane was received at the radar site at Nantucket, Massachusetts, at 0150:34.)[22]

Information about the remainder of the flight came from the airplane's two debris fields and recorded primary radar data from long-range radar sites at Riverhead, New York, and North Truro, Massachusetts, and the short-range radar site at Nantucket. The height estimates based on primary radar data from the joint use FAA/U.S. Air Force (USAF) radar sites indicated that the airplane's descent stopped about 0150:38 and that the airplane subsequently climbed to about 25,000 feet msl and changed heading from 80º to 140º before it started a second descent, which continued until the airplane impacted the ocean.

[17] The cessation of the FDR and CVR recordings was consistent with the loss of electrical power to the recorders that resulted from the engines being shut off. Although the FDR recorded different parameters at different sampling rates and at slightly different times, the last subframe of recorded data was recorded at 0150:36.64.

[18] According to calculations based on FDR data, the airplane's maximum rate of descent was about 39,000 feet per minute (fpm); this rate was recorded at 0150:19.

[19] The engine start lever switches control the flow of fuel to the engines and are located on the center console between the pilot positions. When these levers are moved to the cutoff position, fuel flow to the engines is stopped, and the engines stop operating within about 5 or 6 seconds. They are spring-loaded, lever-lock design switches that must be pulled up to release from one detent before they can be moved to the other position, where they will engage in another detent.

[20] The Safety Board's simulator tests demonstrated that an EgyptAir pilot similar in size to the command captain was able to occupy the captain's seat without physical interference; brace himself against the center console or floor structure; readily apply back pressure on the control column; and reach the throttles, speedbrakes, and other controls on the central console with the seat in its aft position. (The Board recognizes that the simulations could not duplicate the near 0 G loads recorded by the FDR during the accident sequence; however, such near 0 G loads were present only momentarily after the recovery started and should not have substantially affected the fore-and-aft forces either pilot could generate once normally seated and effectively braced.)

Airplane wreckage was located in two debris fields, about 1,200 feet apart, centered at 40° 21' north latitude and 69° 46' west longitude. The accident occurred at night in dark lighting conditions.

PERSONNEL INFORMATION

The Safety Board reviewed the command and relief flight crew's flight and duty times and found no evidence that they were outside the limits established by applicable regulations. Because the command captain and the relief first officer were identified as being the only two crewmembers in the cockpit during the accident sequence, information on only these two crewmembers is included in this section.[23] The cabin crew comprised 10 flight attendants. In addition, several nonduty EgyptAir flight crewmembers were on board the accident airplane.

Command Captain Information

The command captain, age 57, was hired by United Arab Airlines[24] on July 13, 1963. He held an Egyptian airline transport pilot certificate with Boeing 707, 737-200, and 767-200 and -300 type ratings. The command captain's most recent medical certificate was issued on October 21, 1999, and he was found to be medically fit to fly with glasses in accordance with the standards specified in ECAR Part 67, "Medical Standards and Certification." According to his family, the command captain had suffered from chronic back problems but was addressing them and had no recent changes in his health.[25]

The command captain's most recent proficiency check was satisfactorily completed on March 9, 1999, and his most recent recurrent training was satisfactorily completed on August 14, 1999. According to EgyptAir records, at the time of the accident, the command captain had flown approximately 14,384 total flight hours, including 6,356 hours in the 767. The Safety Board's review of EgyptAir training records for the

[21] According to participants in the Cockpit Voice Recorder Group (which included several Arabic/English speakers), occasionally the direct translation of Arabic words into English resulted in awkward or seemingly inappropriate phrases. Throughout the CVR transcript, the Cockpit Voice Recorder Group provided as direct a translation as possible; however, it did not attempt to interpret or analyze the words or the intent of the speaker.

[22] Surveillance radars fall into two categories: primary (also known as "search") and secondary (also known as "beacon"). Secondary radar broadcasts an interrogation signal to which equipment on board an airplane automatically responds by transmitting information to the ground-based site for processing and display. Secondary radar returns contain an identification code and altitude data. Primary radar broadcasts radio waves and detects the reflections of the waves off objects (including airplanes). Primary radar reflections do not contain any unique identification information. (For additional information, see the Aircraft Performance Group Chairman's Aircraft Performance Study.)

[23] For more detailed information regarding the background and recent activities of all EgyptAir flight 990 crewmembers, see the Operational Factors Group Chairman's Factual Report and its addendum and the Human Performance Group Chairman's Factual Report and its addendum.

[24] In 1971, United Arab Airlines was renamed EgyptAir.

[25] There was no mention of treatment for chronic back problems in the captain's records at EgyptAir.

command captain indicated that he had accomplished all required checkrides and satisfactorily performed all required maneuvers.

The command captain arrived in New York the afternoon of October 28, 1999, after serving as a captain on EgyptAir flight 989 from Cairo to JFK. (Additional information about the command captain is contained in the public docket on this accident.)

Relief First Officer Information

The relief first officer, age 59, was hired by EgyptAir on September 8, 1987. He held an Egyptian commercial pilot certificate with 737-200 and 767-200 and -300 type ratings.[26] The relief first officer's most recent medical certificate was issued on July 28, 1999, and he was found to be medically fit to fly with glasses in accordance with the standards specified in ECAR Part 67. According to a close friend, the relief first officer had no family history of major medical difficulties and did not complain of headaches, indigestion, or other medical problems before the accident.

The relief first officer's most recent proficiency check was satisfactorily completed on June 19, 1999, and his most recent recurrent training was satisfactorily completed on December 19, 1998. According to EgyptAir records, at the time of the accident, the relief first officer had flown approximately 12,538 total flight hours, including 5,191 hours in the 767. The Safety Board's review of EgyptAir training records for the relief first officer indicated that he had accomplished all required checkrides and performed all required maneuvers.

Before EgyptAir hired him, the relief first officer was a flight instructor, first for the Egyptian Air Force and later for a Government-operated civilian flight training institute in Egypt. The relief first officer became a Major in the Air Force before he transitioned to the flight training institute, where he eventually became the chief flight instructor.

The relief first officer arrived in New York City the afternoon of October 28, 1999, after serving as a first officer on EgyptAir flight 990 from LAX to JFK. (Additional information about the relief first officer is contained in the public docket on this accident.)

AIRPLANE INFORMATION

The accident airplane, SU-GAP, a 767-300 series airplane[27] (model 767-366ER [extended range]), serial number (S/N) 24542, was manufactured by Boeing and delivered new to EgyptAir on September 26, 1989. According to EgyptAir records, it had 33,354 total hours of operation (7,594 flight cycles)[28] at the time of the accident. It was

[26] The relief first officer did not upgrade to captain even though he was eligible to do so in the early 1990s. Colleagues stated that he did not upgrade because he preferred the benefits of seniority in the first officer position. According to EgyptAir, the relief first officer became ineligible to upgrade after his 55th birthday in February 1995.

[27] The 767-300 is a low-wing, twin-engine, transport-category airplane.

configured to seat a maximum of 10 first-class, 22 business-class, and 185 economy-class passengers and to carry cargo.

The accident airplane was equipped with two P&W 4060 turbofan engines. Company maintenance records indicated that the No. 1 (left) engine, S/N 724126, was installed on the accident airplane on April 19, 1998, and had operated about 25,708 hours since new and that the No. 2 (right) engine, S/N 724127, was installed on the accident airplane on June 3, 1998, and had operated about 19,316 hours since new.

767 Longitudinal Control System Information

Because the accident sequence involved a sustained unusual motion about the airplane's pitch axis, the Safety Board examined the 767's longitudinal flight control system. According to the Boeing 767 Maintenance Manual, the 767's longitudinal flight control system includes two (left and right) sets of linked elevator surfaces (inboard and outboard), which are attached to the rear spar of the movable horizontal stabilizer by hinges. Each outboard elevator surface is driven by three power control actuators (PCA). Because the outboard and inboard surfaces are linked, the inboard elevator surfaces move when the outboard elevator surfaces are driven. Hydraulic power for elevator PCA movement is provided by the 767's three independent hydraulic systems—each hydraulic system powers one of each elevator surface's PCAs, which provides redundancy within the elevator control system. (Components in the elevator control system are shown in figures 1a and 1b.)

Two parallel sets (one operated from the captain's side, the other from the first officer's side) of flight control components move the elevator surfaces. Control column inputs made at the captain's position are linked directly to the actuators for the left elevator surface, whereas control column inputs made at the first officer's position are linked directly to the actuators for the right elevator surfaces. The two parallel sets of flight control components are linked together at the forward and aft override mechanisms/linkages and slave cable interconnects. Flight control commands from the captain's and first officer's control columns are transmitted through linkages and cables[29] from the front of the airplane to the left and right aft quadrant assemblies, respectively. The aft quadrant assemblies then translate the inputs to the respective bellcrank assemblies and the input control rods for each of the three elevator PCAs for each outboard elevator surface.

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[28] A flight cycle is one complete takeoff and landing sequence.

[29] The cables for the captain's (left-side) system are routed below the floor boards, and the cables for the first officer's (right-side) system are routed above the cabin ceiling.

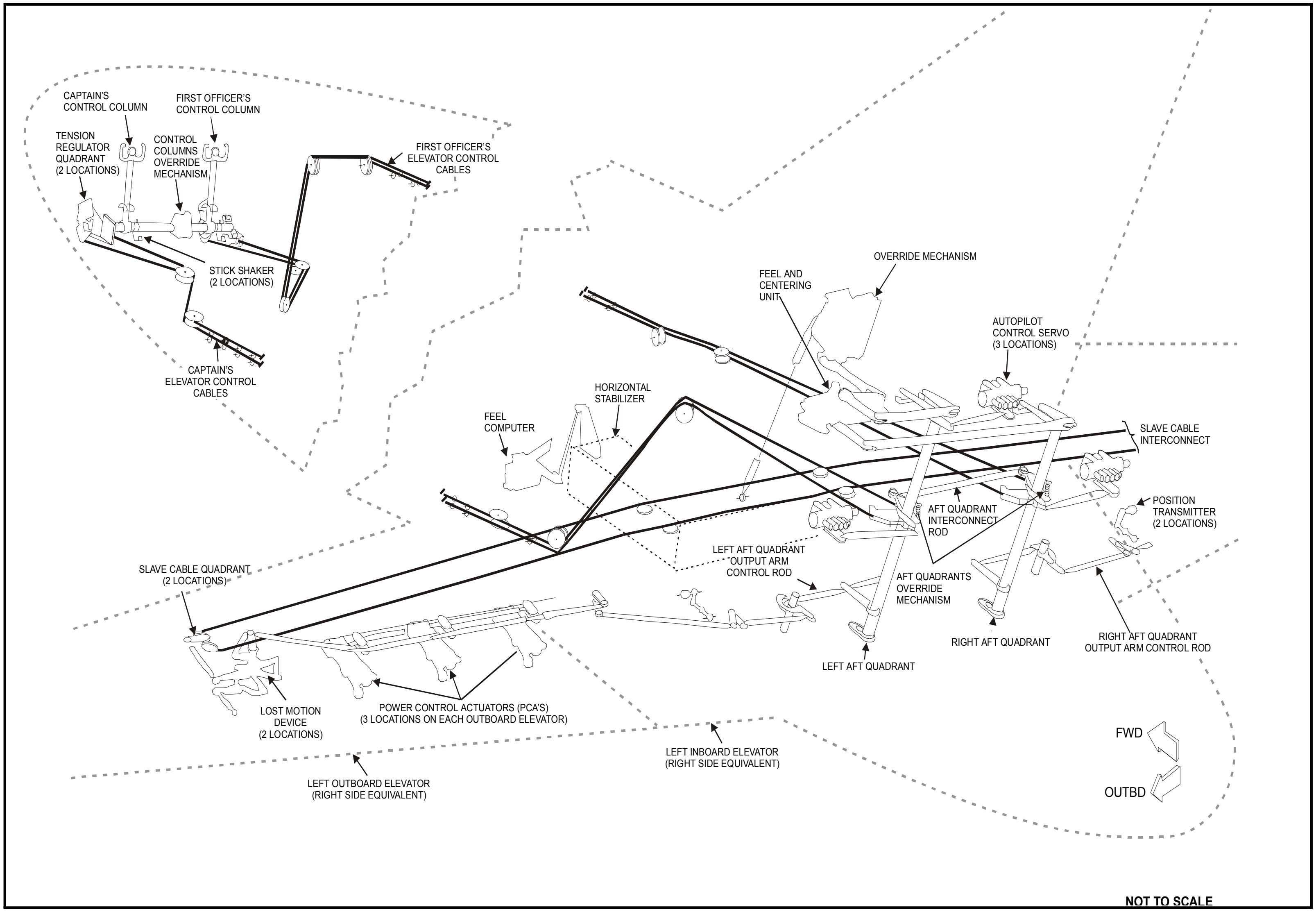

Figure 1a. Diagram of the components in the entire 767 elevator control system.

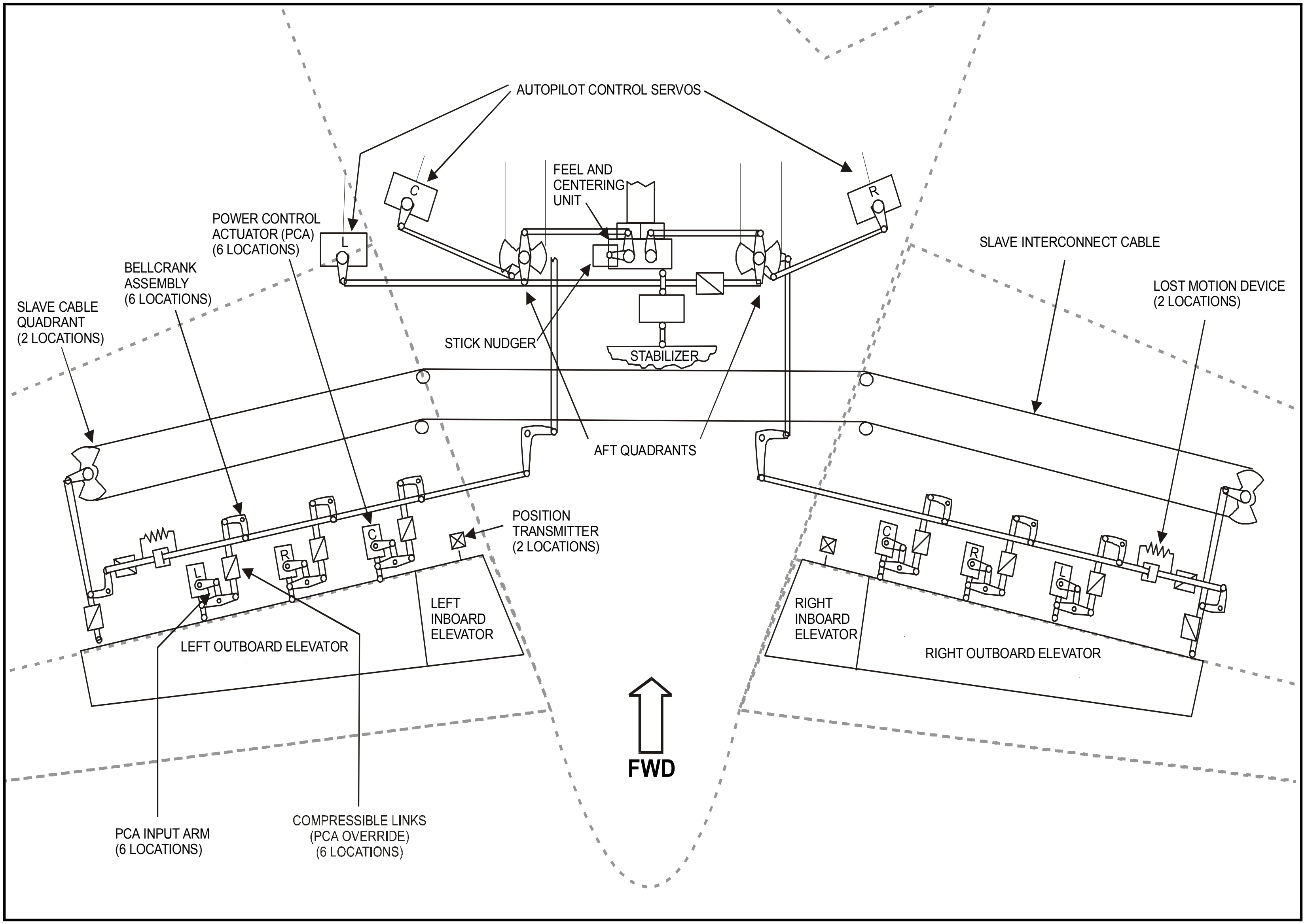

Figure 1b. Diagram of the aft 767 elevator control system components.

After control cable movement is translated to input control rod movement, the control rods move control valves inside the PCAs, allowing high-pressure hydraulic fluid to flow to one side or the other of the actuators' pistons (depending on the direction of the input), resulting in elevator movements that correspond to the direction of the input. When the elevators reach the commanded position, feedback linkages move the control valves to a position in which the hydraulic fluid is blocked off, resulting in no further movement of the actuator piston or elevator.

Testing, evaluation, and analysis of the 767 elevator system showed that any movement of the control columns (whether pilot-induced or not) would have resulted in concurrent, identifiable movements of the elevators, which would have been recorded on the FDR.

An elevator feel-and-centering unit transmits hydraulic and mechanical feel forces to hold the elevator at the neutral (trimmed) position when no control column force is applied. It also provides feedback (or feel) force to the control column that increases as the control column is moved forward or aft. The feel forces provided are essentially equal at both pilot positions because of the connections between the left and right elevator systems.

The captain's and first officer's control columns have authority to command full travel of the elevators under most flight conditions and normally work together as one system. However, the two sides of the system can be commanded independently because of override mechanisms at the control columns and aft quadrant. Therefore, if one side of the system becomes immobilized, control column inputs on the operational side can cause full travel of the nonfailed elevator. In addition, in many cases, control column inputs on the operational side can also result in nearly full travel of the elevator on the failed side through the override mechanisms. The elevator PCAs are installed with compressible links located between each bellcrank assembly and PCA input control rod to provide a means of isolating a jammed PCA, thus allowing the pilots to retain control of that elevator surface through its two remaining (unjammed) PCAs.

767 Elevator Blowdown Information

During ground operations, the 767 elevator PCAs can drive the elevators through a range of motion from 28.5° in the nose-up direction to 20.5° in the nose-down direction. However, in-flight elevator deflections can be limited by the aerodynamic forces acting on the elevator. The maximum position to which the elevator can move is that which balances the aerodynamic forces that are acting on the elevator surfaces against the force produced by the elevator PCAs and is referred to as its "blowdown" position. Thus, as the airplane's airspeed increases (increasing the aerodynamic forces acting against the elevator PCAs), the elevators' range of motion is increasingly limited.

The maximum output force produced by the elevator PCAs is generated by the hydraulic system pressure acting on the PCAs' piston area; if all three elevator PCAs are working properly, the total output force for each elevator surface is the sum of the forces produced by all three of that elevator's PCAs. When a dual elevator PCA failure occurs,[30] the forces produced by the two failed PCAs would overpower the opposing force produced by the one nonfailed PCA. The resultant initial force on the elevator surface in the failed direction would be equivalent to a single functioning PCA operating at 100 percent of its maximum force. The failed PCAs would resist the backdriving force[31] with a force equivalent to about 130 percent of a single functioning PCA. The high internal pressures required for activation of the PCAs' pressure relief valves allow the PCAs' pistons to resist the aerodynamic backdriving movement with more force than normal operating pressures would allow. Therefore, if a dual PCA failure occurred in flight, the elevator would initially move to a position consistent with a single functioning PCA operating at 100 percent of its maximum force, balanced against the aerodynamic forces affecting the elevator surface. As the airspeed increases, the failed elevator surface would remain at this initial position until the backdriving forces exceeded those of a single PCA operating at 130 percent of its normal capability, at which point the deflection of the failed elevator surface would decrease.[32] (Figure 2 is a comparison of the elevator positions recorded by the accident airplane's FDR with failed and nonfailed elevator positions following a dual PCA failure.)

767 Autoflight Systems Information

The 767 autoflight systems include the autopilot/flight director, yaw damper, automatic stabilizer trim, Mach trim, maintenance monitoring, instrument landing system deviation monitor, and thrust management systems. The thrust management system includes autothrottle control.

767 Autopilot Information

The 767 autopilot/flight director system consists (in part) of three separate autopilot systems that can be used singly or in combination to provide automatic control of the ailerons, elevator, stabilizer, and rudder control systems when operating in selected flight modes. Any one of the three autopilot systems can control the airplane in the normal climb, cruise, descent, and approach modes.

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[30] The Safety Board thoroughly examined the dual elevator PCA failure scenarios during its investigation of this accident. For more information, see the section titled, "Potential Causes for Elevator Movements During the Accident Sequence."

[31] The term "backdriving" refers to the effect of aerodynamic forces that act on the elevator surface and move the surface in the direction opposite to that being commanded (by the two failed PCAs, in the case of a dual elevator PCA failure). This backdriving force increases as an airplane's airspeed increases.

[32] For additional information, see the section of this report titled, "Potential Causes for Elevator Movements During the Accident Sequence."

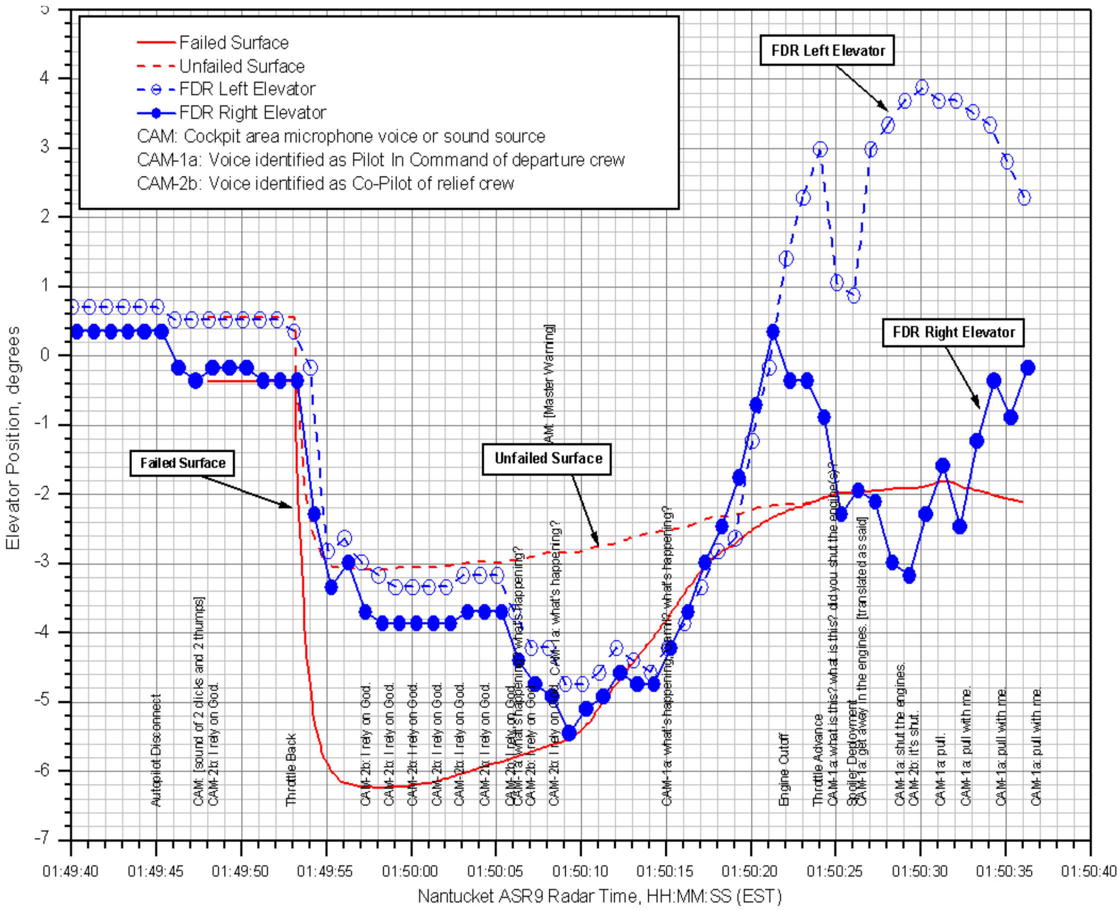

Figure 2. Comparison of the elevator positions recorded by the accident airplane's FDR with failed and nonfailed elevator positions following a dual PCA failure.

The 767 autopilot system controls the airplane's movement about the pitch axis by using the elevators for dynamic control of the airplane's pitch and the horizontal stabilizer to trim out steady-state elevator deflections. When the autopilot is engaged and the airplane is in a steady-state flight condition, the autopilot is designed to keep the elevators near their neutral (or faired) position, using the elevators primarily for short-term dynamic adjustments (such as those necessitated by atmospheric disturbances). The elevators are also used for small trim adjustments, such as those necessitated by fuel consumption during flight. As these small elevator adjustments accumulate over time, the elevator deflections move further from their neutral (or faired) position. When the elevators' deflections reach a threshold value, the autopilot "retrims" the horizontal stabilizer and the elevator returns to a neutral (or faired) position. According to Boeing, when the autopilot system is disconnected, the force applied by the autopilot actuator to the elevator control system is removed, and, if the horizontal stabilizer has not been adjusted recently, small elevator movements result. Boeing representatives indicated that the following circumstances could result in elevator movements at the time of autopilot disconnect:

- Differences between the neutral position recognized by the autopilot and the actual neutral position of the elevator feel-and-centering unit would result in the autopilot actuator holding a force that would be released when the system is disconnected.
- The autopilot may have moved the elevators since it last trimmed the stabilizer, placing the elevators at a position other than their neutral position at the time of disconnect. When the autopilot is disconnected, the elevators would return to the neutral position commanded by the feel-and-centering unit. (During steady-state flight conditions, this situation occurs because of the effect of fuel consumption on the airplane's center of gravity.) According to Boeing, "this type of elevator motion upon autopilot disconnect is inherent in the operation of the autopilot system."
- Pilot forces on the control column at the time of manual autopilot disconnect can affect the movement of the elevator. (The autopilot can be disconnected manually by double-clicking the control yoke-mounted autopilot disconnect switch.)
- Mechanical aspects of the elevator control system (including friction, the effects of compliance in the system,[33] variations among individual autopilot actuator units, and variations in the centering detent force) can cause elevator movement at the time of autopilot disconnect.

Boeing's 767 Maintenance Manual indicates that if the autopilot disconnects because of a system failure, the following cockpit warnings and annunciations would occur:

- the red autopilot disconnect warning light illuminates,
- the red master warning light illuminates,
- the engine indication and crew alerting system computer displays an autopilot disconnect message, and
- a siren alert sounds.

Although these autopilot disconnect warnings and annunciations are also generated when the autopilot is disconnected by pressing the autopilot manual disconnect switch on the control wheel, pressing the manual disconnect switch a second time within 0.5 second resets, and thus cancels, the system's disconnect warnings and annunciations before they are displayed to the flight crew. The 767 autopilot warnings and annunciations system contains multiple redundancies. For example, two warning signals are generated

[33] Compliance in the elevator system can occur as a result of cable stretch; yield, give, or elastic deformation in linkages (that does not damage the linkages but allows additional motion); and variations in tolerance buildups throughout the system.

for each of the warning functions listed above: one warning signal uses software logic that is powered by normal power (which would be inhibited by a loss of normal power or a computer failure), and the other uses hardware logic that is powered by 28-volt alternating current standby power.

767 Autothrottle Information

The 767's thrust management system provides autothrottle control based on selected modes, existing conditions, and engine limitations. The autothrottle can be operated independently of or with the autopilot system. The autothrottle servomotor generator is connected to the throttle levers through a clutch pack assembly, which, when overridden,[34] allows the pilots to make manual thrust inputs when the autothrottle is engaged. Movement of the throttle levers aft of the autothrottle commanded position for a given flight condition would require a manual force of about 9 lbs at the throttle levers to override the autothrottle servomotor clutch.

When the autothrottle function is engaged, it controls throttle lever movement. The maximum autothrottle commanded throttle lever movement rate for a normally functioning autothrottle system is 10.5° per second. Manual throttle lever inputs can exceed this rate; for example, the accident airplane's FDR recorded throttle lever movement at a rate of 25° per second at the beginning of the accident sequence. The minimum throttle lever position that the autothrottle can command varies as a function of the airplane's speed and the autothrottle mode selected. For the accident airplane's flight conditions and the selected autothrottle mode at the beginning of the accident sequence, this position would have been 40° to 50°. The FDR recorded a throttle lever position of about 33° at the beginning of the accident sequence.

Reported Autopilot Anomalies in the Accident Airplane

During interviews conducted at the request of the Egyptian Government on February 21, 2001, an EgyptAir captain who had flown the accident airplane from Newark International Airport (EWR), Newark, New Jersey,[35] to LAX on October 30, 1999, reported that he had experienced difficulties with the autopilot during a portion of that flight.[36] The captain told investigators that the autopilot was "hunting" for the glideslope at 8,000 to 10,000 feet msl during the approach to LAX and that, because he was uncomfortable with the autopilot's performance, he disconnected it. The captain reported that his three subsequent attempts to reengage the autopilot to intercept the glideslope in

[34] A manual force of about 9 pounds (lbs) is required to override the clutch.

[35] The October 30, 1999, EgyptAir flight from Cairo was scheduled to land at JFK but diverted to EWR because of weather.

[36] During interviews conducted 3 days after the accident, the captain that had flown the airplane from EWR to LAX on October 30, 1999, described several noncritical anomalies (a deactivated thrust reverser, an intermittent air conditioning pack "inoperative" light, a full aft lavatory holding tank, and the autopilot anomaly previously mentioned) but stated that the airplane was "almost perfect." The first officer of the flight to LAX did not describe the autopilot anomaly.

flight were unsuccessful; therefore, he continued the approach and landed the airplane manually. This captain told investigators that the autopilot operated normally when he engaged it on the ground after landing at LAX. Examination of the accident airplane's maintenance logbooks revealed no autopilot-related maintenance writeups, and no subsequent autopilot anomalies were verbally reported.

Examination of the FDR data for the October 30th flight to LAX revealed that at the time the captain reported he disconnected the autopilot because it was "hunting" for the glideslope during the approach to LAX, the autopilot was operating in its LOC (localizer approach) mode, which does not have glideslope intercept capability. The FDR data indicated that, later in the approach to LAX, when the captain tried to reengage the autopilot using the APP (approach) mode, which has both localizer and glideslope intercept capability, the airplane had descended far enough below the glideslope that the autopilot system could not capture the glideslope signal.[37]

The Safety Board's review of the FDR data revealed that nine autopilot disconnects were recorded on the accident airplane's 25-hour-long FDR tape: one just before landing at Cairo the day before the accident; one just before its next landing at EWR; four during the approach to LAX (during which the reported autopilot difficulties occurred); one on the ground at LAX; one just before landing at JFK the night of the accident flight; and one immediately preceding the accident sequence. No elevator movement was recorded after the autopilot disconnect that occurred on the ground at LAX. The elevator movements recorded following the other eight autopilot disconnects were primarily in the trailing-edge-down (TED) direction and were less than 0.88° in magnitude. According to Boeing, the elevator movements recorded by the accident airplane's FDR were consistent with the movements that would be expected as a result of the normal operation of the autopilot on a properly rigged 767.

Accident Airplane Maintenance Information

During its investigation of the EgyptAir flight 990 accident, the Safety Board reviewed EgyptAir's maintenance program and maintenance recordkeeping procedures and conducted a detailed examination of the accident airplane's maintenance records. The Board's review revealed that the accident airplane had been maintained in accordance with EgyptAir's continuous airworthiness maintenance inspection program for its 767 fleet. Additionally, the accident airplane's maintenance records indicated that all applicable airworthiness directives (AD) had been complied with; no related discrepancies were noted. Further, the Board's review of the accident airplane's technical log sheets from July 29 to October 30, 1999, revealed no pertinent unresolved discrepancies.

[37] According to Boeing, the autopilot is designed to capture the glideslope signal when the proper autopilot mode is selected if the airplane is within 80 feet of the glideslope.

FAA Service Difficulty Reports (SDR)[38] and accident and incident data from all operators flying 767s between 1990 and 2000 were also reviewed by investigators. Although some elevator-related SDRs were noted,[39] there were no documented maintenance trends or anomalies that were relevant to the circumstances of this accident.

767 Bellcrank Anomalies

On March 8, 2000, Boeing personnel reported to the Safety Board that Boeing had been informed of an air carrier incident involving a 767 in which failed bellcrank shear rivets were found in the left inboard and left center elevator PCA bellcrank assemblies.[40] The bellcrank shear rivets are designed to shear if an elevator PCA jam occurs, the compressible links between the bellcrank assemblies and the PCA input arms are bottomed out,[41] and a force of about 50 lbs is applied to the control column. Research and testing indicated that sheared rivets in a bellcrank assembly could result in an elevator PCA disconnect. Such a failure is discussed briefly later in this section and in detail in the section titled, "Potential Causes for Elevator Movements During the Accident Sequence."

Boeing and the FAA conducted additional tests and research to further investigate why the rivets failed and what the possible repercussions of such a failure would be, including metallurgical examination of high-time bellcranks, material properties testing on old and new bellcranks, review of bellcrank failure rate data obtained from 767 operators, and examination of maintenance procedures to determine whether changes in procedures and/or intervals were warranted. The Safety Board monitored the FAA's and Boeing's tests and research into the bellcrank shear rivet failures.

The research conducted by Boeing and the FAA revealed that single bellcrank shear rivet failures had occurred on other 767s, some of which might not have been detected during the single hydraulic system maintenance check that is to be conducted by 767 operators every 400 flight hours.[42] On August 17, 2000, Boeing issued Service Bulletin 767-27A0166, which described methods by which failed bellcrank shear rivets that might not be detected during the single hydraulic system maintenance check could be identified. Subsequently, the FAA issued AD 00-17-05, effective September 11, 2000, which required all 767 operators to perform a one-time functional check of one shear rivet in all six elevator PCA bellcrank assemblies within 30 days, reworking or replacing the bellcrank assembly if needed. AD 00-17-05 indicates the following:

> [F]ailure of two [of the three] bellcrank assemblies on one side can result in that single elevator surface [but not both surfaces] moving to a hardover position independent of pilot command resulting in a significant pitch upset recoverable by the crew. Failure of [all] three bellcrank assemblies on one side can cause an elevator hardover that may result in loss of controllability of the airplane…the FAA has received no factual information that indicates that this incident is related to [the EgyptAir flight 990] accident….The cause of that accident is still under investigation.

[38] Through its SDR program, the FAA collects information about mechanical failures from reports submitted by aircraft operators or maintenance facilities, as required by regulations.

Because the FAA received reports that the one-time functional check required by AD 00-17-05 revealed failed shear rivets on several 767-300 airplanes, on March 5, 2001, the FAA issued AD 01-04-09, effective March 20, 2001, which required all 767 operators to perform repetitive functional testing of the elevator control system to determine whether the elevator PCAs are properly rigged and accomplish followup actions (including depth penetration inspection of the shear rivets),[43] as necessary. AD 01-04-09 required operators to perform the repetitive testing of the elevator control system at least every 400 flight hours, beginning within 90 days of the AD's effective date. Although the cause of the bellcrank shear rivet failures has not yet been determined, Boeing and the FAA are continuing to study the issue.

One of the mechanical failure conditions evaluated by the Safety Board during the EgyptAir flight 990 investigation involved disconnection of the input linkages to two of the three PCAs on one elevator surface. This failure condition could be caused by the failure of any of the components that comprise the elevator PCAs' input linkage systems, including the bellcranks. As further discussed in the section titled, "Potential Causes for Elevator Movements During the Accident Sequence," the Board's tests and simulations indicated that the nonfailed elevator and the airplane are controllable from either control column with a dual PCA disconnect on one elevator surface. Those tests showed that neither a dual disconnection nor a triple disconnection (such as would result from a triple bellcrank failure) on one elevator surface would produce elevator deflections that matched the FDR data from the accident sequence.

[39] The SDRs included two reports of anomalous elevator behavior on the same United Airlines 767, the first incident occurred on September 12, 1994, and the second on June 20, 1996. Both incidents involved "stiff" or "frozen" elevator flight controls, and, in both cases, the pilots regained control of the elevator by applying higher-than-normal pressure on the control column. Postincident examination of the elevator system components revealed no discrepancies.

The Safety Board is also aware of the following two similar, more recent incidents:

1) On March 27, 2001, an American Airlines 767 experienced elevator control difficulties during an approach to land. The pilots landed safely using horizontal stabilizer trim for pitch control and reported that as they taxied to the gate, they "broke [the elevator] free" by applying a higher-than-normal force on the control column. Postincident examination revealed no discrepancies in the elevator's mechanical flight control rigging, PCAs, pushrods, bellcranks, or shear rivets; however, during postincident examination, investigators observed water dripping directly on elevator system components in the empennage.
2) On April 23, 2001, the pilots of another 767 experienced elevator control binding during the approach to land. The pilots applied additional force to the control column, and the elevator binding released. Postincident examination revealed no evidence of mechanical anomalies; however, investigators observed an accumulation of water and ice in the empennage around the elevator system components.

Additional tests indicated that water could freeze on the elevator components and create the effects described by these flight crews and observed in the FDR data of the two recent incidents. (FDR data were not available for the two earlier incidents.) The Safety Board compared the FDR data from the two recent incidents with that from EgyptAir flight 990 and found no similarities. Boeing and the FAA are evaluating possible corrective actions related to preventing or limiting water from entering the 767 empennage, freezing at altitude, and impinging on elevator system components.

METEOROLOGICAL INFORMATION

The Safety Board's review of data from the National Climatic Data Center National Radar Mosaic (from about 0100 through 0230 on October 31, 1999) and other meteorological data revealed no record of significant meteorological conditions in the area at the time of the accident. No pilot reports indicating any significant meteorological event were transmitted in the accident area between about 2300 EDT on October 30 and 0700 on October 31, 1999.

FLIGHT RECORDERS

The FDR and CVR were recovered from the Atlantic Ocean by U.S. Navy remote-operated vehicles on November 9 and November 14, 1999, respectively. Upon recovery, they were immediately packed in water to prevent/delay the onset of corrosion and shipped to the Safety Board's laboratory in Washington, D.C., for readout.

Cockpit Voice Recorder

The CVR installed on the accident airplane was a Fairchild model A-100, S/N 3193. Although the CVR unit exhibited external and internal structural damage and the recording medium (magnetic tape) was wet, the tape was otherwise in good condition. The CVR recording consisted of four channels of audio information, the following three of which recorded usable audio information: the cockpit area microphone (CAM) and the hot microphones at the captain's and first officer's positions.[44] The quality of the audio information recorded by the CAM was good, whereas the quality of the audio information recorded by the hot microphone at the first officer's position was excellent until 0141:11, after which time it was poor.[45] The audio information recorded by the hot microphone at the captain's position was difficult or impossible to decipher throughout most of the recording.[46]

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[40] This anomalous condition was discovered when a drooping elevator surface was observed during a preflight inspection; there were no reports of in-flight anomalies before this discovery. The air carrier's maintenance personnel found sheared rivets in the bellcranks, which they repaired. The system was functionally checked after the repair, and the airplane was returned to service. The air carrier reported the anomalous condition and repair to Boeing and has reported no further anomalies. FDR data were not available.

[41] For the purposes of this report, the compressible links are described as "bottomed out" when they have been deflected to the full extent of their travel in either direction.

[42] The single hydraulic system maintenance check tests the operation of each PCA individually by powering each of the airplane's three hydraulic systems, one at a time. An inoperative elevator PCA will not operate the elevator when powered by its hydraulic system. A PCA with a failed bellcrank shear rivet will not operate the elevator properly.

[43] Indications of an improperly rigged PCA can occur as a result of yielded or failed shear rivets in a bellcrank assembly.

[44] The fourth channel of audio information recorded by the CVR is usually recorded through audio equipment at a cockpit jumpseat position. The FAA does not require a fourth channel to be installed/used on airplanes equipped with CVRs.

The CVR recording started at 0119:13, as the flight was cleared for takeoff from runway 22R at JFK. As previously discussed, the cessation of the CVR recording at 0150:38.47 (shortly after the FDR recorded the airplane's loss of engine power) was consistent with the loss of electrical power to the recorder that occurred after the engines were shut off.

Two transcripts were prepared of the entire 31-minute 30-second recording, one in Arabic/English words and phrases exactly as spoken on the accident flight and the other with Arabic words translated to English. As stated previously, throughout the CVR transcript, the Cockpit Voice Recorder Group provided as direct a translation as possible, without attempting to interpret the words or the intent of the speaker. According to participants in the Cockpit Voice Recorder Group (which included several Arabic/English speakers), occasionally the direct translation of Arabic words into English resulted in awkward or seemingly inappropriate phrases.

Cockpit Voice Recorder Sound Spectrum and Speech Studies

The Safety Board conducted CVR speech and sound spectrum studies to document any unknown sounds and to verify and expand on the information contained in the CVR transcript.[47] The results of these studies are discussed in the following sections.

Audio Information Recorded by First Officer's Hot Microphone

The Safety Board's study of the CVR information recorded by the hot microphone at the first officer's position during the accident flight revealed that, at 0141:03, the CVR recorded a decrease in the audio level of the first officer's hot microphone system, and, at 0141:11, the CVR recorded a rustling sound through the first officer's hot microphone system. According to a member of the Speech Examination Study Group, this rustling sound resembled the sound of the headset being stowed as the command first officer

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[45] The Safety Board uses the following categories to classify the levels of CVR recording quality: excellent, good, fair, poor, and unusable.

- An excellent recording is one that is very clear and easily transcribed.
- A good recording is one in which most of the crew conversations can be accurately and easily understood. The transcript that is developed may indicate unintelligible several words or phrases. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.
- A poor recording is one in which a transcription is nearly impossible because a large portion of the recording is unintelligible.

The quality of audio information recorded by the hot microphone at the first officer's position is discussed further later in this report.

[46] The captain apparently did not use the hot microphone system; however, depending on the nature and volume of the captain's communications, the sounds were recorded by the CAM.

[47] For additional sound spectrum and speech study information, see the Cockpit Voice Recorder Group Chairman's Factual Report/Sound Spectrum Study and the Speech Examination Study Factual Report.

prepared to leave the first officer's position. Until this time, the hot microphone at the first officer's position had recorded the first officer's utterances clearly, as well as some additional cockpit noises and conversations; however, subsequently, this microphone (which is a part of the first officer's headset assembly) provided muffled recordings of some, but not all, of the cockpit conversations. Command and relief first officer statements after 0141:11 were recorded more clearly by the CAM.

The study concluded that the recording quality of the first officer's hot microphone was excellent while the command first officer wore the headset/microphone and poor when the headset/microphone was believed to be stowed.[48] After 0150:24, the first officer's hot microphone stopped recording cockpit conversation and started recording a sudden increase in background noise. The speech evaluation study indicated that this most likely occurred because a pilot inadvertently activated the air-to-ground/interphone button on the back of the control wheel and thereby altered the amplitude of the recording to the amplitude level set at the individual pilot position.

Speech Sample Information

All speech samples analyzed in the speech study were captured through the CAM located in the overhead panel. Investigators identified recorded speech samples for six EgyptAir crewmembers that were in the cockpit at various times during the accident flight, including the command captain, the relief first officer, the command first officer, the EgyptAir 767 chief pilot, and two nonduty first officers on board the airplane.

All utterances made after the captain departed the cockpit (at 0148:18) were analyzed to the extent possible; however, in part because of occasional loud background noise in the cockpit after that time, only 15 of the 23 utterances recorded by the CAM after such time were strong enough (relative to background noise) to be analyzed by computer for fundamental frequency (pitch) and formant dispersion[49] information.

Fundamental Frequency and Speech Duration Information

Research[50] has shown that fundamental frequency and speech duration vary characteristically among speakers and often convey information about the speaker's psychological stress. The Safety Board has used the following guidelines[51] with regard to fundamental frequency for evaluating the degree of psychological stress experienced by a speaker:

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[48] The study stated that the exact stowage location of the headset was unknown; however, according to an EgyptAir representative, it would normally be stowed in the storage console, which located at the first officer's right side, or in his flight bag, which is located just aft of the storage console.

[49] Formants, which determine many aspects of perceived speech, are frequencies at which the vocal tract above the larynx (acting as a filter because of its normal modes of vibration) will allow maximum energy to pass from the sound produced by the vocal cords. Formant dispersion refers to the relative spacing between successive formants.

- An increase in fundamental frequency of about 30 percent (compared with that individual's speech in a relaxed condition) would be characteristic of a stage 1 level of stress, which could result in the speaker's focused attention and improved performance.
- An increase in fundamental frequency of between 50 to 150 percent would be characteristic of a stage 2 level of stress, which could result in the speaker's performance becoming hasty and abbreviated; however, the speaker's performance would not display gross mistakes.
- An increase in fundamental frequency of between 100 to 200 percent would be characteristic of a stage 3 level of stress, or panic, which could result in the speaker's inability to think or function logically or productively.

On the basis of these guidelines, the CVR speech study concluded that the relief first officer exhibited no more than a 25 percent increase in fundamental frequency, compared to what he exhibited during routine flight, when he made any of his "I rely on God" statements and when he stated, "it's shut," during the emergency sequence. However, the speech study concluded that the command captain exhibited an increase in fundamental frequency of 29 percent when he stated, "what's happening?," shortly after he returned to the cockpit and of between 47 and 65 percent when he stated, "get away in the engines," "shut the engines," "pull," and "pull with me," during the emergency sequence, compared to what he exhibited during routine flight.

Previous research has also shown that speech duration often becomes shorter (that is, speaking rate becomes faster) when psychological stress increases. Speech duration measurements were performed on the phrase "I rely on God" (repeated by the relief first officer 11 times between 0148:39 and 0150:08). The CVR transcript indicated that the first utterance of the phrase "I rely on God" was spoken faintly, about 1 minute 6 seconds before the autopilot was disconnected, and had a duration of 1.02 seconds. The second utterance of this phrase, which occurred about 5 seconds before the throttle levers were moved to idle and while the airplane was still in level flight, had a duration of 0.81 second. The remaining nine utterances of this phrase, which began about 8 seconds later (as the airplane began its abrupt nose-down pitch and steep descent), varied in duration from 0.73 to 0.87 seconds, with pauses of 0.51 and 0.70 seconds between successive utterances.

[50] For additional information, see Williams, C. E. and Stevens, K. N. 1981. "Vocal Correlates of Emotional States." *Speech Evaluation in Psychiatry.* Grune & Stratton. New York, New York; Ruiz, R.; Legros, C.; and Guell, A. 1990. "Voice Analysis to Predict the Psychological or Physical State of a Speaker." *Aviation, Space, and Environmental Medicine.* Vol. 61. p. 266-71; Johannes, B.; Salnitski, V. P.; Gunga, H.; and Kirsch, K. 2000. "Voice Stress Monitoring in Space—Possibilities and Limits." *Aviation, Space, and Environmental Medicine.* Vol. 71. p. A58-65; Brenner, M.; Doherty, E. T.; and Shipp, T. 1994. "Speech Measures Indicating Workload Demand." *Aviation, Space, and Environmental Medicine.* Vol. 65. p. 21-6; Brenner, M.; Mayer, D.; and Cash, J. 1996. "Speech Analysis in Russia." *Methods and Metrics of Voice Communications*. Ed. B. G. Kanki and O. V. Prinzo. Department of Transportation, Federal Aviation Administration, and Office of Aviation Medicine. DOT/FAA/AM-96/10. Washington, DC; and National Transportation Safety Board. 1999. *Uncontrolled Descent and Collision with Terrain, USAir Flight 427, Boeing 737-300, N513AU, near Aliquippa, Pennsylvania, September 8, 1994.* Aircraft Accident Report. NTSB/AAR-99/01. Washington, DC.

[51] For additional information, see NTSB/AAR-99/01.

According to the speech study, the relief first officer's rate of speech did not increase significantly when saying, "I rely on God," during the pitchdown and descent.

The Safety Board also examined the length of time between the relief first officer's "I rely on God" statements for evidence of psychological stress. About 67 seconds passed between the first and second utterances of the phrase, 8.1 seconds passed between the second and third, and 0.51 to 0.70 seconds passed between subsequent utterances of the phrase. According to the speech study, after the second utterance, the data suggested a "rhythmic repetition of the phrase rather than an accelerating trend, as might be expected with increased psychological stress."

The speech study concluded that, although the relief first officer's speech displayed some evidence of increased psychological stress between the first and second utterance of "I rely on God" (when the airplane was still in level flight at cruise altitude), there was no evidence of increased psychological stress in the relief first officer's speech after he uttered the phrase the second time. As previously discussed, after the second utterance of the phrase, the airplane departed level flight to a steep nose-down pitch attitude and experienced an increased nose-down pitch attitude and rate of descent and a decrease in its load factor (to negative Gs) while the relief first officer repeated, "I rely on God," the last nine times.

Unintelligible Comment

The Safety Board's audio examination and sound spectrum analysis of the unintelligible comment that was recorded by the CAM at 0148:30 showed that it appeared to have characteristics consistent with human speech. It consisted of three syllables, with the accent on the second syllable, and was probably spoken very softly (as shown by very poor speech signal definition). The speech examination study indicated that the comment was preceded by 19.2 seconds without speech and followed by 9.2 seconds without speech, suggesting that it was an isolated statement rather than part of a conversation. Unfortunately, the speech segment was not long or clear enough to determine what was said and who said it. However, two speech characteristics of the unintelligible comment—fundamental frequency and formant dispersion—displayed values that, of the six pilots' speech that had been recorded earlier on the CVR tape, most closely resembled the speech values displayed by the relief first officer.

As previously discussed, and as noted as follows in the CVR transcript:

> The five Arabic speaking members of the [CVR] group concur that they do not recognize this as an Arabic word, words, or phrase. The entire group agrees that three syllables are heard and the accent is on the second syllable. Four Arabic speaking group members believe that they heard words similar to 'control it.' One English speaking member believes that he heard a word similar to 'hydraulic.' The five other members believe that the word(s) were unintelligible.

Because the content of the comment (the word[s] and the language in which it was spoken) could not be positively identified, the members of the Cockpit Voice Recorder Group agreed to characterize the comment as "unintelligible."

Flight Data Recorder

The FDR installed on the accident airplane was a Sundstrand Data Corporation (now named Honeywell Aerospace Electronic Systems) Universal Flight Data Recorder, S/N unknown. Although the FDR unit exhibited external and internal structural damage and the recording medium (magnetic tape) was wet, the tape was otherwise in good condition. After waveform recovery techniques were used to correct areas of weak FDR signals, a complete set of accident flight data, from takeoff through the last recorded FDR parameter (which was recorded at 0150:36.64),[52] was prepared.

Flight performance parameters recorded by the FDR included the following: pressure altitude; airspeed (computed); engine rpm; pitch; roll; heading; angle of attack; normal (vertical), longitudinal, and lateral acceleration (load factors); left and right elevator positions; left and right inboard and outboard aileron positions; left and right trailing edge flap positions; rudder position; and horizontal stabilizer position. In addition, the FDR recorded speedbrake handle position, throttle resolver angle, autopilot engagement/disengagement, engine low oil pressure, and engine fuel cut signals. The FDR was not required to and did not record control wheel, control column, or spoiler positions nor did it record control wheel and column forces.[53] Excerpts from the FDR data plots and CVR transcript are shown in figures 3a through 3h.

[52] As previously discussed, the last FDR parameter was recorded at 0150:36.64, and the cessation of the FDR data was consistent with the loss of electrical power that resulted from the engines being shut off.

[53] Although control column position was not recorded by the FDR, the Safety Board's testing and evaluation of the 767 elevator system showed that any movement occurring at the control columns would have resulted in concurrent, identifiable movements of the elevators, which would have been recorded on the FDR. For additional information, see Flight Data Recorder Group Chairman's Factual Report and its attachments. Also, see the section of this report titled, "Tests and Research," for a discussion of the airplane's performance during the emergency/accident sequence, as determined by the Safety Board's evaluation of the available FDR, radar, weather, and airplane performance data.

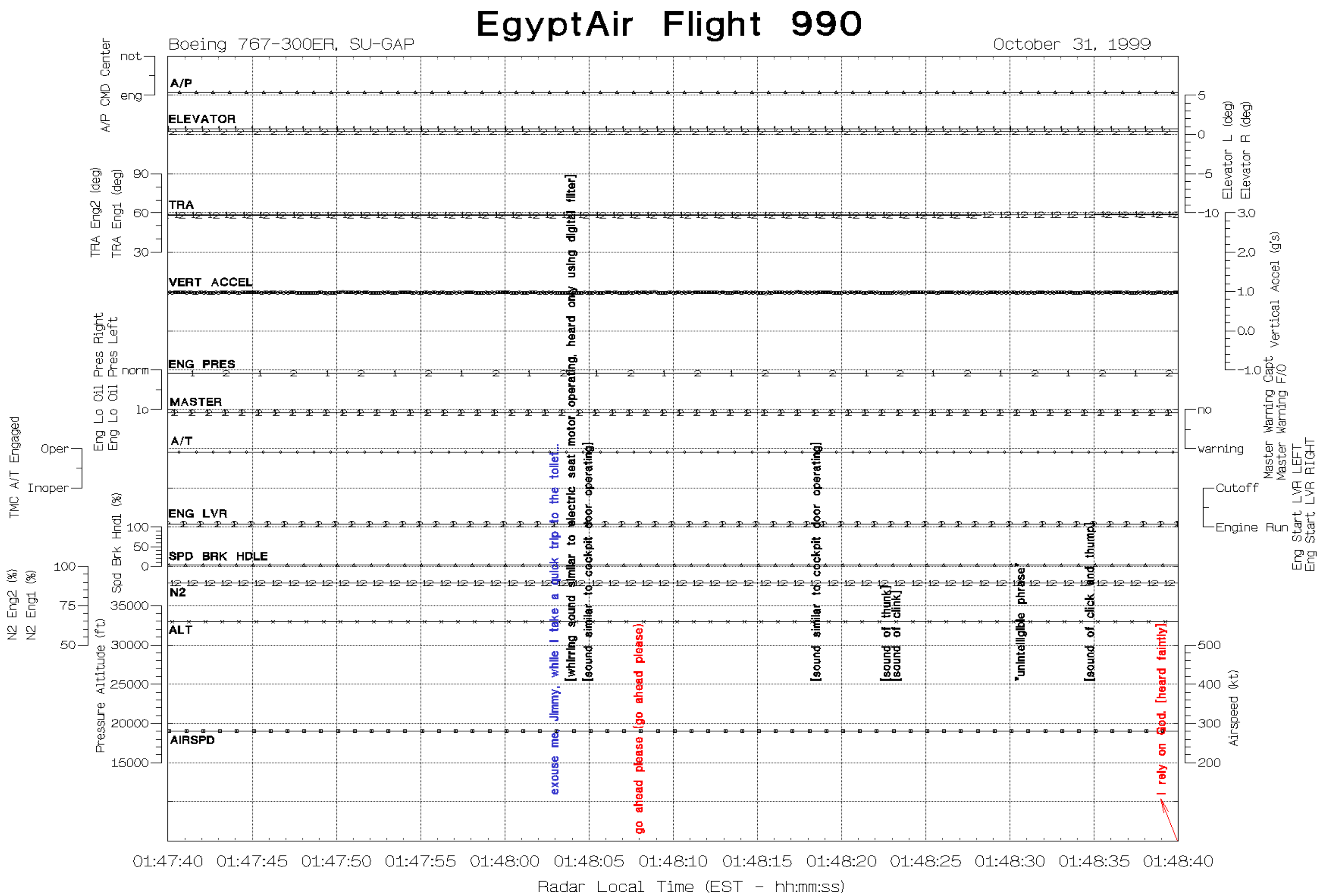

Figure 3a. A graph depicting selected FDR data from 1:47.40 to 1:48.40.

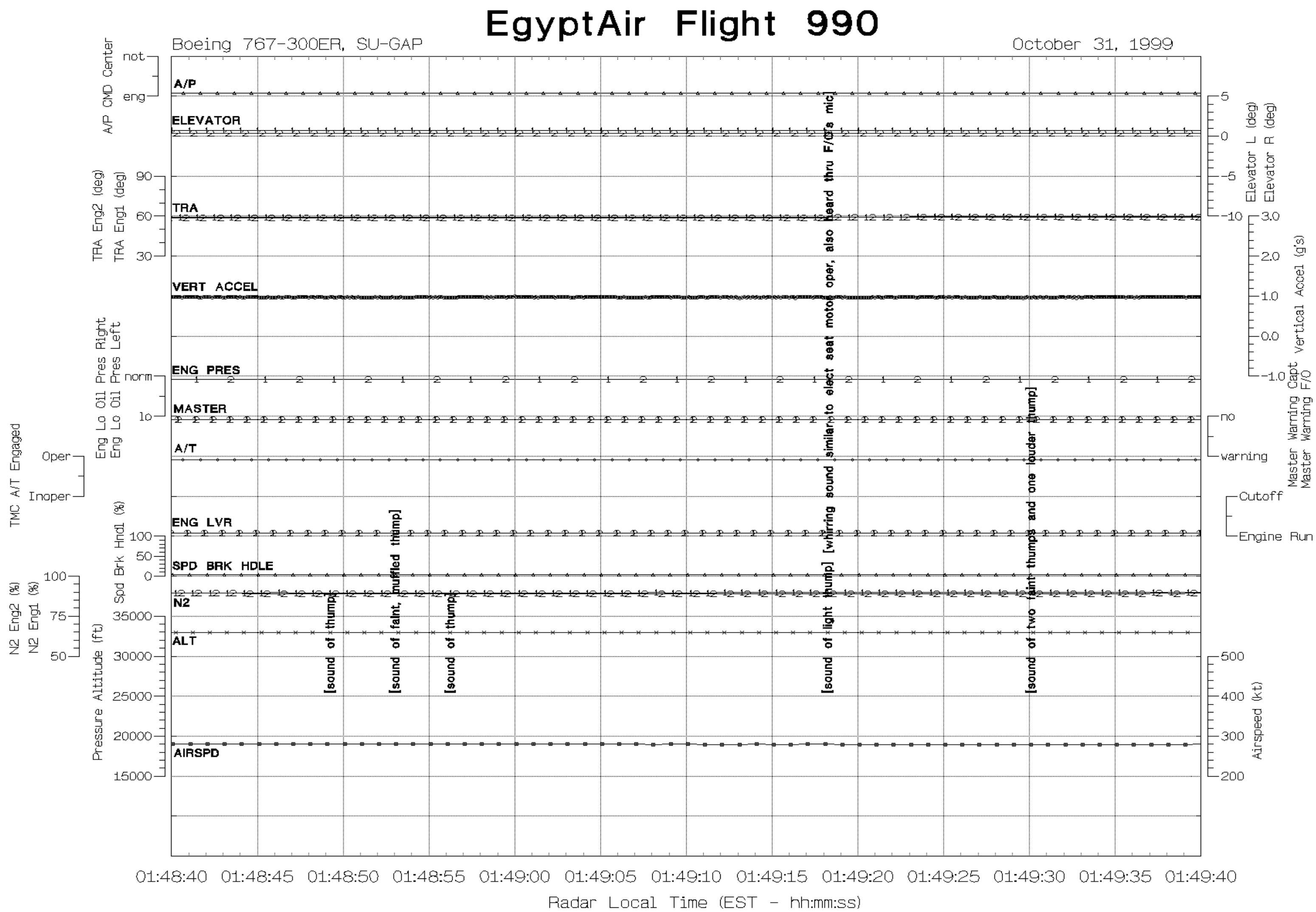

Figure 3b. A graph depicting selected FDR data from 1:48.40 to 1:49.40.

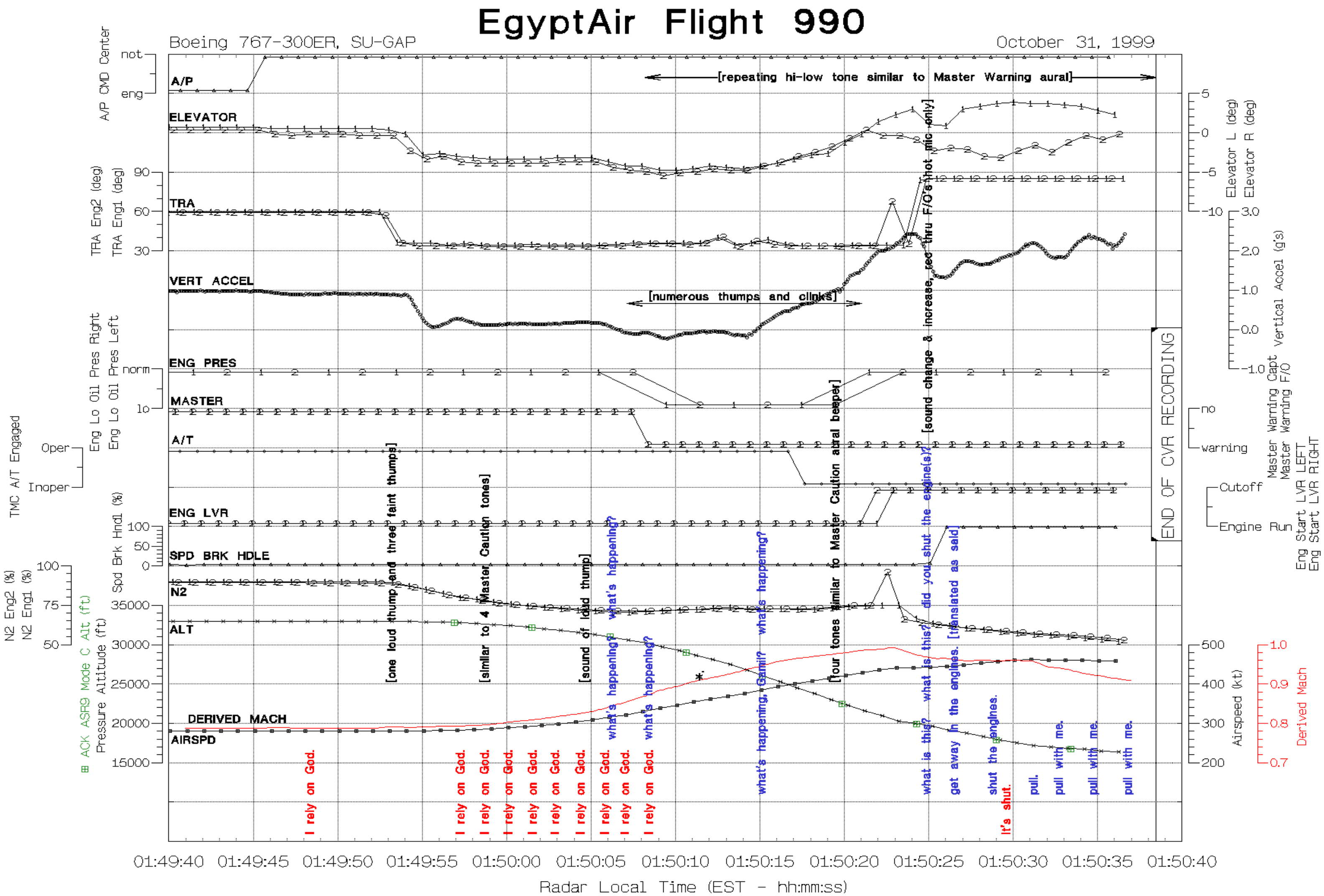

Figure 3c. A graph depicting selected FDR data from 1:49.40 to 1:50.40.

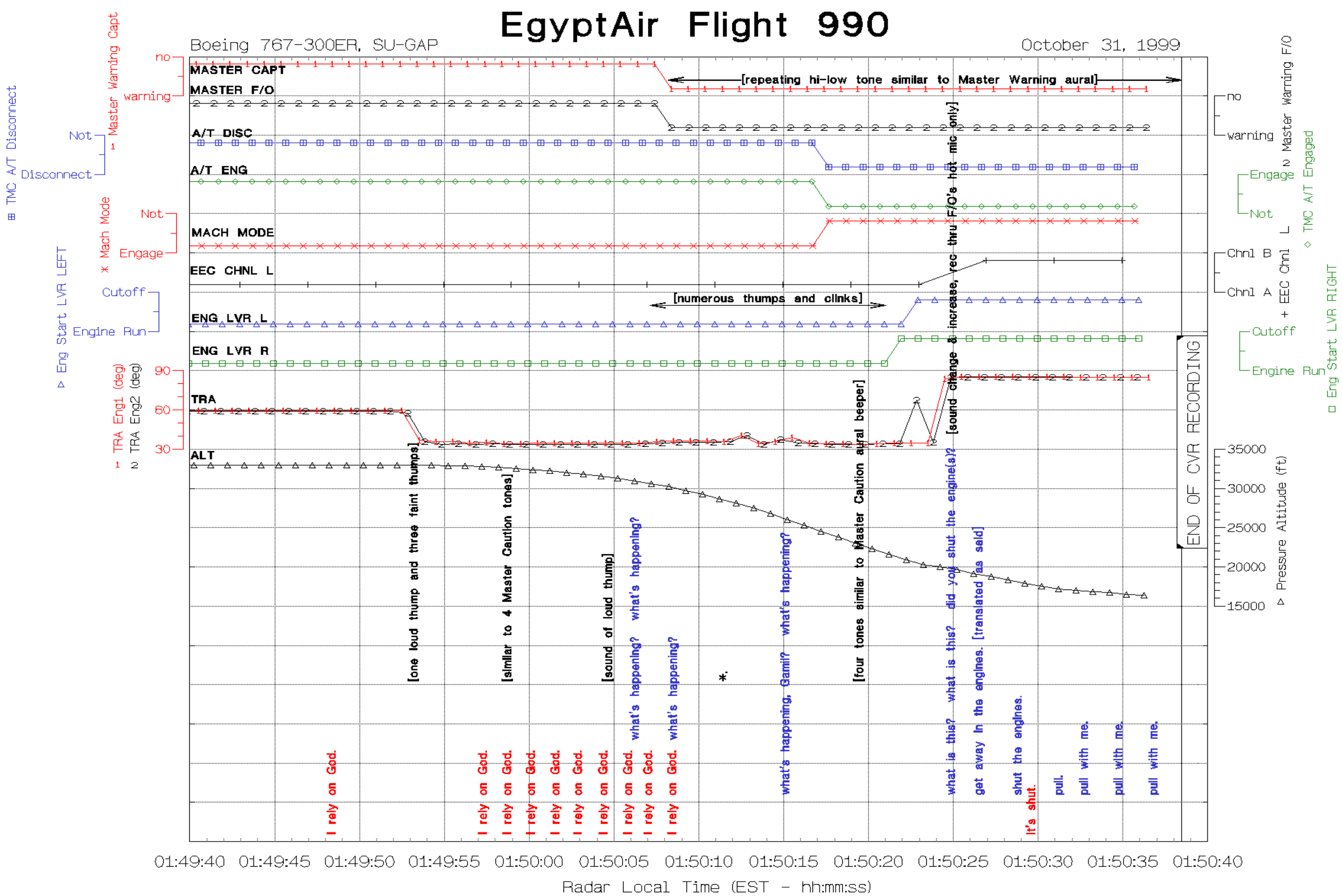

Figure 3d. A graph depicting selected FDR data from 1:49.40 to 1:50.40.

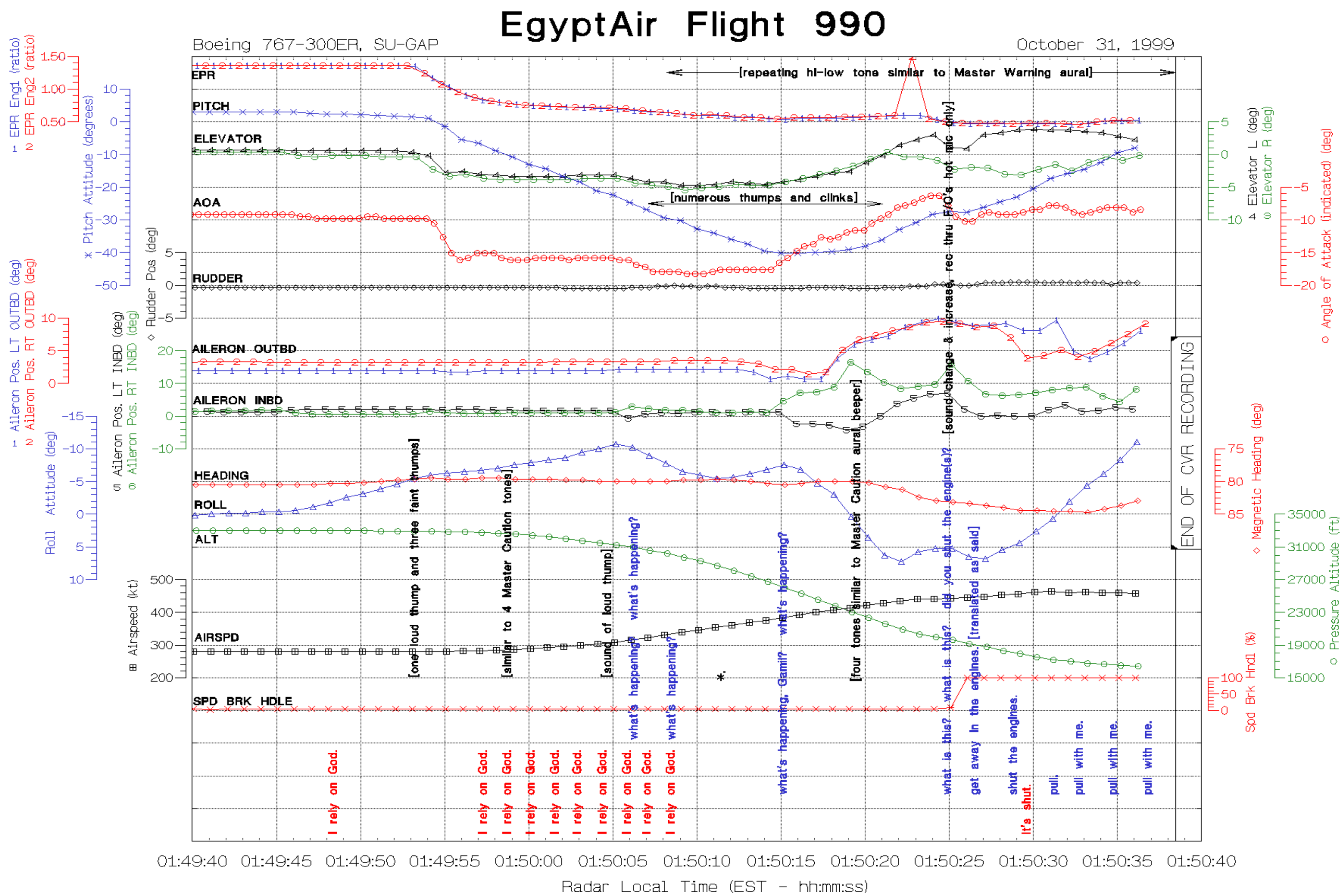

Figure 3e. A graph depicting selected FDR data from 1:49.40 to 1:50.40.

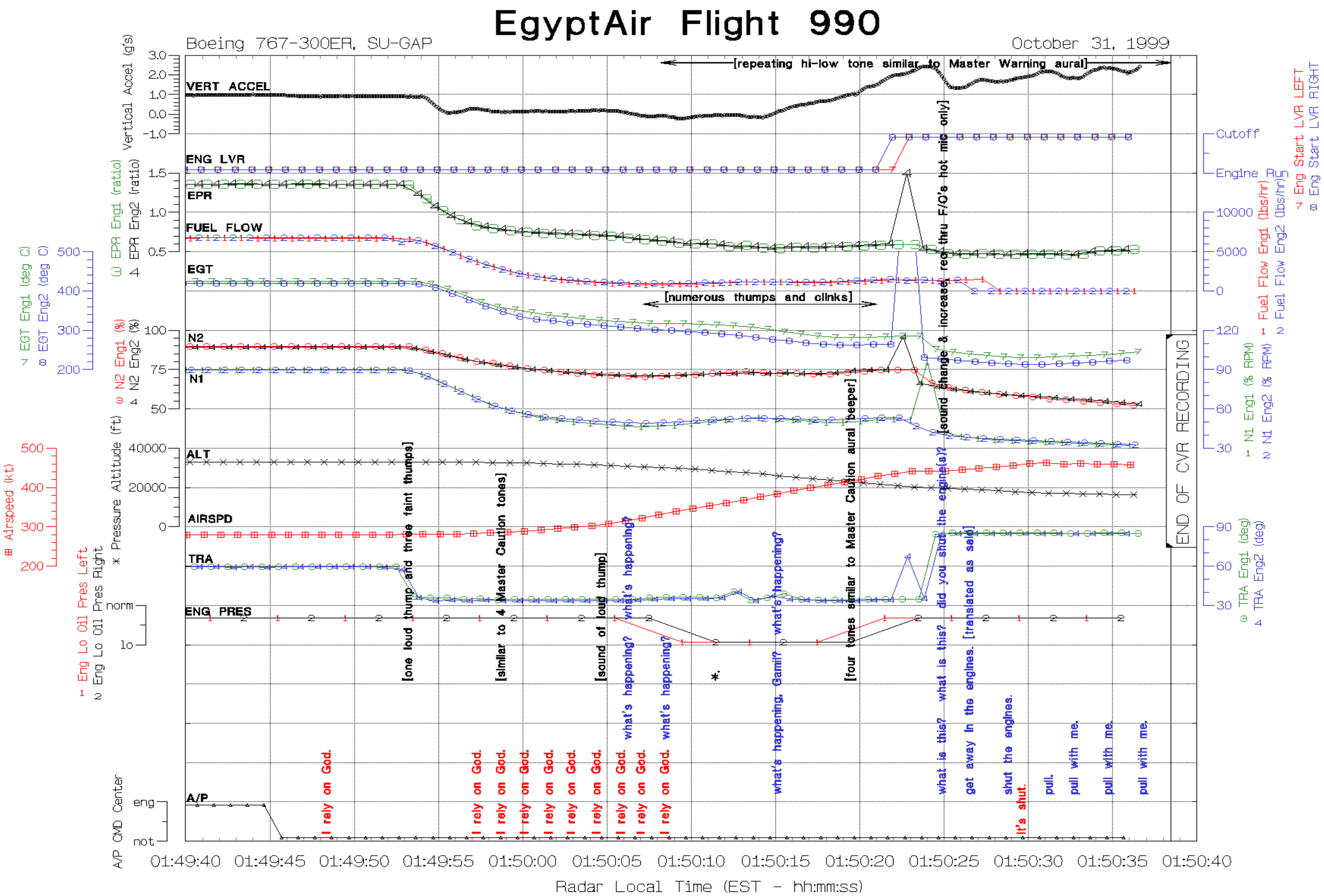

Figure 3f. A graph depicting selected FDR data from 1:49.40 to 1:50.40.

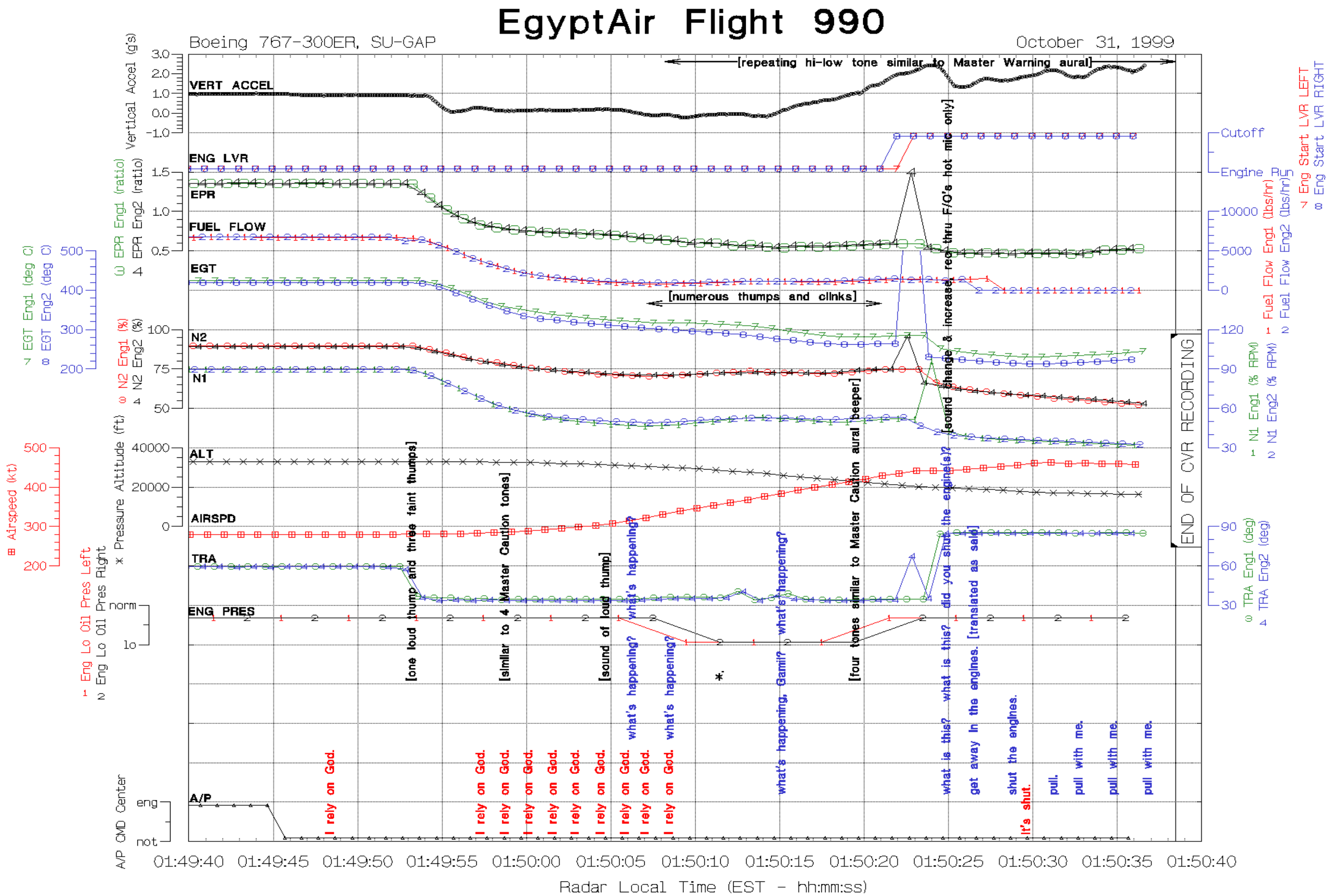

Figure 3g. A graph depicting selected FDR data from 1:49.40 to 1:50.40.

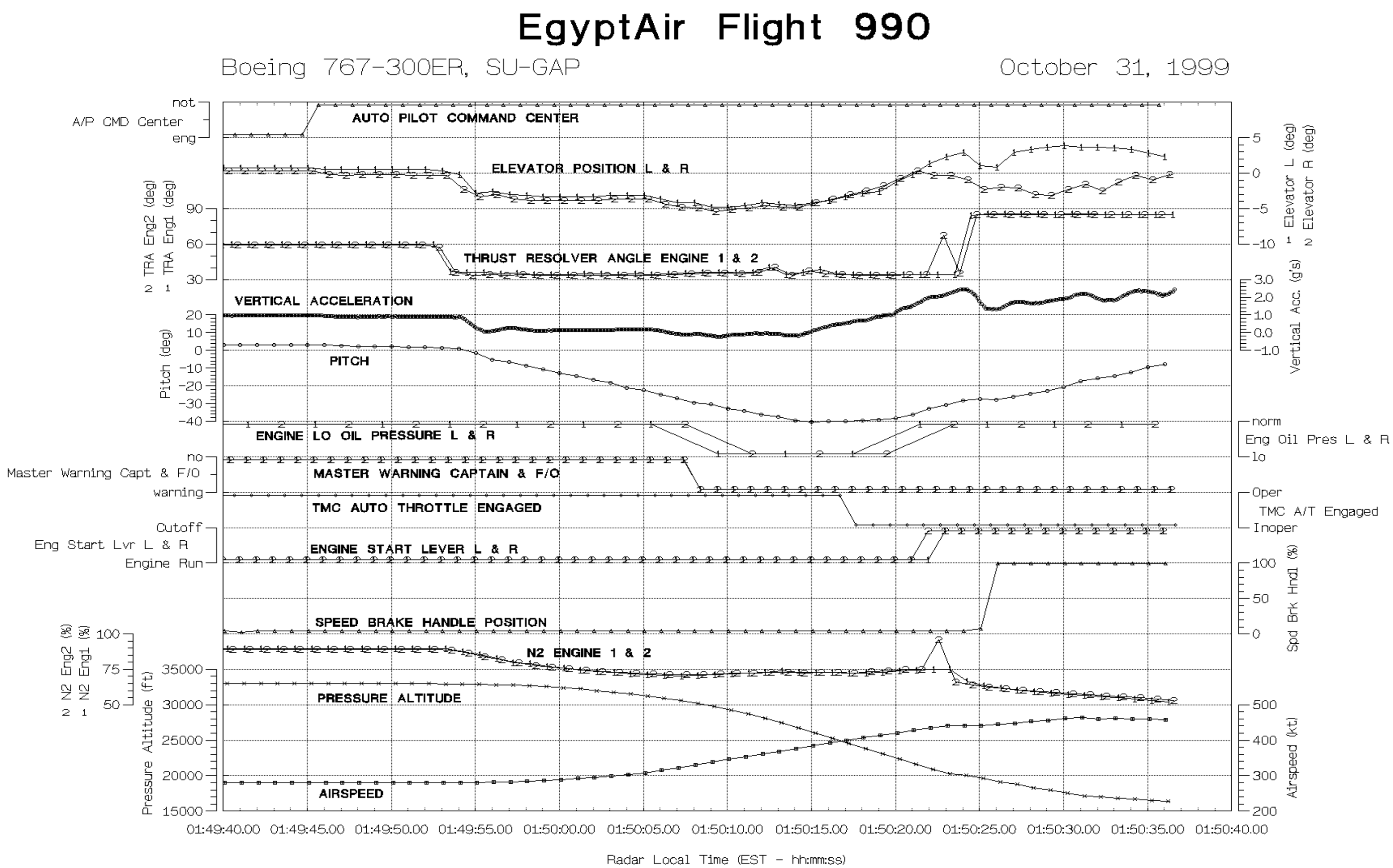

Figure 3h. A graph depicting selected FDR data from 1:49.40 to 1:50.40.

WRECKAGE INFORMATION

About 70 percent of the airplane was recovered during the initial recovery operations, which began on the morning of October 31 and ended on December 22, 1999. Subsequent recovery efforts conducted between March 29 and April 3, 2000, resulted in the recovery of the left engine and additional pieces of airplane wreckage.

Sonar mapping of the wreckage site depicted two distinct underwater debris fields, which were identified by recovery personnel and investigators as the western and eastern debris fields. These debris fields were about 366 meters (1,200 feet) apart from center point to center point. The western debris field, which was estimated to be 62 meters by 66 meters and was centered about 40° 20' 57" north latitude, 69° 45' 40" west longitude, contained mainly parts associated with the left engine and various other small pieces of wreckage (including portions of two wing panels, fuselage skin, horizontal stabilizer skin, and the majority of the nose landing gear assembly). The eastern debris field, which was estimated to be 83 meters by 73 meters and was centered about 40° 20' 51" north latitude, 69° 45' 24" west longitude, contained the bulk of the airplane's fuselage, wings, empennage (including the outboard tips of the right and left elevators and all recovered elevator PCAs), right engine, main landing gear, and flight recorders. Many pieces of floating wreckage (including pieces of the right and left elevator surfaces)[54] were recovered from the water's surface in or near the eastern debris field shortly after the accident; specific recovery locations for some of these pieces were not noted. The small size of most of the recovered pieces of wreckage was consistent with the airplane impacting the water at a high speed. The locations of the two main wreckage debris fields were consistent with the accident airplane's flightpath, as indicated by the primary radar data.[55]

The Safety Board leased a commercial vessel to recover the wreckage that had settled on the ocean floor. Pieces of wreckage were recovered from a depth of about 230 feet using a clamshell scoop and a crane, loaded (using a front loader) into containers on the recovery vessel, and moved to shore. Upon reaching shore, the containers of wreckage were lifted off the recovery vessel and rinsed thoroughly twice. The containers were then moved into the hangar at Quonset Point, Rhode Island, where they were tipped onto their sides. The wreckage was then moved out of the containers onto the floor using rakes and shovels. Once on the hangar floor, the wreckage was spread evenly by a front loader to assist the drying process. During this process, FBI and Safety Board investigators examined the recovered wreckage for evidence of fire or explosion damage. The FBI placed identification tags on some of the debris; accident investigators then documented all of the debris.

Four of the elevators' six PCAs (the center and outboard right elevator PCAs and two elevator PCAs whose positions could not be determined)[56] were recovered. Postaccident examination revealed that all four of the recovered PCAs exhibited

[54] In total, about 37 percent of the total elevator surface area was recovered.

[55] For additional information, see the section titled, "Review of Radar Data."

impact-related damage. One of the four also exhibited the following two unusual characteristics on its internal mechanisms: (1) the pin that attaches the spring guide to the valve slide was sheared, and (2) a portion of the bias spring (about one full coil) was improperly positioned over the head portion of the spring guide. It could not be determined whether these conditions existed before impact or whether they were impact related. The Safety Board's measurements of these components indicated that the inside diameter of the servo valve cap into which the bias spring and spring guide fit was 0.872 inch and that the outside diameter of the spring guide at its widest point was 0.749 inch, leaving a clearance of 0.123 inch between the spring guide and the servo valve cap. Measurements indicated that the bias spring wire had a diameter of 0.031 inch. Impact marks and damage were observed on other components in this PCA; however, there was no evidence of scraping, abrasion, or other marks on the improperly positioned bias spring or adjacent surfaces that would indicate that these metal parts had jammed in the PCA.[57]

Five of the elevators' six bellcranks (all three right elevator and two of the left elevator bellcrank assemblies) were recovered. Postaccident examination of the recovered bellcrank assemblies revealed that all of the shear rivets in the recovered bellcrank assemblies were sheared,[58] with the sheared surfaces appearing consistent with shear overstress. However, the rivets in some of the bellcrank assemblies sheared in a direction opposite to others; shear rivets in the two recovered bellcrank assemblies from the left elevator surface and in the inboard bellcrank assembly from the right elevator surface were sheared as if the bellcrank arms were moving to a higher relative angle, whereas the shear rivets in the middle and outboard bellcrank assemblies from the right elevator surface were sheared as if the bellcrank arms were moving to a lower relative angle. Most of the recovered elevator control linkages were found broken or otherwise damaged.

Examination of the fracture surfaces on the recovered pieces of wreckage revealed that the fractures were consistent with failures generated by a high-speed impact. None of the fracture surfaces examined exhibited any sign of preexisting fatigue or corrosion. No evidence of foreign object impact damage or pre- or postimpact explosion or fire damage was observed.[59]

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[56] The right elevator center PCA was identified as such because of its location in recovered horizontal stabilizer wreckage. The right elevator outboard PCA was identified as such by EgyptAir personnel, who matched the PCA's S/N to their maintenance documents for the accident airplane. The condition of the other two recovered PCAs precluded identification of their location on the airplane.

[57] The Safety Board recognizes that a jam between two surfaces can occur without leaving any physical evidence. However, as discussed in the Board's report on the September 8, 1994, accident involving USAir flight 427, tests conducted in connection with that accident investigation showed that physical evidence of a jam was always observed after tests involving hardened steel chips jammed and/or sheared in a PCA.

[58] As previously discussed, the shear rivets are designed to fail when they are subjected to about 50 lbs of force or more at the control column, the PCA is jammed, and the compressible links are bottomed out. In addition, shear rivets may fail as a result of impact or recovery-related forces.

[59] For additional information, see Systems Group Chairman's Factual Report and its appendixes and addendum, Materials Laboratory Factual Report, and Structures Group Chairman's Factual Report and its appendixes and addendum.

Examination of the left engine (which was recovered relatively intact) revealed evidence of little, if any, rotation at the time of impact. The right engine was severely broken up, and only about 80 percent of it was recovered. Examination of the recovered portions of the right engine showed evidence of little, if any, rotation at the time of impact. The observed deformations on the right engine were consistent with a steep impact angle, whereas observed deformations on the left engine were consistent with an inverted, slightly aft-end-down impact angle. Although the recovery location of and damage to the left engine were consistent with it separating from the airplane before impact, no evidence of any preimpact catastrophic damage or fire was observed on either engine.[60]

TESTS AND RESEARCH

Review of Radar Data

Five radar sites detected primary and/or secondary returns from EgyptAir flight 990. These sites are located at North Truro, Massachusetts; Riverhead, New York; Gibbsboro, New Jersey; Oceana, Virginia; and Nantucket, Massachusetts. The Safety Board's examination of the available radar data revealed that four of the five radar sites recorded no sequence of primary or secondary radar returns that intersected EgyptAir flight 990's position at any time nor did they reveal any radar returns consistent with a projectile or other object traveling toward the accident airplane. Although the Riverhead radar site recorded numerous radar returns near the flightpath of EgyptAir flight 990 within 5 minutes of the accident, none of the radar sites with areas of coverage that overlapped this area of Riverhead's coverage recorded similar radar returns. Consultation with the USAF Radar Evaluation Squadron revealed that the primary returns in question from the Riverhead radar site were caused by radio frequency interference from the Bucks Harbor, Maine, long-range radar site.

No secondary radar returns were received from EgyptAir flight 990 after 0150:36 (about the time the CVR and FDR stopped recording); however, after this time, several radar sites recorded primary radar returns that continued along the accident airplane's extended flightpath from its last recorded radar position. As previously discussed, these primary radar data (with extrapolated FDR data and simulation results) indicated that after the airplane's FDR and CVR stopped recording, the airplane descended to an altitude of about 16,000 feet msl, then climbed to about 25,000 feet msl and changed heading from 80º to 140º before it began its second descent, which continued until it impacted the ocean.[61]

[60] For additional information, see Powerplants Group Chairman's Factual Report.

[61] For additional information, see the Aircraft Performance Group Chairman's Aircraft Performance Study.

Accident Sequence Study

The Safety Board used the FDR, radar, winds aloft, and 767 performance data to determine the accident airplane's motions and performance during the accident sequence. These data (and associated calculations) indicated the following:

- Aside from the very slight movement of both elevators (the left elevator moved from a 0.7° to about a 0.5° nose-up deflection, and the right elevator moved from a 0.35° nose-up deflection to about a 0.3° nose-down deflection)[62] and the airplane's corresponding slight nose-down pitch change, which were recorded within the first second after autopilot disconnect at 0149:45, and a very slow (0.5º per second) left roll rate, the airplane remained essentially in level flight about FL 330 for about 8 seconds after the autopilot was disconnected.
- At 0149:53, the left and right throttles were retarded to the aft idle stop (equivalent to a throttle lever angle of about 33º) at a rate of about 25º per second.[63] About 1 second after the start of the throttle movement, the FDR recorded slight motion in the inboard ailerons, the left elevator surface moved to about a 3.4º TED position, and the right elevator surface moved to about a 3.8º TED position.[64]
- At 0149:54, the airplane began to pitch nose down, reaching a pitch attitude of about 40º nose down at 0150:15. During the dive, the wings remained within about 10º of level and the heading remained about 80º, increasing to about 85º between 0150:20 and 0150:33.
- Between 0150:05 and 0150:06, the FDR recorded additional movements in the inboard ailerons, and the left and right elevators moved an additional 1.5º TED to about 5.5º TED. Before this time, the load factor had been about 0.2 G; after this time, the load factor decreased to about -0.1 G. Between 0150:06 and 0150:10, the FDR began to record "Low Engine Oil Pressure" signals for both engines; the FDR recorded these signals until after the load factor increased to above 0 G between 0150:17 and 0150:21.[65]

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[62] Throughout the FDR data for the accident airplane (including data recorded during uneventful portions of the accident flight and during previous flights and ground operations), small (generally less than 1°) differences between the left and right elevator surface positions were observed. The elevator surface movements were consistent (that is, moved in the same direction about the same time) where these offsets were observed.

[63] As previously mentioned, at the accident airplane's flight conditions at the beginning of the accident sequence, the minimum autothrottle commanded throttle lever position would have been between 40º and 50º; this value would have decreased as the airplane's airspeed increased. The maximum autothrottle commanded throttle lever movement rate for a normally functioning autothrottle system is 10.5º per second.

[64] Elevator movement in the TED direction would result in a decrease in the airplane's lift and load factor and an increase in the airplane's nose-down attitude.

- At 0150:08, as the airplane passed through about 30,800 feet msl, the airplane exceeded its maximum operating airspeed (0.86 Mach), and the Master Warning alarm sounded. The maximum rate of descent recorded during the dive was about 39,000 fpm at 0150:19, as the airplane descended through about 24,600 feet msl. At 0150:23, the airspeed reached its peak calculated value of 0.99 Mach, as the airplane descended through about 22,200 feet msl.
- At 0150:15 and about 27,300 feet msl, the left and right elevator surfaces started to move slowly (about 0.6º per second) in the trailing-edge-up (TEU) direction, back toward their neutral position. The pitch angle, angle of attack, and load factor also started to increase at this point, so that when the FDR recorded the last data for the accident flight at 0150:36.64, the pitch angle had increased to about 8º nose down, and the airplane was experiencing about 2.4 Gs.
- Between 0150:18 and 0150:27, the FDR recorded TEU movements of the left and right outboard ailerons and the left inboard aileron.[66]
- At 0150:21, the left and right elevator surfaces started to split (that is, to move asymmetrically). The right elevator surface started to move TED, whereas the left elevator surface moved TEU. This split between the left and right elevator surface positions continued to the end of the FDR data, varying in magnitude but averaging about 4º difference between the surfaces (see figure 2).
- Between 0150:21 and 0150:23, the engine start lever switches for both engines moved from the run to the cutoff position.
- Between 0150:24 and 0150:25, both throttle handles moved full forward.
- Between 0150:25 and 0150:26, the speedbrake handle moved to its fully deployed position. Coincident with this activity, between 0150:24 and 0150:27, the left elevator surface moved briefly in the TED direction (from 3º TEU to 1º TEU) before it returned to 3º TEU.
- Almost immediately after the speedbrakes were deployed at 0150:26, the left elevator surface deflection increased further, reaching its maximum deflection of more than 3.8º nose up about 0150:30.[67] After 0150:30, the left elevator's nose-up deflection gradually reduced, until the data for that parameter ended at 0150:36 with a left elevator deflection of about 2.3º nose up.

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[65] The Safety Board's examination of Boeing's 767 certification flight test data revealed that the low oil pressure warnings for P&W 4060 engines would occur when the engine's oil pressure drops below 70 lbs per square inch, as occurred when the accident airplane was operating at low (near 0) load factors. (For additional information, see Powerplants Group Chairman's Factual Report and appendixes 1 through 8.)

[66] According to Boeing, these movements were consistent with the effects of blowdown on those surfaces as documented during flight tests. However, the outboard aileron split recorded by the FDR after about 0150:27, which is discussed later in this section, was not consistent with the flight test data.

[67] As previously discussed, Safety Board simulations demonstrated that a pilot in the left seat could have moved his right hand from the control wheel to the throttle, advanced the throttles, moved his hand a little to the left, and deployed the speedbrakes in the 3 to 4 seconds it took for these events to occur.

- Between 0150:21 and 0150:24, the right elevator surface's nose-down deflection increased gradually, then increased rapidly until just after 0150:25, when the nose-down deflection briefly reduced from about 2.35º to about 1.9º nose down. Between 0150:21 and 0150:23, the engine start levers moved to the cutoff position. At 0150:26, the right elevator's nose-down deflection began to increase again, reaching its maximum nose-down deflection of about 3.2º at 0150:29. Subsequently, the right elevator's deflection moved generally toward a nose-up position, with occasional movements in a nose-down direction; when the FDR data ended, the right elevator deflection was 0.2º nose down.
- Between 0150:27 and 0150:32, the FDR recorded a split condition in the outboard ailerons (the left outboard aileron maintained its approximate presplit deflection, while the left outboard aileron began to move in a TED direction).[68] The outboard ailerons had been moving in a TEU direction since 0150:18.
- During the elevator split, the larger movements of the left and right elevators individually corresponded with changes in the load factor (see figure 4). For example, between 0150:30 and 0150:36, the recorded movements of the right elevator (lower graph) are reflected in the load factor profile (upper graph).
- No secondary radar returns were received from the accident airplane after the last data were recorded by the FDR at 0150:36.64.
- Performance calculations based on primary radar returns indicated that the airplane's rapid descent stopped at an altitude of about 16,000 feet msl. The primary radar returns indicated that the airplane then began to climb, reaching about 25,000 feet msl about 0151:15. During this climb, the airplane's heading changed from about 80º to about 140º.
- After 0151:15, the data indicated that the airplane began a second rapid descent that continued until it impacted the ocean.

Seven primary radar returns from the airplane were recorded during the second dive; the altitude estimates from these returns are subject to potentially large errors, which introduces significant uncertainty into the performance calculations during the second dive. However, the data indicate that the airplane impacted the ocean about 0152:30, with an average descent rate during the second dive of about 20,000 fpm.

[68] Wind tunnel tests and computational fluid dynamics analyses show that a small sideslip angle and/or roll rate could produce large changes in the aerodynamic forces acting on the outboard ailerons at speeds approaching Mach 1.0, but these forces would not likely be strong enough to cause the split elevator condition recorded by the accident airplane's FDR. For additional information, see Aircraft Performance – Addendum #1.1, Addendum to Group Chairman's Aircraft Performance Study, including appendixes B and C (correspondence from Boeing, dated April 12 and 16, 2001).

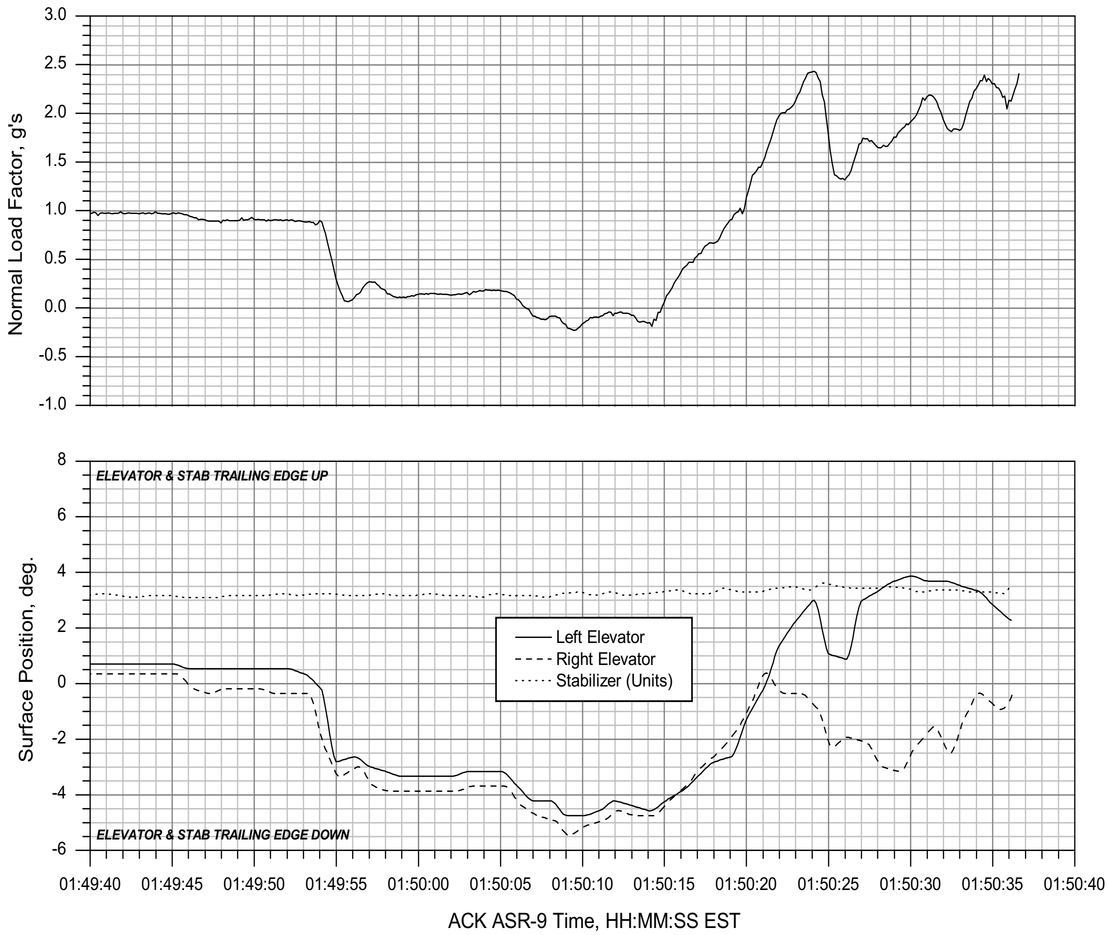

Figure 4. Graphs depicting the accident airplane's normal load factor response to elevator and stabilizer movement.

Potential Causes for Elevator Movements During the Accident Sequence

Investigators used Boeing's six-degree-of-freedom, full-flight engineering simulator (which incorporated, to the maximum extent possible, the flight characteristics of the 767) to evaluate whether the accident airplane's recorded pitch motions were consistent with the elevator position movements recorded on the FDR.[69] The results showed that the elevator movements required to make the simulator duplicate the pitch motions and flightpath recorded on the FDR were consistent with the elevator movements recorded by the FDR throughout the recorded data, even during the time that the data

[69] The simulator data are based on wind tunnel tests and updated with available flight test data. The maximum Mach number for which the simulator is programmed (Mach 0.91) corresponds to the airplane's never-exceed airspeed. The maximum speed calculated for the accident airplane during the accident sequence was Mach 0.99 at 0150:23. To evaluate the performance of the airplane at Mach numbers greater than 0.91, the simulator's database was adjusted to reflect extrapolations, based on 777 wind tunnel tests. (The 767 and 777 have aerodynamically similar horizontal stabilizers and elevators.)

indicated a split between the left and right elevator surfaces.[70] The investigation attempted to determine if any mechanical failures could have caused these elevator movements.

The Systems Group reviewed numerous potential failure scenarios to evaluate whether any of them might have been capable of causing the elevator surface movements recorded on the FDR during the accident sequence, including failures associated with the elevator system's flight control cables,[71] failures associated with elevator surface PCAs,[72] and other system-related failures.[73] On the basis of the results of failure modes and effects analyses, the Safety Board ruled out all but four of these potential failure scenarios because they failed to reflect the accident flight's elevator movements in obvious and significant ways.[74] For example, it was determined that neither an autopilot malfunction nor EMI[75] would have caused any elevator movements during the accident sequence.[76] Although some of the other scenarios could have caused some elevator movements, the nature and degree of those movements differed so greatly from the elevator movements recorded during the accident flight that they did not warrant further consideration.

However, the failure modes and effects analyses showed that the following four elevator failure scenarios (each of which involves two failures) warranted further study because they could potentially cause nose-down elevator movements or a split elevator condition that might resemble some portions of the data recorded on the accident flight's FDR:

1. Disconnection of the input linkages to two of the three PCAs on the right elevator surface. This failure scenario could be caused by the failure of any of the components that comprise the actuator input linkage system, including the bellcranks.

[70] For additional information, see Systems Group Chairman's Factual Report and its appendixes and addendums, Flight Data Recorder Group Chairman's Factual Report and its attachments, Cockpit Voice Recorder Group Chairman's Factual Report and Sound Spectrum Study, and the Aircraft Performance Group Chairman's Aircraft Performance Study and its attachments and addendum.

[71] The cable-related failures considered included a single failed elevator body cable; a failed slave cable; a failed component or other object falling on elevator cables; a cable tension regulator failure; an aft pressure bulkhead failure, resulting in cable displacement; and a cable break combined with a jam in the same cable.

[72] The elevator PCA-related failure scenarios considered included an input rod/cable jammed at an offset position (position jam), an input arm for a single PCA jammed at an offset position to command a specific control surface rate of movement (rate jam), failure of the bellcrank assemblies on all three of the PCAs on a single elevator surface, jam of the input linkage or servo valve of one PCA with a high breakout force compressible link (a high breakout force compressible link would allow more force to be transmitted to the input linkages of the nonfailed side before compressing and negating the jammed PCA), disconnection of the input linkages to two of the three PCAs on a single elevator surface, a jam of the input linkage or servo valve on one PCA and the disconnection of the input linkage to another PCA on a single elevator surface, and a jam of the input linkages or servo valves in two of the three PCAs on a single elevator surface.

[73] The other system-related failures considered included erroneous stick nudger activation; air in the hydraulic system and elevated return pressure; hydraulic system failure to one surface; elevator position transducer disconnect, resulting in erroneous indications on the FDR of an elevator surface offset or split; a single linkage disconnect downstream of feel unit; a failure of the elevator feel unit's attachment to aircraft structure; electromagnetic interference (EMI); and an autopilot malfunction such as a servo jam, resulting in a hardover autopilot output.

2. A jam of the input linkages or servo valves in two of the three PCAs on the right elevator surface. In order for this failure scenario to occur, the internal slides of the affected servo valve would first have to be moved (by manual or autopilot input) to an offset position and then jam. Although such jams could theoretically occur in either direction, all tests and simulations involving jammed elevator PCAs were intentionally configured to produce nose-down (rather than nose-up) elevator input.

3. A jam of the input linkage or servo valve in one PCA and the disconnection of the input linkage to another PCA on the right elevator surface.

4. A jam in the elevator flight control cable connecting the right-side control column to the right aft quadrant assembly combined with a break in the same cable. (Four variants of this scenario were studied. For additional information, see the Systems Group Chairman's Factual Report and its addendum regarding the cable break/jam and PCA jam with high breakout force [compressible link] ground testing.)

For further evaluation, the Systems Group conducted ground tests on an instrumented 767 to record the elevator system's response to each of these failure scenarios. During the ground tests, the test airplane's systems were configured to simulate the accident airplane's altitude and airspeed. The Systems Group also studied the effect that each failure scenario would have on the elevator control system and calculated the effect on the elevators that each scenario would have had at the specific conditions of the accident flight at the time of the initial pitchdown. The results of the tests, studies, and calculations were as follows:

1. Disconnection of the input linkages to two of the three PCAs on the right elevator surface.

- During the ground tests, the failed elevator surface was driven to its full nose-down position and would not respond to nose-up flight control inputs from either control column. A study of the elevator control system indicated that if this scenario occurred in flight, it would result in an initial deflection of the failed surface to a position consistent with a single functioning elevator PCA operating at 100 percent of its maximum force (as limited by aerodynamic blowdown forces); the failed elevator surface would resist being

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[74] For additional information, see Systems Group Chairman's Factual Report and its appendixes.

[75] EMI is electromagnetic radiation that is emitted and/or received by an electronic device and adversely affects the performance of that device or other devices.

[76] An autopilot malfunction was ruled out as a potential cause of the elevator movements because the autopilot was disconnected before the beginning of the nose-down elevator movements. Even assuming that the autopilot was engaged during the accident sequence, the elevator movements recorded by the FDR exceeded the maximum inputs that could be commanded by the autopilot. EMI was ruled out because elevator surface movements are not electrically actuated (and, therefore, are not susceptible to the effects of EMI) except through the autopilot. (When the autopilot is not engaged, elevator surface movements on the 767 are mechanically signaled and hydraulically actuated.)

backdriven with a force equivalent to about 130 percent of a single functioning PCA.[77] Calculations showed that at 280 knots (the accident airplane's airspeed when the initial descent began), this position would initially have been about 6° nose-down elevator deflection, and the degree of deflection would be reduced as the airplane's speed increased above 290 knots. See figure 2 for additional elevator blowdown position information.[78]

- During the ground tests, the nonfailed elevator surface remained in its prefailure position unless it received inputs from either control column. A study of the elevator control system's force balance and calculations of the effect of this failure under the conditions of the accident flight indicated that the nonfailed surface would remain in its prefailure position.
- During the ground tests, either control column could be used to control the nonfailed elevator surface and to command the full travel of that surface available at the existing flight condition. The Safety Board's study of the elevator control system indicated that under the accident flight conditions, inputs from either control column would have resulted in corresponding movement of the nonfailed elevator surface.

2. A jam of the input linkages or servo valves in two of the three PCAs on the right elevator surface.

- During the ground tests, the failed elevator surface was driven to its full nose-down position and would not respond to nose-up flight control inputs from either control column. A study of the elevator control system indicated that if this scenario occurred in flight, it would result in an initial deflection of the failed surface to a position consistent with a single functioning elevator operating at 100 percent of its maximum force (as limited by aerodynamic blowdown forces); the failed elevator surface would resist being backdriven with a force equivalent to about 130 percent of a single functioning PCA. As discussed in connection with the previous failure scenario, calculations showed that, under the conditions of the accident flight, this position would initially have been about 6° nose-down elevator deflection, and the degree of deflection would be reduced as the airplane's speed increased above 290 knots.
- During the ground tests, the nonfailed elevator surface moved to about 4° nose-down deflection in the same direction as the failed surface. A study of the elevator control system's force balance and calculations of the effect of this failure under the conditions of the accident flight indicated that the nonfailed surface would move to a position corresponding to 30 lbs of feel force.[79]

[77] For a detailed explanation of why a failed surface would deflect to this position, see the Aircraft Performance Group Chairman's Factual Report and its addendum 1.1.

[78] Elevator hinge moment data provided by Boeing were used to estimate the 767 elevator blowdown positions during the first three failure scenarios. Boeing extrapolated available elevator data based on Boeing 777 wind tunnel data, which were available for Mach numbers 0.91, 0.94, and 0.96. (As previously stated, the 767 and 777 have aerodynamically similar horizontal stabilizers and elevators.)

Calculations showed that under the conditions of the accident flight when the initial descent began, the degree of deflection for the nonfailed surface would be the same as during the ground tests (about 4º).

- During the ground tests, either control column could be used to control the nonfailed elevator surface and to command that surface in either the nose-up or the nose-down direction.[80] The Safety Board's study of the elevator control system indicated that under the accident flight conditions, inputs from either control column would have resulted in corresponding movement of the nonfailed elevator surface.

3. A jam of the input linkage or servo valve in one PCA and the disconnection of the input linkage to another PCA on the right elevator surface.

- During the ground tests, the failed elevator surface was driven to its full nose-down position and would not respond to nose-up flight control inputs from either control column. A study of the elevator control system indicated that if this scenario occurred in flight, it would result in an initial deflection of the failed surface to a position consistent with a single functioning elevator operating at 100 percent of its maximum force (as limited by aerodynamic blowdown forces); the failed elevator surface would resist being backdriven with a force equivalent to about 130 percent of a single functioning PCA. As discussed in connection with the previous failure scenarios, calculations showed that, under the conditions of the accident flight, this position would initially have been about 6º nose-down elevator deflection, and the degree of deflection would be reduced as the airplane's speed increased above 290 knots.
- During the ground tests, the nonfailed elevator surface moved to about 2.1º nose-down deflection in the same direction as the failed surface. A study of the elevator control system's force balance and calculations of the effect of this failure under the conditions of the accident flight indicated that the nonfailed surface would move to a position corresponding to 15 lbs of feel force. Calculations showed that under the conditions of the accident flight when the initial descent began, the degree of deflection for the nonfailed surface would be the same as during the ground tests (about 2.1º).

[79] Feel force is the amount of force generated by the aircraft's feel-and-centering unit. In normal operation, the feel force is a function of control column deflection and aircraft flight condition. If a jam of the input linkages or servo valves in two of the three PCAs on a single elevator surface occurred, the airplane's feel-and-centering unit would provide a force to oppose the forces needed to deflect the compressible links on the input side of the failed elevator PCAs.

[80] To avoid shearing the test airplane's bellcrank rivets during the ground tests evaluating the two failure scenarios that involved jammed PCA linkages and/or servo valves, full travel of the elevator surface was not commanded. However, a study of the elevator control system indicated that full travel of the nonfailed surface could have been achieved under these two failure scenarios, if commanded.

- During the ground tests, either control column could be used to control the nonfailed elevator surface and to command that surface in either the nose-up or the nose-down direction. The Safety Board's study of the elevator control system indicated that under the accident flight conditions, inputs from either control column would have resulted in corresponding movement of the nonfailed elevator surface.

4. A jam in the elevator control cable connecting the right-side control column to the right aft quadrant assembly combined with a break in the same cable.

- During the ground tests, the left elevator surface moved to nose-down deflections of 1.2º to 3.9º and the right elevator surface moved to nose-down deflections of 1.4º to 5.0º, depending on the scenario tested. Analysis of the elevator system indicated that if such failures occurred in flight, the resultant elevator surface positions would not have varied as a result of changes in the aerodynamic forces acting on the elevator in the same manner as the previous three failures because all three PCAs would still be functioning properly.
- During the ground tests for all break/jam combinations, either control column could be used to control both elevator surfaces. Testing showed that a pull from either control column of 25 lbs would result in sufficient movement of both elevators in a nose-up direction to be evident on the FDR. A pull from either control column of 50 to 100 lbs would result in sufficient movement of both elevators in a nose-up direction to either reverse or significantly slow the airplane's nose-down dive.

Pilots from Boeing, EgyptAir, the FAA, and the Safety Board evaluated the controllability of the airplane following the first three of these failure scenarios in Boeing's fixed-base engineering simulator. The simulations assumed that the right elevator was affected by the failure scenario being evaluated and duplicated the airplane's response to the occurrence of that scenario. As previously mentioned, the simulator reflected the flight characteristics of the 767 to the maximum extent possible. Although all flight conditions (for example, airspeed, altitude, roll attitude, load factor, and pitch attitude) were calculated correctly in the simulator, the fixed-base simulator could not duplicate the physical sensations that would have resulted from these flight conditions. For example, the load factors that would be produced under actual flight conditions were not produced in Boeing's fixed-base simulator nor were the actual attitude changes that would have occurred in flight.[81] In addition, the simulator did not model the override mechanisms between the two control columns.

Simulations of the three failure scenarios showed that it was possible to regain control of the airplane using either control column and return it to straight and level flight using normal piloting techniques and that the airplane could be trimmed to hands-off level flight after each of the three failure scenarios occurred.[82] Further, for all three failure

[81] The simulator's cockpit displays did replicate the visual cues (cockpit instrument displays and out-the-window presentation) that would have been present during actual flight.

scenarios, full recovery was possible even when no efforts were made to recover the airplane until 20 seconds after the failure occurred. Although additional force beyond that required for recovery from a dive of this magnitude without a failure was necessary in all tested scenarios, the nonfailed surface responded immediately to nose-up inputs and recovery could be accomplished by a single pilot using either the left or right control column. Although the recovery was easier and the required control column force was reduced when stabilizer trim was used, it was not necessary to use stabilizer trim to recover from any of the three failure scenarios. Further, the simulations also demonstrated that the engines could have been restarted throughout most (if not all) of the recovery from the dive and/or the subsequent climb and that the airplane could have been returned to straight and level flight after the recorders stopped recording. The elevator deflections resulting from the fourth scenario were less extreme, and would therefore be easier to recover from, than those resulting from the first three failure scenarios.

Additional Information

Submissions

The Safety Board received submissions from EgyptAir,[83] Boeing, and P&W.[84] (Note: The fourth failure scenario [a cable jam with a break of the same cable] was studied after these submissions were received; therefore, these submissions do not reference this scenario.)

EgyptAir's April 28, 2000, Presentation

During EgyptAir's April 28, 2000, presentation to the Safety Board, its representatives stated, in part, the following:

- The suicide scenario is not consistent with data and facts of [the EgyptAir flight 990] accident.

[82] For additional information, see Systems Group Chairman's Factual Report and its addendum regarding the ground and simulation testing.

[83] EgyptAir provided the Safety Board with a presentation and several documents and letters that documented its position, including the following: a presentation, dated April 28, 2000; a formal submission, dated August 11, 2000; and a document, dated January 12, 2001, titled, "Response of EgyptAir to October 31, 2000, Submission of The Boeing Company Regarding the EgyptAir Flight 990 Investigation." These documents and letters are available in the public docket for this accident.

[84] The Egyptian Government also provided the Safety Board with additional documents, including the following: (1) the Egyptian Government's comments regarding the Board's draft report of this accident, (2) the Egyptian Government's own report regarding this accident, and (3) the Egyptian Government's addendum to its report regarding this accident. Although these documents are not submissions, and therefore are not discussed in this section, they are available for review. The Egyptian Government's comments regarding the Board's draft report are attached to this report, and the Egyptian Government's accident report and its addendum are available in the public docket for this accident.

- [Left and right] elevator deflection as a result of right elevator dual PCA jam is consistent with the FDR data where Boeing data is valid.
- In the area beyond the airplane normal design envelope where the data is not valid, all the flight control behavior is uncertain, control surfaces are subject to flutter.
- The right elevator middle and outboard bellcrank rivets shear direction is consistent with a jammed PCA reacting against pilot input to move the elevator up.
- Analysis revealed that there are a lot of [radar] returns forming continuous paths crossing the flightpath of [EgyptAir flight 990], which may reflect deliberate [evasive] action by one of the pilots.

EgyptAir's August 11, 2000, Submission

In its August 11, 2000, submission, EgyptAir asserted that ground tests and simulations conducted during the investigation were flawed because simulations were conducted using Boeing's published 767 data and "did not reflect the actual operation of the airplane"; steady-state values were used to calculate the control column forces in various dynamic flight conditions, thus invalidating conclusions; and extrapolation of data for calculated airplane speeds in excess of those for which test data existed (Mach 0.91) "cannot produce accurate results."

EgyptAir also argued in its submission that the relief first officer did not deliberately cause the accident. According to the submission, "the deliberate act theory was based, in large part, on the initial inaccurate translation of an expression repeated several times by the [relief] first officer…[which] has been eliminated not only by credible evidence and analysis but also by accurate translation of the CVR." EgyptAir further stated that (1) the relief first officer had no motive to kill himself or others aboard EgyptAir flight 990; (2) the relief first officer did not use his seniority to insist that he be allowed to fly the airplane; (3) the relief first officer may not have been alone in the cockpit at the onset of the dive; and (4) the captain returned to the cockpit almost immediately after the dive started, and there was no indication of a struggle or disagreement between the two flight crewmembers. EgyptAir further stated that "the cockpit conversations showed an effort at teamwork rather than a crew working at cross purposes." Further, EgyptAir indicated that several of the relief first officer's actions were not consistent with a deliberate attempt to crash the airplane. For example, it stated that the cockpit door was not closed and locked; the throttle levers were moved to idle, whereas engine power would have accelerated the descent; and more radical flight control inputs were available (more nose-down elevator deflection or aileron and rudder with elevator deflections) but not used.

EgyptAir also contended in its submission that at least three flight crewmembers were in the cockpit during the descent, as evidenced "by the fact that if either the captain or [relief] first officer had let go of their control columns to shut the engines or to deploy the speedbrake…the aircraft would have pitched down at the same time.” The EgyptAir submission further stated that the split elevators “do not support the conclusion that there was a struggle in the cockpit” because (1) the CVR provides no indication of a struggle, argument, or refusal to follow a command; (2) the FDR recorded control surface positions but did not record the control column position or forces—“accordingly, one cannot conclude from examining only the FDR data that pilot input to his control column caused the elevators to be in a given position”; and (3) “at the same moment the elevators split, both outboard ailerons moved upward…when this unusual aileron movement occurred during the dive, the aircraft’s speed was approaching Mach 1.0, and no published performance data is available to predict what will occur to ailerons at these high speeds. It is likely, however, that aerodynamic shocks or flutter were occurring at the control surfaces.”

In its submission, EgyptAir summarized its position as follows:

- Accordingly, from an impartial review of the factual evidence gathered during the investigation, it is clear that the [relief] first officer did not intentionally dive the aircraft into the ocean.
- At this point in the investigation considering the factual evidence gathered, it is clear that the first officer did not commit suicide. Further investigation of the elevator control system’s design in conjunction with the other factual information available is necessary before a conclusion can be reached regarding the true cause of this accident. Specifically, further engineering analysis, including wind tunnel tests, is necessary to examine the dual actuator malfunction in the speed ranges for which current data is not available. In addition, further investigation of radar data is also necessary to completely rule out the possibility of conflicting traffic. Until this work is accomplished, the cause of this accident cannot be truly established.
- An analysis of the facts and of the elevator control system’s design indicates that malfunctions in two PCAs on the right elevator may have precipitated the airplane’s dive. This dual PCA malfunction may have consisted of a latent or nearly latent failure in one PCA that may have existed for a period of time followed by a jam of a second PCA shortly before the dive.
- The facts do not support the initial, and widely reported, theory that the [relief] first officer deliberately dove the plane toward the ocean.
- Without further information concerning the data from military and FAA radar, one cannot rule out the possibility that the [relief] first officer may have been attempting to avoid or maneuver the aircraft out of a perceived dangerous situation at the time the dive occurred.

Boeing’s Submission

Boeing’s October 31, 2000, submission indicated that none of the mechanical failure modes examined during the investigation were consistent with the FDR data because (1) "the FDR elevator positions did not displace to the positions [predicted by the failure mode and effects analysis] during the initial pitchover" and (2) "the elevator motions after the initial pitchover indicate that both surfaces were functioning normally."

Boeing also considered several operational scenarios, including collision avoidance, rapid descents, response to engine oil pressure lights, and loss of thrust on both engines. Boeing's submission stated that, "EgyptAir 990 crew actions were determined to be inconsistent with the performance of standard Boeing recommended operating procedures and training for the 767 airplane."

In its submission, Boeing summarized its position as follows:

- Flight control surface movements recorded on the [FDR] are capable of generating the airplane flight path recorded by the [FDR] and radar.
- Based on the examination of the recovered wreckage, Boeing did not find any evidence of a failure condition within the airplane flight control system that could have caused or contributed to the initial pitchover, or prevented recovery from the dive.
- Boeing participated in examining all potential failure conditions developed during the investigation and could not find a failure condition that: (1) matched the data recorded by the [FDR] or (2) resulted in a condition that was not recoverable by the pilot.
- Therefore, Boeing does not believe that the loss of EgyptAir 990 was the result of a mechanical failure of the aircraft or aircraft systems.

EgyptAir's January 12, 2001, Response to Boeing's Submission

In its January 12, 2001, response to Boeing's submission, EgyptAir stated that Boeing did not "account for or…comment on" the FAA's ADs regarding bellcrank shear rivet failures in its submission. However, EgyptAir's response to Boeing's submission indicated that it could not determine whether the bellcrank shear rivet failures were involved in the accident, "[the FDR data were] remarkably consistent with test data of a jam of two right elevator servos in the trailing edge down position." EgyptAir further stated that "the differences between the test data and the FDR can be adequately explained as either performance variances within normal limit or limitations of the test facilities and protocols."

Additionally, EgyptAir's response to Boeing's submission indicated that there was evidence of a mechanical malfunction of the elevator system; specifically, EgyptAir cited the reported autopilot difficulties during an approach to LAX the day before the accident and the downward elevator deflections recorded by the FDR at autopilot disconnect. EgyptAir stated the following:

> [This evidence] shows that an anomaly existed in the flight 990 elevator system even before the aircraft left New York for Cairo on October 31, 1999—a latent

> defect that could not be detected by the crew. In light of these facts, it is plausible to believe that—just as [the captain of the flight into LAX] had done a day earlier—the [relief] first officer on flight 990 disconnected the autopilot after observing some unusual movement of the column.

The EgyptAir response to Boeing's submission also stated that examination of the recovered wreckage "indicated damage to the elevator system prior to impact." Specifically, EgyptAir asserted that the damage to the right outboard PCA (sheared pin and improperly positioned bias spring) and right elevator bellcrank shear rivets (failed in opposite directions) likely occurred before the airplane impacted the ocean.

Further, in its response to Boeing's submission, EgyptAir reiterated its position that its analysis of the elevator's motions[85] indicated that the elevator split observed in the FDR data was not the result of a struggle between the captain and the relief first officer. The response stated that the split "may [have been] the result of the loss of the right elevator." To support this statement, EgyptAir asserted that (1) there was no indication on the CVR transcript that a struggle occurred in the cockpit; (2) the uncommanded elevator positions might have resulted from unique aerodynamic phenomena as the airplane's speed increased; (3) when an FDR records elevator position, it is actually recording the sensor position, which does not, by itself, indicate the position of the elevator or the control column; and (4) the pitch and roll motions recorded during the last 15 seconds of FDR operation were "much closer to the expected aircraft performance if the right elevator is missing."

EgyptAir's response to Boeing's submission also stated the following:

> EgyptAir has determined that the FDR flight profile after the split is consistent with the expected aircraft performance only if the right elevator has departed the airplane….this conclusion is based upon the absence of expected rolling moment that would have been induced by a differential deflection of the elevators…shown on the FDR.

In addition, EgyptAir's response stated the following:

- Boeing's engineering simulator did not provide an accurate model of real aircraft performance.
- Boeing often ignored the more reliable ground test results.
- Boeing's selective use of test data resulted in inconsistent conclusions.
- Boeing's conclusions regarding crew actions are erroneous.

[85] For its analysis of the elevator motions, EgyptAir used the methods of Roskam (Airplane Design, Part VI, Roskam Aviation and Engineering Corporation).

In its response to Boeing's submission, EgyptAir summarized its position as follows:

- Boeing's submission to the NTSB [National Transportation Safety Board] dated October 31, 2000, contains many inaccuracies, omissions, and the selective use of evidence.
- Boeing's own ground test and simulator data does not support its conclusion that FDR data is inconsistent with a dual jam scenario.
- A dual PCA control valve failure on the right elevator is consistent with the EgyptAir flight 990 FDR data.
- There is physical evidence consistent with a malfunction in the elevator control system which might be a plausible cause for the accident.

P&W's Submission

In an October 6, 2000, letter, P&W stated that it believed that "the facts, as gathered to date, sufficiently represent Pratt & Whitney's perspective on this crash. Therefore, Pratt & Whitney will not be providing a further submission to be considered during the development of the final report."

ANALYSIS

General

The command captain and relief first officer were properly certificated and qualified and had received the training and off-duty time prescribed by applicable regulations and company requirements. (For more detailed information regarding the background and recent activities of all EgyptAir flight 990 crewmembers, see the Operational Factors Group Chairman's Factual Report and the Human Performance Group Chairman's Factual Report and their addendums.)

The accident airplane was properly certificated and was equipped, maintained, and dispatched in accordance with applicable regulations and industry practices.

The Safety Board's review of air traffic control (ATC) information revealed no evidence of any ATC problems or issues related to the accident. Further, examination of the recovered airplane wreckage and cockpit voice recorder (CVR), flight data recorder (FDR), ATC, weather, and radar data revealed no evidence that an encounter with other air traffic or any other airborne object was involved in the accident or that weather was a factor in the accident.

Examination of the wreckage revealed no evidence of preexisting fatigue, corrosion, or mechanical damage that could have contributed to the airplane's initial pitchover.[86] (The condition of the recovered elevator power control actuators (PCA) and bellcrank shear rivets is discussed in the next section titled, "Mechanical Failure/Anomaly Scenarios.") No evidence of explosion or fire damage or foreign object impact damage was found.

Additionally, the Safety Board's examination of the accident airplane's maintenance records revealed no evidence of any mechanical problems that could have played a role in the accident sequence. Although during interviews conducted at the request of the Egyptian Government more than 1 year after the accident an EgyptAir 767 captain reported that he had experienced autopilot difficulties in the accident airplane during the approach to Los Angeles International Airport (LAX), Los Angeles, California, the day before the accident, these difficulties were likely the result of improper autopilot approach mode selection. Additionally, as previously noted, neither the captain nor the first officer of the flight to LAX reported any autopilot anomalies in the airplane's maintenance logbooks, and the first officer of that flight did not mention any autopilot difficulties during interviews conducted 3 days after the accident. Although the captain reported several minor anomalies during these interviews (including an autopilot

[86] For additional information, see the Systems Group Chairman's Factual Report and its addendum and the Materials Laboratory Factual Report.

anomaly), he told investigators that the airplane was "almost perfect." No autopilot difficulties were reported by the flight crew that flew the airplane from LAX to John F. Kennedy International Airport (JFK), New York, New York, immediately before the accident flight nor did they report any autopilot anomalies in the airplane's maintenance logbooks. Further, the Board's examination of the FDR data before and after all recorded autopilot disconnects in the 25 hours of data recorded by the FDR (including the accident flight) revealed no evidence of abnormal autopilot or elevator surface behavior.

The Safety Board's review of ATC, FDR, CVR, and radar information indicated that the airplane's movements during the accident flight were routine until about 0149:54 (9 seconds after the autopilot disconnect occurred), when an abrupt sustained nose-down elevator motion occurred. A review of the FDR data indicated that the accident airplane's pitch motion before and during the accident sequence was consistent with the elevators' recorded movements. Boeing's full-flight engineering simulator was used to evaluate the consistency of the elevator positions with the pitch motions recorded on the FDR. During these evaluations, the elevator movements required to make the simulator duplicate the pitch motions recorded by the accident airplane's FDR and the flightpath developed from the available data closely matched the elevator movements recorded by the FDR. Further, the recorded load factors were consistent with the recorded movements of both elevator surfaces throughout the recorded data, even during the time that the data indicated a split between the left and right elevator surfaces (see figure 4).[87]

The results of the Safety Board's examination of CVR, FDR, radar, airplane maintenance history, wreckage, trajectory study, and debris field information were not consistent with any portion of the airplane (including any part of the longitudinal flight controls) separating throughout the initial dive and subsequent climb to about 25,000 feet mean sea level (msl). It is apparent that the left engine and some small pieces of wreckage separated from the airplane at some point before water impact because they were located in the western debris field about 1,200 feet from the eastern debris field. Although no radar or FDR data indicated exactly when (at what altitude) the separation occurred, on the basis of aerodynamic evidence and the proximity of the two debris fields, it is apparent that the airplane remained intact until sometime during its final descent. Further, it is apparent that while the recorders were operating, both elevator surfaces were intact, attached to the airplane, and placed in the positions recorded by the FDR data and that the elevator movements were driving the airplane pitch motion, and all associated recorded parameters changed accordingly.

Mechanical Failure/Anomaly Scenarios

The Safety Board evaluated possible mechanical failure and pilot action scenarios in an attempt to determine whether they were consistent with the elevator movements made during the accident sequence. As previously discussed in the section titled,

[87] The engineering simulator was modified to model the left and right elevator surfaces independently, and, using split elevator movements similar to those recorded on the FDR, the simulator was able to duplicate the FDR-recorded pitch history.

"Potential Causes for Elevator Movements During the Accident Sequence," the investigation ruled out all but four possible anomalies and failure scenarios as potential factors in the accident because they diverged too far from what was reflected on the accident flight's FDR to warrant further consideration.[88] Analysis showed that the effects of four failure scenarios (each of which involves dual failures) bore some resemblance to some portions of the accident flight's FDR data. Specifically, initially it appeared that each of these failure scenarios could potentially cause nose-down elevator movements or a split elevator condition that might resemble those recorded on the accident flight's FDR. Those four failure scenarios were (1) disconnection of the input linkages to two of the three PCAs on the right elevator surface,[89] (2) a jam of the input linkages or servo valves in two of the three PCAs on the right elevator surface,[90] (3) a jam of the input linkage or servo valve in one PCA and the disconnection of the input linkage to another PCA on the right elevator surface,[91] and (4) a jam in the elevator flight control cable connecting the right-side control column to the right aft quadrant assembly combined with a break in the same cable.[92] Therefore, the wreckage from the accident airplane was examined for possible evidence of PCA anomalies, and the predicted elevator movements resulting from these failure scenarios were evaluated and compared with the data from the accident flight.

As previously mentioned, one of the recovered PCAs was found with a pin (that attached the spring guide to the servo valve slide) sheared and one coil of the bias spring improperly positioned over the head portion of the spring guide. However, there were no marks on any of the surfaces or any deformation of the spring coil to suggest that the spring coil had become jammed between the servo cap and the spring guide, as would be expected if such a jam had occurred.[93] Moreover, investigators measured the clearances between these components and determined that those clearances were large enough that even if a coil of the bias spring had become misplaced between the spring guide and the servo valve cap, no jam would have resulted.[94] Further, the FDR data preceding the accident sequence do not show any evidence of a single jammed PCA.[95]

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[88] For additional information, see Systems Group Chairman's Factual Report and its appendixes.

[89] This would result in the failed surface moving to a nose-down deflection of about 6º and the nonfailed surface remaining at its prefailure position.

[90] This would result in the failed surface moving to a nose-down deflection of about 6º and the nonfailed surface moving to a nose-down deflection of about 4º.

[91] This would result in the failed surface moving to a nose-down deflection of about 6º and the nonfailed surface moving to a nose-down deflection of about 2.1º.

[92] This would result in the left elevator moving to a nose-down deflection of between 1.2º and 3.9º and the right elevator moving to a nose-down deflection of between 1.4º and 5.0º (depending on which variation of this scenario is being tested).

[93] As previously mentioned, the Safety Board recognizes that a jam between two surfaces can occur without leaving any physical evidence. However, as discussed in the Board's report on the accident involving USAir flight 427, physical evidence of a jam would be expected if a hardened steel component (such as the bias spring in this case) were to become jammed between two surfaces because such evidence was always observed after tests involving hardened steel chips jammed/sheared in a PCA.

[94] Even if two coils of the spring had somehow become displaced into the space between the spring guide and servo valve cap wall, there would still have been sufficient clearance to avoid a jam.

Most of the recovered elevator control linkages were broken; however, this type of damage is typical following a high-speed water impact and underwater wreckage recovery operations. The shear rivets in the recovered elevator bellcrank assemblies were sheared in different directions; however, the Safety Board considers it likely that the rivets sheared as a result of impact or recovery-related forces. Nonetheless, on the basis of the examination of the structure alone, the absence or presence of a jammed or disconnected input linkage or a jam in the servo valve in one of the accident airplane's elevator PCAs could not be established.

However, ground tests, studies, and calculations showed that each of the first three failure scenarios would have resulted in airplane and flight control movements that were inconsistent with the accident airplane's elevator movements. Specifically, each of those three failure scenarios would have caused the failed elevator surface to move to, and remain at, a position consistent with a single functioning PCA operating at 100 percent of its maximum force. The failed elevator surface would resist being backdriven with a force equivalent to about 130 percent of a single functioning PCA and would not have responded to nose-up flight control inputs. If one of these scenarios occurred at the accident airplane's indicated airspeed at the time of the initial dive (280 knots), the failed elevator surface would have initially moved from its prefailure position (close to neutral) to about a 6º nose-down position.[96] However, the initial elevator movement (for both elevator surfaces) on the accident airplane recorded during the accident sequence was to a nose-down position of only about 3.6° .[97]

The Safety Board also compared the recorded elevator movements following the initial upset to elevator movements resulting from the first three failure scenarios. As the airplane's speed increased after the initial upset, the maximum deflection value associated with the three failure scenarios would have decreased in response to the increased aerodynamic forces on that surface. However, subsequent movements of both elevator surfaces on the accident airplane deviated repeatedly, for sustained periods of time in both the nose-up and nose-down directions,[98] from the maximum deflection values that the failure scenarios would have produced, at times exceeding the maximum deflection values by several degrees. As shown in figure 2, the elevator movement profile from the accident

[95] FDR and ground test data indicated that a single PCA failure would have resulted in much higher offsets between the two elevator surfaces than were recorded during the accident flight and on the ground before takeoff. During the accident flight, the slight offset that was recorded by the FDR was only 47 percent of the offset that would be expected if a latent single PCA failure had occurred. On the ground before takeoff, the recorded offset was only 27 percent of what would be expected if a latent single PCA failure had occurred.

[96] As previously discussed, failure scenarios resulting in nose-up motions of the elevators were also possible but were not considered relevant to this accident investigation.

[97] As discussed in the section titled, "Accident Sequence Study," the initial deflection for the left elevator surface was about 3.4º, and the initial deflection for the right elevator surface was about 3.8º. As shown in the graphical representations of the recorded elevator positions, a position of about 6º can be easily distinguished in the data from a position of either 3.4º or 3.8º.

[98] The failure scenarios would not preclude additional commanded nose-down movement of the failed elevator surface. However, commanding additional nose-down movements would be inconsistent with an attempt to recover the airplane.

flight differs significantly throughout the accident sequence from the elevator movement profile that would have resulted from any of these three failure scenarios,[99] indicating that neither elevator surface on the accident airplane was limited by a mechanical failure but, rather, that both surfaces were responding normally to flight control inputs. Therefore, the first three failure scenarios are inconsistent with the elevator movements recorded after the initial upset.

Similarly, the elevator movements that would have followed any variant of the fourth failure scenario are also inconsistent with the accident airplane's recorded elevator movements after the initial upset. The Safety Board notes that, in one of the four variations of this scenario (a jam in the aft portion of the elevator control cable combined with a cable break forward of the jam), the initial elevator positions match those on the accident airplane. However, this similarity between the failure scenario and the accident airplane's elevator movements lasts only a few seconds. For the remainder of that variation of the scenario (and for the entire duration of the other three variations of this failure scenario), the elevator positions are inconsistent with those of the accident airplane.

In addition, if one of the first three failure scenarios had occurred, the nonfailed surface would have responded immediately to any nose-up flight control inputs from either control column and would have resulted in an increase in the magnitude of the difference between the two elevator surface positions (because the failed surface would remain at its failure-induced position). If the fourth failure scenario had occurred, both elevator surfaces would have responded immediately to nose-up inputs from either control column. However, the FDR data from the accident flight showed that there was no significant nose-up elevator movement or difference between the two elevator surface positions for the first 28 seconds of the accident sequence—until the captain returned to the cockpit.[100] If a failure had actually occurred, this would indicate that no attempts were made to recover the airplane for the first 28 seconds after the initial pitchdown. Further, after the captain returned to the cockpit, both elevator surfaces began moving together in the nose-up direction, indicating that neither surface was limited by a mechanical failure but, rather, that both surfaces were responding normally to flight control inputs. Similarly, later in the accident sequence, when the elevator split occurred, the right elevator deflected well beyond the maximum position possible for a failed elevator surface in any

[99] The Safety Board recognizes that there was some uncertainty in the aerodynamic hinge moment data used to calculate the elevator movement profiles for the failure scenarios depicted in figure 2, especially at Mach speeds greater than 0.91. However, for the initial elevator movement on the accident flight to match the elevator deflections in response to the failure scenarios, the aerodynamic hinge moment data used to calculate the failure scenario profiles would have to have been about 79 percent greater than assumed. The Board considers this amount of error to be extremely unlikely, particularly because the initial elevator movement occurred below Mach 0.91, where hinge moment data were validated by certification flight tests.

[100] As previously mentioned, throughout the FDR data for the accident airplane (including data recorded during uneventful portions of the accident flight and during previous flights and ground operations), small (less than 1°) differences between the left and right elevator surface positions were observed. Even where these offsets were observed, the elevator surfaces always moved in the same direction about the same time. However, beginning at 0150:21, the elevator surfaces moved in opposite directions and remained there until the FDR ceased recording.

of the first three failure scenarios. However, the elevator movements during the split are well within the limits of a pilot-commanded movement.

After reviewing all of the inconsistencies between the effects of the four potential failure scenarios evaluated in depth, the actual behavior of the airplane, and the controllability of the airplane in the event of such failures, the Safety Board determined that none of these failure scenarios occurred during the accident sequence.[101] Therefore, these four failure scenarios can be ruled out along with all of the other potential failure scenarios considered during this investigation.

The Safety Board also conducted simulations in which pilots from Boeing, EgyptAir, the Federal Aviation Administration (FAA), and the Board evaluated the controllability of the airplane following an initial upset that might have been caused by any of these failure scenarios. During these simulations, the pilots were consistently able to regain control of the airplane and return it to straight and level flight using normal piloting techniques, and the airplane could be trimmed to hands-off level flight. In fact, the 767's redundant actuation system is designed to allow pilots to overcome dual failures such as these.

Even though increased control forces were necessary, recovery could be accomplished by a single pilot using either the left or right control column.[102] Further, the simulations also demonstrated that the airplane could climb to about 25,000 feet msl with the engines shut down, even with the speedbrakes extended. The simulation also documented that the engines could have been promptly restarted and (assuming there were no opposing pilot inputs) that the airplane could have been recovered during the climb after the recorders stopped recording. Although the Safety Board recognizes that the simulator did not duplicate the accident airplane's actual flight conditions in every way,[103] such limitations are not uncommon in simulations, and the Board takes those limitations into account when evaluating simulator results. In this case, the Board determined that the differences were not significant and did not affect the validity of the results of the simulations.

Immediately after the airplane's initial nose-down dive, the relief first officer would have felt an immediate uncomfortable sensation as the airplane's load factor decreased to near 0 Gs. He should also have noted sudden changes in the airplane's pitch attitude, pitch rate, airspeed, and altitude. In response to these obvious cues, the relief first officer did not attempt to counter the dive by commanding nose-up elevator, a largely intuitive pilot response to initiate a recovery.

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[101] Further, although the first three failure scenarios evaluated in depth involved simultaneous dual PCA failures at the start of the accident sequence, as previously discussed, it is also clear from the FDR data that no latent jam of a single PCA occurred before the accident sequence.

[102] As a former chief flight instructor with 5,191 hours in the 767, the relief first officer should have been readily able to regain control of the airplane.

[103] For more information about the limitations of Boeing's simulator, see the section titled, "Potential Causes for Elevator Movements During the Accident Sequence."

Nor did the relief first officer exhibit any audible expression of anxiety or surprise or call for help during the airplane's initial dive or at any time during the remainder of the recorded portions of the accident sequence. Further, the relief first officer did not respond to the captain's repeated question, "What's happening?" after the captain returned to the cockpit. Rather, he continued his calm repetitions of the phrase "I rely on God" (which began about 74 seconds before the airplane's dive began) for 2 to 3 seconds, and then became silent, despite the captain's repeated requests for information. The absence of any reaction from the relief first officer (such as anxiety or surprise, a nose-up elevator input to regain control of the airplane, or a request for assistance) to the airplane's sudden departure from cruise flight to a steep descent is not consistent with his encountering an unexpected mechanical problem. Whereas the captain's audible alarm and the content of his statements in reaction to the situation upon returning to the cockpit were consistent with the reaction of a pilot who has encountered an unexpected flight condition, the passive behavior of the relief first officer was not.

The primary radar data indicated that the airplane climbed for about 40 seconds after the FDR stopped recording before it rapidly descended again and impacted the ocean. Therefore, the relief first officer and captain had about 83 and 69 seconds, respectively, from the time the airplane began its initial nose-down pitch until it began its second (final) descent, in which to regain control of the airplane; return it to level flight and restart the engines; or at least establish the airplane in a gradual, controlled glide while attempting an engine restart. (If control of the airplane had been regained during this time, the flight crew would have had several minutes in which to restart the engines.) However, a successful recovery—although possible—was not accomplished.

In summary, the investigation did not reveal any evidence of a failure condition within the airplane's elevator system that would have caused or contributed to the airplane's initial pitchover or prevented the flight crew's successful recovery from the airplane's rapid descent. Further, the relief first officer's reaction was inconsistent with his having encountered an unexpected airplane anomaly. Therefore, the investigation determined that neither the nose-down elevator movements nor the failure to recover from those movements could be explained by a mechanical failure.

Pilot Action Scenario

Simulations showed that certain combinations of pilot inputs could result in elevator motions consistent with those recorded by the accident airplane's FDR and a flightpath consistent with the FDR and radar data for the accident airplane.[104] Therefore, the Safety Board evaluated the actions of the pilots as recorded on the CVR, in the context of all of the evidence gathered in this investigation, to determine whether pilot action provided a possible explanation for the accident scenario.

[104] For additional information, see Systems Group Chairman's Factual Report and its appendixes and addendums, Flight Data Recorder Group Chairman's Factual Report and its attachments, Cockpit Voice Recorder Group Chairman's Factual Report and Sound Spectrum Study, and Aircraft Performance Group Chairman's Aircraft Performance Study and its attachments and addendum.

Events Before and During the Initial Descent, While the Relief First Officer Was Alone in the Cockpit

About 20 minutes after takeoff (about 0140), the relief first officer suggested that he relieve the command first officer. A transfer of control this early in the flight was contrary to the EgyptAir practice typically agreed-upon by flight crews of waiting until 3 or 4 hours into the flight before relieving the command crewmembers. The command first officer initially reacted with surprise and resistance to the relief first officer's suggestion that he assume first officer duties at that time, indicating that the relief first officer's suggestion was unexpected. However, after some discussion, the command first officer agreed to the change, and sounds recorded by the CVR indicated that, about 0142, the command first officer vacated and the relief first officer moved into the first officer's seat.

About 0147, the relief first officer asked an unidentified crewmember to return a pen to another first officer, who was in the cabin. The unidentified crewmember agreed and left the cockpit. At 0148:03, the command captain excused himself from the cockpit, saying that he wanted to "take a quick trip to the toilet…before it gets crowded." While the command captain was excusing himself, the CVR recorded the sound of an electric seat motor, presumably the captain's, as he maneuvered to leave his seat and the cockpit.[105] At 0148:18.55, the CVR recorded a sound similar to the cockpit door operating.

The Safety Board considered whether another flight crewmember might have been in the cockpit with the relief first officer during this time period. However, careful laboratory examination of the CVR recording indicated that the CVR did not record any speech or human sounds other than those attributed to the captain and relief first officer from 0148:30 until the end of the recording at 0150:38.47.[106] The Board determined that the possibility that another person, especially a pilot, was present during the airplane's sudden transition from cruise flight to steep descent and did not audibly express surprise at the abrupt change in the flight situation (as the captain did when he returned to the cockpit) or offer help/suggestions on how to deal with the emergency situation was extremely unlikely. Therefore, the evidence indicates that the relief first officer was alone in the cockpit from about 0148:19, when the command captain left the cockpit, to 0150:06, when he returned to the cockpit.

Ten seconds after the unintelligible comment was made (at 0148:40), the relief first officer stated quietly, "I rely on God." At 0149:18, the CVR recorded a "whirring

[105] This electric seat motor was recorded by the cockpit area microphone (CAM) but not by the hot microphone at the first officer's position, which (as previously discussed) was likely stowed at the first officer's side of the airplane. Because of its position on the right side of the airplane and its directionally sensitive nature, it is likely that all seat motions recorded by the hot microphone at the first officer's position after 0141 represented motions of the right seat.

[106] As previously discussed, about 0148:30, the CVR recorded an unintelligible comment that could not positively be attributed to any previously identified crewmember. Two speech characteristics of the unintelligible comment (fundamental frequency and formant dispersion) more closely resembled values displayed by the relief first officer than by the other voices evaluated.

sound similar to [the] electric seat motor operating." Because the relief first officer's seat was likely moved into an aft position because the command first officer had vacated the seat, and in light of the autopilot disconnect and subsequent flight control movements, the whirring sound is consistent with the relief first officer moving his seat forward into a position from which he could manually fly the airplane.[107] Thus, all manual flight control inputs made after 0148:19, until the command captain's return to the cockpit at 0150:06, must have been made by the relief first officer.

The absence of an autopilot disconnect warning tone on the CVR recording when the autopilot disconnected at 0149:45 is consistent with the autopilot being manually disconnected by rapidly double-clicking on the control yoke-mounted autopilot disconnect switch. Because the relief first officer was alone in the cockpit, the evidence indicates that he manually disconnected the autopilot. The Safety Board's examination revealed no evidence in the CVR, FDR, ATC, or radar data of any system malfunction, conflicting air traffic, or other event that might have prompted the relief first officer to disconnect the autopilot; therefore, there was no logical operational reason for the relief first officer to disconnect the autopilot while in cruise flight over the ocean. Further, as previously stated, the Board's testing and evaluation of the 767 elevator system showed that none of the failure modes examined during this investigation would have resulted in control column movements without concurrent identifiable movements of the elevators, which would have been observed in the FDR data. The FDR did not record any unusual or alarming elevator movements before the autopilot was disconnected; therefore, it is unlikely that the relief first officer was prompted to disconnect the autopilot because he sensed unusual control column movements.

Aside from some very slight elevator movements and a very gradual left roll, the airplane remained in level flight at flight level 330 for about 8 seconds after the autopilot was disconnected. As previously discussed in the section titled, "767 Autopilot Information," such slight movements are normal and expected when the autopilot is disengaged and the pilot takes manual control of the airplane. There was no indication of an upset or loss of control at this time.

At 0149:48, the relief first officer again quietly stated, "I rely on God." At 0149:53, the throttle levers were retarded (moved from their cruise power setting to idle). This throttle lever movement occurred at a rate that was more than twice that which the autothrottle can command. Further, the throttle levers moved 10º to 15º beyond the minimum position that the autothrottle would have been able to command at the existing flight conditions to the throttle levers' full aft idle stop, about 33º.[108] Movement of the throttles aft of the autothrottle commanded position requires a manually applied force of about 9 pounds on the throttle levers to override the autothrottle servomotor clutch. Thus, it is apparent that the throttle lever movements at 0149:53 were caused by the relief first officer's manual inputs and were not the result of autothrottle commands.[109]

[107] This electric seat motor sound was recorded by both the CAM and the hot microphone at the first officer's position, further confirming that this sound represented a motion of the relief first officer's seat.

[108] This throttle lever position was consistent with manually input throttle lever positions recorded by the FDR earlier in the accident flight.

At 0149:54, the FDR recorded a very slight movement of the inboard ailerons and both elevator surfaces beginning to rapidly pitch nose down (to about 3.6° nose-down deflection). The nose-down elevator movement began after the throttle levers started to move to idle; therefore, the relief first officer did not move the throttle levers to idle in response to the nose-down elevator movement. As previously noted, the relief first officer did not audibly express surprise or seem anxious or disturbed by the airplane's sudden and extreme nose-down movement or the reduction in load factor to near 0 G, nor did he call for help during the accident sequence. Again, there was no evidence in the CVR, FDR, ATC, or radar data of any system malfunction, conflicting air traffic, or other event that would have prompted the relief first officer to adjust the throttle levers at all, let alone take an action as drastic as moving the throttle levers to the idle position while in cruise flight at night over the ocean or to then command a sustained nose-down elevator movement.

About 11 seconds after the initial nose-down movement of the elevators, the FDR recorded additional (larger) movements of the inboard ailerons and the elevators started to move further in the nose-down direction, decreasing the airplane's load factor to negative G loads. The relief first officer would have been gripping the control wheel with his hand(s) when he applied these significant nose-down elevator control column inputs. It is unlikely that he could make such significant control column inputs without (intentionally or unintentionally) also affecting the control wheel's lateral position and thus providing some input to the ailerons. Therefore, these inboard aileron movements, and those that occurred at 0149:54 (both of which were coincident with changes in the relief first officer's inputs to the control column), are consistent with evidence indicating that the relief first officer was providing manual inputs to the flight controls during the accident sequence.

Events After the Command Captain Returned to the Cockpit

Immediately after this increase in nose-down elevator movement, at 0150:06, the CVR recorded the command captain exclaiming, "What's happening? What's happening?," as he returned to the cockpit.[110] At 0150:08, the captain repeated his question. While the captain was still speaking and moving toward his seat in the forward portion of the cockpit (at 0150:07 and again at 0150:08), the relief first officer quietly repeated, "I rely on God."[111] However, the relief first officer did not answer the captain's question. The Safety Board considers it unlikely that the captain—who was likely

[109] The Safety Board notes that several of its incident and accident investigations (including EgyptAir flight 990) might have benefited from a visual record of cockpit images/events. On April 11, 2000, the Board issued Safety Recommendations A-00-30 and -31. Safety Recommendation A-00-30 asked the FAA to require that all aircraft operated under 14 *Code of Federal Regulations* (CFR) Part 121, 125, or 135 and currently required to be equipped with a CVR and FDR be retrofitted with a crash-protected cockpit image recording system by January 1, 2005. Safety Recommendation A-0-31 asked the FAA to require that all aircraft manufactured after January 1, 2003; operated under 14 CFR Part 121, 125, or 135; and required to be equipped with a CVR and FDR be equipped with two crash-protected cockpit image recording systems. The Board specified that the cockpit image recording system should have a 2-hour recording duration and be "capable of recording, in color, a view of the entire cockpit including each control position and each action…taken by people in the cockpit." Safety Recommendations A-00-30 and -31 are currently classified "Open—Unacceptable Response."

focusing on getting into his seat, troubleshooting the upset, and attempting to regain control of the airplane—would have suspected at this point that the relief first officer's actions were directly contributing to the airplane's dive.[112] Rather, the captain likely would have assumed that the relief first officer was also attempting to regain control of the airplane and would work cooperatively with him.

As previously discussed, the relief first officer's passive behavior in response to the airplane's nose-down movements and the captain's questions is not consistent with what would be expected from a pilot who was dealing with an unexpected or undesired airplane problem. To the contrary, the timing of the increased nose-down elevator movement and the corresponding decrease in load factor was consistent with the relief first officer having increased the forward control column pressure when the captain returned to the cockpit.

At 0150:15, as the airplane continued to descend rapidly in a 40° nose-down attitude, the captain again asked, "What's happening, [relief first officer's first name]? What's happening?" Again, the relief first officer did not respond to the captain's question. Although the relief first officer remained unresponsive to the captain's queries, there is no specific evidence to indicate that the captain suspected at this point that the relief first officer's actions were causing the airplane's dive.

At the same time, as the airplane was descending through about 27,300 feet msl, both elevator surfaces began moving to reduced nose-down deflections. Shortly thereafter, the airplane's rate of descent began to decrease. Because there was no evidence that the relief first officer had attempted to regain control of the airplane before this, the Safety Board considers it likely that these movements were the result of nose-up flight control inputs made by the captain after he returned to the cockpit.[113] Six seconds later

[110] Although the CAM recorded all of the captain's remarks, the "What's happening? What's happening?" comments at 0150:06 were of a poorer recording quality and less audible than similar remarks made at 0150:08 and 0150:15. The evidence from both microphones was consistent with the captain speaking from outside the cockpit or the rear portion of the cockpit when he made the earlier statement and from the forward portion of the cockpit when he made the later statements, suggesting that the captain was moving forward as he made these statements. Further, the content and tone of the captain's statements were consistent with his trying to understand an unexpected situation upon his return to the cockpit.

When the captain asked, "What's happening? What's happening?" at 0150:06, his words were not recorded by the hot microphone at the first officer's position; however, the hot microphone recorded the captain's subsequent remarks until it stopped recording cockpit conversation at 0150:25. (None of the relief first officer's comments during the accident sequence were recorded by the hot microphone. For additional information, see the section titled, "Audio Information Recorded by First Officer's Hot Microphone.")

[111] The Safety Board considers it likely that the captain never heard any of the relief first officer's "I rely on God" statements. None of these statements were recorded by the hot microphone at the first officer's position, suggesting that they were spoken very quietly. (By contrast, the hot microphone at the first officer's position did record the captain's statements of "What's happening?" as he moved to his seat at the forward portion of the cockpit [at 0150:08] and again after he was seated in his seat [at 0150:15], despite the fact that the captain was farther from that hot microphone.)

[112] The visual difference between pushing forward on the control column and pulling aft on the control column to create elevator movements of the magnitude recorded on the FDR would not have been readily apparent to the captain in the darkened cockpit during the unexplained crisis, especially when he was trying to understand the many abnormal events and sensations that were occurring during the dive.

(at 0150:21), both elevator surfaces passed through their neutral positions into nose-up deflections. However, less than 1 second later, the right surface reversed its motion and moved back in the nose-down direction, and the left surface continued to move in the nose-up direction.

According to Boeing's tests and research, with the elevator PCAs operating normally, the accident airplane's elevators would have only been minimally affected by the aerodynamic forces that would have resulted from the small sideslip angle, roll rates, and the Mach numbers that existed during the accident sequence. Therefore, it follows that the elevator split recorded by the FDR was the result of flight control inputs to each elevator surface and not the result of aerodynamic forces on those surfaces.[114] (In contrast, Boeing indicated that an outboard aileron split recorded between 0150:27 and 0150:32 could be explained by the aerodynamic effects of the small sideslip angles and roll rates calculated to have been present at that time.)[115]

Testing confirmed that the left and right elevator surfaces could be moved in different directions by differential column movements from the relief first officer and captain in the cockpit. As intended by the elevator control system design, the elevators would split, each surface following the movements of the control column on its side (the left elevator moving in response to the left column movement, and the right elevator moving in response to the right column movement). The opposing control column inputs likely existed during the 7 to 8 seconds before the elevator split (when both elevators were moving in a trailing-edge-up direction); however, the elevator split would not occur until the difference between the two control column forces was great enough to engage the override mechanism. Tests conducted in a 767 simulator and airplane (on the ground) demonstrated that pilots with heights and weights similar to those of the command captain and relief first officer could apply enough force on the control column to produce and maintain the split elevator condition recorded by the FDR.

The captain's actions just after the elevator split began were consistent with an attempt to recover the airplane and the relief first officer's were not. In rapid sequence,

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[113] During the Safety Board's tests and simulations, a pilot similar in height and weight to the EgyptAir flight 990 command captain was physically able to move from the aft cockpit into the captain's seat, to brace himself against the control console or floor structure, and to apply enough back pressure on the control column to match the physical pulling forces computed to have been required to generate the split elevator condition recorded by the FDR. However, the pilot stated that it was physically difficult or uncomfortable for him to manipulate the control column while kneeling on the floor or standing behind the captain's seat and suggested that, given his build and his need to manipulate the controls, the captain of EgyptAir flight 990 would almost certainly have attempted to enter his seat immediately upon his return to the cockpit.

As previously discussed, the simulator did not duplicate the accident airplane's actual flight conditions in every way; for example, the simulator did not duplicate the negative G loads recorded by the FDR. However, once the captain was normally seated and effectively braced, these forces should not have substantially affected the maximum fore-and-aft forces he could generate. Further, the G loads on the accident airplane did not remain negative for long; FDR data show that the G loads increased to greater than 1/2 G within 2 to 3 seconds of the start of the recovery.

[114] For additional information, see Boeing's April 16, 2001, letter in the public docket for this accident.

[115] For additional information, see Boeing's April 12, 2001, letter in the public docket for this accident.

just after the elevator split began, the engine start lever switches were moved to the cutoff position, the throttle levers were advanced to full throttle, and the speedbrakes were deployed.[116] After the throttle levers were advanced (but the engines did not respond), the captain reacted with surprise, asking the relief first officer, "What is this? What is this? Did you shut the engine(s)?"[117] The timing and direction of the left elevator motions during this time suggest that the captain, who had likely been using both hands to pull aft on the left control column, released his right hand to advance the throttles and deploy the speedbrakes, resulting in a decrease in his total aft pressure on the control column, which was reflected in the decrease in the left elevator's nose-up deflection that was recorded by the FDR at this time. Subsequently, when the captain likely had returned his right hand to the control column, the FDR recorded a corresponding increase in the left elevator's nose-up deflection. As previously stated, tests and simulations demonstrated that a pilot seated in the captain's position could easily have advanced the throttles, moved his hand a little to the left, and deployed the speedbrakes in the 3 to 4 seconds it took for these events to occur.

Concurrent with the brief downward motion of the left elevator that was recorded when the throttles were advanced and the speedbrakes deployed, a brief downward motion of the right elevator was recorded. This movement of the right elevator suggests that when the captain's aft pressure on the left control column decreased, the relief first officer's sustained forward pressure on the right control column caused that column to move forward briefly. Although it would have been physically possible for the relief first officer to have advanced the throttles and deployed the speedbrakes, the evidence does not support the notion that the relief first officer performed these actions. Rather, the evidence indicates that the relief first officer moved the engine start lever switches to the cutoff position (a counterproductive action, in terms of recovery), whereas the captain deployed the speedbrakes in an attempt to arrest the airplane's descent.

Additionally, the surprised reaction from the captain when the engines did not respond to the throttle movement ("What is this? What is this? Did you shut the engine(s)?") suggested that it was he (not the relief first officer) who advanced the throttle levers. This response clearly indicated that the captain was unaware that the engine start lever switches had been moved to the cutoff position, that such an action was at odds with his intentions, and that it was, therefore, not part of a mutual, cooperative troubleshooting exercise between the captain and relief first officer.

At 0150:26.55, the captain stated, "Get away in the engines," and at 0150:28.85, he stated, "shut the engines."[118] At 0150:29.66, the relief first officer responded for the first (and only) time after the captain returned to the cockpit, stating, "It's shut."

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[116] Tests and simulations demonstrated that the magnitude of the elevator split would vary, but a split could be maintained even when the pilot in the left seat temporarily removed his right hand from the control yoke to advance the throttles and deploy the speedbrakes and the pilot in the right seat temporarily removed his left hand from the control yoke to move the engine start lever switches to the cutoff position.

[117] The Safety Board notes that the captain's statement "What is this? What is this? Did you shut the engine(s)?" might reflect the beginning of a suspicion that the relief first officer's actions were not appropriate for recovery.

Between 0150:31 and 0150:37, the captain repeatedly asked the relief first officer to "pull with me" on the control column. However, the FDR data indicated that the elevator surfaces remained in a split condition (with the left surface commanding nose up and the right surface commanding nose down) until the last data were recorded by the FDR at 0150:36.64.

As with the earlier portion of the accident sequence (before the captain's return to the cockpit), the relief first officer's responses during this portion of the accident sequence did not indicate that he was surprised or disturbed by the events. Similarly, his rate of speech and fundamental frequency when he repeated, "I rely on God," and stated, "It's shut," did not indicate any significant increase in his level of psychological stress. In contrast, the captain's fundamental frequency was about 65 percent higher when he repeatedly asked the relief first officer to "pull with me" during the elevator split period than it was during routine flight, reflecting an increased level of psychological stress.

As previously discussed, simulations showed that even if a failure condition had affected the elevator system, it would have been possible to regain control of the airplane at any time during the recorded portion of the accident sequence and to have restarted the engines and recovered the airplane during the climb after the recorders stopped. However, those simulations assumed that there were no opposing pilot inputs. The captain's failure to recover the airplane can be explained, in part, by the relief first officer's opposing flight control inputs. It is possible that efforts to recover the airplane after the airplane lost electrical power were also complicated by the loss of electronic cockpit displays.

In summary, the evidence establishes that the nose-down elevator movements were not the result of a failure in the elevator control system or any other airplane system but were the result of the relief first officer's manipulation of the airplane controls. The evidence further indicates that the subsequent climb and elevator split were not the result of a mechanical failure but were the result of pilot inputs, including opposing pilot inputs where the relief first officer was commanding nose-down and the captain was commanding nose-up movement. The Safety Board considered possible reasons for the relief first officer's actions; however, the Board did not reach a conclusion regarding the intent of or motivation for his actions.

[118] This sentence, "Get away in the engines," is an example of a phrase where direct translation of the Arabic words into English with no attempt to interpret or analyze the words resulted in an awkward or seemingly inappropriate phrase. In this case, it is possible that the captain, surprised to realize that the engines had been shut off, was trying to tell the relief first officer to leave the engines alone. However, research indicates that poor word choice, improper grammar, and the use of incomplete phrases can be symptomatic of high levels of psychological stress in a speaker.

Summary

1. The accident airplane's nose-down movements did not result from a failure in the elevator control system or any other airplane failure.

   There was no evidence of any failure condition within the elevator system of the accident airplane that would have caused or contributed to the initial pitchover or prevented a successful recovery.

   No mechanical failure scenario resulted in airplane movements that matched the flight data recorder data from the accident airplane.

   Even assuming that one of the four examined failure scenarios that the investigation evaluated in depth had occurred, the accident airplane would still have been recoverable because of the capabilities of the Boeing 767's redundant elevator system.

2. The accident airplane's movements during the initial part of the accident sequence were the result of the relief first officer's manipulation of the controls.

   At the relief first officer's suggestion, a transfer of control at the first officer's position occurred earlier than normal during the accident flight.

   The relief first officer was alone in the cockpit when he manually disconnected the autopilot and moved the throttle levers from cruise to idle; there was no evidence of any airplane system malfunction, conflicting air traffic, or other event that would have prompted these actions.

   The nature and degree of the subsequent nose-down elevator movements were not consistent with those that might have resulted from a mechanical failure but could be explained by pilot input.

   There was no apparent reason for the relief first officer's nose-down elevator inputs.

   The relief first officer's calm repetition of the phrase "I rely on God," beginning about 74 seconds before the airplane's dive began and continuing until just after the captain returned to the cockpit (about 14 seconds into the dive), without any call for help or other audible reaction of surprise or alarm from the relief first officer after the sudden dive is not consistent with the reaction that would be expected from a pilot who is encountering an unexpected or uncommanded flight condition.

   The absence of any attempt by the relief first officer to recover from the accident airplane's sudden dive is also inconsistent with his having encountered an unexpected or uncommanded flight condition.

   The relief first officer's failure to respond to the command captain's questions ("What's happening? What's happening?") upon the captain's return to the cockpit is also inconsistent with the reaction that would be expected from a pilot who is encountering an uncommanded or undesired flight condition.

3. The accident airplane's movements after the command captain returned to the cockpit were the result of both pilots' inputs, including opposing elevator inputs where the relief first officer continued to command nose-down and the captain commanded nose-up elevator movements.

   Nose-up elevator movements began only after the captain returned to the cockpit.

   Testing showed that recovery of the airplane was possible but not accomplished.

   Seconds after the nose-up elevator movements began, the elevator surfaces began moving in different directions, with the captain's control column commanding nose-up movement and the relief first officer's control column commanding nose-down movement.

   After the elevator split began, the relief first officer shut down the engines.

   The captain repeatedly asked the relief first officer to "pull with me," but the relief first officer continued to command nose-down elevator movement.

   The captain's actions were consistent with an attempt to recover the accident airplane and the relief first officer's were not.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the EgyptAir flight 990 accident is the airplane's departure from normal cruise flight and subsequent impact with the Atlantic Ocean as a result of the relief first officer's flight control inputs. The reason for the relief first officer's actions was not determined.

Attachment A

EgyptAir Flight 990 Cockpit Voice Recorder Transcript

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INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0119:13 **START OF RECORDING START OF TRANSCRIPT**			
		0119:20 **TWR**	...nine ninety heavy, the wind is two four zero at one zero, runway two two right, RVR is more than six thousand, runway two two right, cleared for takeoff.
		0119:32 **RDO-2a**	cleared for takeoff. confirm climbing six thousand?
		0119:36 **TWR**	negative sir. the runway two two right RVR is more than six thousand. you fly the Gateway Climb, climbing to five thousand.
		0119:43 **RDO-2a**	following Gateway, clear for takeoff runway two two right, EgyptAir nine nine zero heavy.
0119:45 **CAM-?**	okay.		
0119:52 **CAM-?**	***.		
0119:54 **CAM-1a**	cabin crew advised?		
0119:54 **HOT-2a**	in the name of God, the Merciful, the Compassionate. cabin crew takeoff position.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0119:58 **CAM**	[sounds similar to increase in engine RPM]		
0120:07 **CAM**	[sounds similar to nose wheel traveling over bumps on runway]		
0120:19 **HOT-2a**	eighty knots, throttle hold.		
0120:22 **CAM-1a**	cross check.		
0120:40 **HOT-2a**	V one.		
0120:41 **HOT-2a**	rotate.		
0120:42 **HOT-2a**	positive rate of climb both side.		
0120:46 **CAM-1a**	gear.		
0121:06 **HOT-2a**	one thousand.		
		0121:07 **TWR**	EgyptAir nine ninety heavy contact departure now one two five point seven.
		0121:11 **RDO-2a**	one two five seven, bye.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		0121:14 **RDO-2a**	departure, EgyptAir nine eight nine in your frequency.
		0121:18 **DEP**	EgyptAir nine ninety heavy New York you're radar contact, climb and maintain uh, one three thousand.
		0121:25 **RDO-2a**	climbing one three thousand, nine nine zero.
0121:40 **CAM-?**	***.		
0121:41 **CAM-1a**	flaps *.		
0121:45 **CAM**	[sound similar to flap handle movement]		
0121:52 **CAM-?**	** two sixty.		
		0121:57 **DEP**	EgyptAir nine ninety heavy turn left then proceed direct to SHIPP.
		0122:00 **RDO-2a**	direct SHIPP, nine nine zero heavy.
0122:05 **HOT-2a**	turn right direct SHIPP, execute sir?		
0122:08 **CAM-1a**	did he tell you turn left?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0122:08 **HOT-2a**	yes, establish.		
0122:11 **CAM-1a**	flaps up.		
0122:15 **CAM**	[sound similar to flap handle movement]		
0122:16 **CAM-1a**	did you enter it or not yet?		
0122:17 **HOT-2a**	I entered it.		
0122:19 **CAM-?**	***.		
0122:28 **HOT-2a**	execute, execute?		
0122:31 **HOT-2a**	*.		
0123:32 **CAM-1a**	please reset the... okay.		
0123:35 **HOT-2a**	after take off.		
0123:39 **CAM-1a**	(after take off)		
0123:41 **HOT-2a**	landing gear lever off, flaps up, after takeoff checks complete.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0125:11 **CAM**	[brief interruption in audio similar to CVR tape splice]		
0125:20 **HOT-2a**	at your service, sir.		
0125:24 **CAM-?**	***.		
0125:26 **HOT-2a**	no, I didn't enter two nine zero. I entered three one zero.		
0125:32 **CAM-3**	that's why it gave you maximum altitude.		
0125:35 **HOT-2a**	I swear I entered three one zero.		
0125:40 **HOT-2a**	ten thousand climbing.		
0125:42 **CAM-1a**	thirty three.		
0125:48 **HOT-2a**	I had even entered two nine zero.		
0126:02 **HOT-2a**	we're already in the middle of the Atlantic...		
		0126:03 **DEP**	EgyptAir nine ninety heavy climb and maintain flight level two three zero and contact New York center one three four point five five.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		0126:10 **RDO-2a**	one three four five five, two three zero.
0126:14 **CAM-1a**	how much, two three zero?		
		0126:35 **RDO-2a**	New York, EgyptAir nine nine zero heavy, good evening.
		0126:39 **CTR1**	EgyptAir nine nine zero, go.
		0126:42 **RDO-2a**	your frequency.
		0126:46 **CTR1**	EgyptAir nine nine zero, go ahead.
		0126:47 **RDO-2a**	ah, approaching three thousand, up to flight level two three zero.
		0126:54 **CTR1**	roger.
0127:13 **CAM-3**	[unintelligible conversation in background]		
0127:51 **HOT-2a**	aaahhh.		
0127:52 **HOT-2**	[tone similar to cabin crew call chime]		
0127:54 **CAM-?**	[sounds similar to coughing]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0127:58 **CAM-3**	[unintelligible conversation in background]		
0129:14 **HOT-2a**	one zero one three.		
0129:20 **HOT-2a**	after takeoff (checks) complete.		
0129:28 **CAM-3**	the chart, Adel...		
0129:29 **HOT-2a**	what, sir?		
0129:31 **HOT-2a**	the chart, sir?		
0129:33 **CAM**	[unintelligible conversation in background]		
0129:33 **CAM-3**	the chart of the Atlantic.		
0129:39 **HOT-2a**	aye aye... would you like, sir, the atlas or the one... both available.		
0129:42 **CAM-?**	***.		
0129:48 **CAM**	[sound similar to rustling papers]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		0129:54 **CTR1**	EgyptAir nine ninety, say the altitude leaving.
		0129:57 **RDO-2a**	uh, leaving, approaching one niner zero, up two three zero.
		0130:04 **CTR1**	EgyptAir nine ninety, roger.
0130:07 **HOT-2a**	Mademoiselle, Madame, if you please, I want a bottle of water and a cup of coffee, two creams, yes, two creams, and one sugar. Captain Habashi, would you like to drink something? Captain Hatem, would you like to drink something?		
0130:23 **CAM-?**	[sounds similar to coughing]		
0130:45 **CAM-?**	[unintelligible conversation in background]		
0130:55 **CAM-?**	where is our chart?		
0130:57 **CAM-?**	[sounds similar to coughing]		
0131:05 **CAM-?**	[sounds similar to coughing]		
0131:19 **HOT-2a**	it seems that Samir left it, sir.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		0131:24 **CTR1**	EgyptAir nine ninety, New York one three two point one five.
		0131:29 **RDO-2a**	one three two one five, bye.
0131:33 **HOT-2a**	don't bother yourself, sir.		
		0131:39 **RDO-2a**	New York center EgyptAir niner niner zero heavy, good evening, approaching two two zero up two three zero.
		0131:47 **CTR2**	EgyptAir niner niner zero, New York center roger.
0131:54 **CAM-?**	[sounds similar to coughing]		
0132:03 **HOT-2a**	[sound similar to yawn]		
0132:06 **HOT-2a**	one thousand to level.		
0132:06 **CAM-3**	didn't he bring you the chart?		
0132:07 **HOT-2a**	what?		
0132:09 **CAM-3**	didn't he give you the chart?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0132:10 **HOT-2a**	no, I asked him,"where is our chart," and I think he put it on the drawer or...		
0132:17 **CAM-3**	he should have plotted for you ***.		
0132:18 **HOT-2a**	that guy was busy, the one who plots, he told me that I had come late.		
0132:25 **CAM**	[sound of click]		
0132:33 **CAM-3**	[unintelligible conversation]		
0132:51 **CAM**	[two high-low tones similar to cabin crew call chime]		
0132:58 **HOT-2a**	merci, sir.		
0133:00 **HOT-2a**	just a bottle of water.		
0133:01 **CAM-?**	[sounds similar to coughing]		
0133:05 **CAM**	[sound similar to cockpit door operating]		
0133:35 **CAM**	[sound of click]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0133:50 **CAM-3**	* Adel.		
0133:52 **HOT-2a**	merci, sir, excuse me.		
0133:55 **CAM-?**	*.		
0134:01 **HOT-2a**	thank you, sir. thanks.		
0134:04 **CAM**	[sound similar to cockpit door operating]		
0134:10 **CAM-?**	thank you, Commandant. may your blessings be multiplied.		
0134:11	[brief interruption in audio on all CVR channels]		
0134:13 **CAM-?**	[sound similar to clearing of throat]		
0134:15 **CAM**	[sound similar to cockpit door operating]		
0134:25 **HOT-2a**	Ayyad, if you want to take these things now, take them.		
0134:28 **CAM-4**	what?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0134:29 **HOT-2a**	If you want to take these things, take them.		
0134:31 **CAM-4**	(sure)		
0134:33 **CAM**	[sound similar to cockpit door operating]		
0134:44 **CAM-?**	*** .		
0134:53 **CAM**	[sound similar to cockpit door operating]		
0135:08 **HOT-2a**	what's new? what's wrong with you?		
0135:13 **CAM-1a**	that's nonsense.		
0135:14 **HOT-2a**	yeah, of course.		
0135:14 **CAM-1a**	quite frankly, that's nonsense. I don't accept it.		
0135:17	[brief interruption in audio on all CVR channels]		
0135:17 **HOT-2a**	a market, it's a market in the cockpit.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0135:20 **CAM-1a**	I don't accept this situation. never... you can't call that flying. by Great God, call it anything else. that has nothing to do with flying, this business... I didn't want to cause trouble for one reason only: just because Hatem is here and he will see before him how the situation is.		
0135:44 **HOT-2a**	Captain, you...		
0135:44 **HOT-2a**	all of this because of this good-for-nothing guy named Ayyad...		
0135:46 **CAM-1a**	what?		
0135:47 **HOT-2a**	this Ayyad who keeps saying Zulu Alpha... Zulu Alpha.		
0135:49 **CAM-1a**	I am aware of it.		
0135:50 **HOT-2a**	he sat here and entered three nine.		
		0135:52 **CTR2**	EgyptAir nine ninety climb and maintain flight level three three zero, cleared direct DOVEY.
		0135:57 **RDO-2a**	three three zero, direct DOVEY, EgyptAir nine nine zero.
0136:02 **CAM-1a**	between me and you this is not work, by God seriously.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0136:05 **HOT-2a**	no, not at all.		
0136:08 **CAM-1a**	Hisham is telling me that -- I don't know -- he has simulator tomorrow.		
0136:11 **HOT-2a**	execute... VNAV?		
0136:18 **CAM-1a**	you see, he is telling me he has simulator tomorrow... is that any good? he is coming straight from Los Angeles, you know, and he is going to have simulator.		
0136:26 **CAM**	[sound similar to cockpit door operating]		
0136:38	[brief interruptions in audio on all CVR channels]		
0136:42 **CAM-1a**	what's your opinion about the crowding on this plane?		
0136:44 **CAM-3**	what crowding?		
0136:47 **CAM-1a**	the crew that is aboard this plane.		
0136:50 **CAM-3**	there is one going back that has simulator and another whom I have told in Egypt to come back on the same airplane from Los Angeles direct to Egypt for training... what difference does it make?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
0136:59 **CAM-1a**	what?		
0137:00 **CAM-3**	what difference does it make?		
0137:00 **CAM**	[sound of squeak]		
0137:01 **CAM-1a**	no, it doesn't make any difference to me. I, I am saying that for their sake.		
0137:07 **CAM-3**	because those, you see, are not active.		
0137:08 **CAM-1a**	I know that. I didn't say anything. but I mean when you are surprised to see people about whom you don't know anything. It's good that you are here, you know. I don't know, I mean, anybody could...		
0137:24 **CAM-3**	isn't the extra crew written in the general dec?		
0137:28 **CAM-1a**	I mean, as long as you are here, there is no problem, you are here. if you were not here, anyone could tell me, "Captain Hatem," should I say okay?		
0137:38 **CAM-3**	no, I sent a telex concerning this operation.		
0137:40 **CAM-1a**	bravo for you.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0137:41 **CAM-3**	***.		
0137:41 **CAM-1a**	bravo for you, bravo for you, and what about the one that doesn't have?		
0137:45 **CAM-3**	what do you mean by the one that doesn't have?		
0137:46 **CAM-1a**	the one that comes aboard and doesn't have any document that says that he should board.		
0137:49 **CAM-3**	they're all reported to the station from Egypt, each with his own schedule. anyone who will come back should inform the station in Egypt.		
0137:55 **CAM-?**	[sound similar to clearing of throat]		
0137:57 **CAM-1a**	good, what about the one who comes back and nobody knows anything about him?		
0138:01 **CAM-3**	I gave my instructions in the station...		
0138:05 **CAM-1a**	fine. that's what I told them, I, I, I'm not a trouble maker. I mean you know me. I don't need any headache. I'm telling them I am looking after all your interests. when you all are covered, neither the station nor any pilot can argue with you all, and should anything happen to you, you see, nobody could say I know nothing about you.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0138:12 **CAM**	[sound similar to cockpit door operating]		
0138:28 **CAM-3**	why, why would I put anybody, Habashi?		
0138:28 **CAM-?**	yes.		
0138:31 **CAM-1a**	no, that's what I'm saying.		
0138:32 **CAM-3**	even if somebody makes a mistake, we'll cover him too.		
0138:35 **CAM-1a**	I'm not saying anything. I'm not saying anything but I get surprised by three, four people going back and I know nothing. everyone is telling me that he has work in Egypt *.		
0138:50 **HOT-2a**	may God make the seven six prosperous, Captain Habashi. tomorrow, we'll have a hard time up there. let us be, "Uncle Haj".		
0138:56 **CAM-1a**	why, "Uncle", by God?		
0138:58 **HOT-2a**	very sweet, may our Lord make it prosperous. sweet, sweet.		
0139:00 **CAM-1a**	have we ever shorted you? [sound of laughter]		
0139:01 **HOT-2a**	that's why I'm saying to you, sir, may our Lord make it prosperous, but we'll have a hard time...		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0139:04 **CAM-1a**	this man is saying, he's saying to you, "even the one that makes a mistake, I will cover him." I mean, where can you see someone who says that?		
0139:11 **HOT-2a**	so, why are you upset, Captain?		
0139:12 **CAM-1a**	I'm not upset, I'm only speaking because I'm actually finding people about whom I know nothing, that's why they got upset with me.		
0139:21 **HOT-2a**	the man didn't get upset or anything.		
0139:22 **CAM-1a**	no, I'm not talking about those. when I say, "people, please, anyone not scheduled on the plane should have something saying that he should board the plane," am I wrong in saying that? but I didn't tell anybody to board or not to board or, "you have it" or "you don't have it."		
0139:40 **CAM-3**	nobody can go back without receiving instructions.		
0139:43 **CAM-1a**	that's what I'm telling you...		
0139:45 **CAM-3**	nobody can go back like this on his own. nobody can go back without receiving instructions.		
0139:51 **CAM**	[sound similar to cockpit door operating]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0139:56 **CAM-1a**	how are you, Jimmy?		
0139:58 **CAM-2b**	how are you, sir?		
0139:58 **CAM-?**	*.		
0139:59 **CAM-1a**	what's new?		
0139:59 **HOT-2a**	I slept, I swear.		
0140:00 **CAM-2b**	just wait, let me tell you something. I'm not going to sleep at all. I might come and sit for two hours, and then...		
0140:07 **HOT-2a**	but I, I, I slept. I slept.		
0140:09 **CAM-2b**	you mean you're not going to get up? you will get up, go and get some rest and come back.		
0140:14 **HOT-2a**	you should have told me, you should have told me this, Captain Gamil. you should have said, "Adel...		
0140:16 **CAM-2b**	did I even see you?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0140:16 **HOT-2a**	... I will work first." just leave me a message. now I am going to sit beside you. I mean, now, I'll sit by you on the seat. I am not sleepy. take your time sleeping and when you wake up, whenever you wake up, come back, Captain.		
0140:28 **CAM-2b**	I'll come either way...		
0140:28 **HOT-2a**	Captain...		
0140:31 **CAM-2b**	come work the last few hours, and that's all.		
0140:35 **HOT-2a**	no... that's not the point, it's not like that, if you want to sit here, there's no problem.		
0140:37 **CAM-2b**	I'll come back to you, I mean, I will eat and come back, all right?		
0140:42 **CAM**	[sound similar to cockpit door operating]		
0140:43 **HOT-2a**	fine, look here, sir. why don't you come so that... you want them to bring your dinner here, and I'll go sleep.		
0140:49 **CAM-2b**	that's good.		
0140:52 **HOT-2a**	with your permission, Captain.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0140:56 **CAM**	[sound similar to cockpit door operating]		
0140:57 **HOT-2a**	[spoken in a soft voice] do you see how he does whatever he pleases?		
0140:59 **CAM-1a**	do you know why that is? that's because you all get upset with me.		
0141:03 **HOT-2a**	I'm not upset with you, what is it to me? [audio level from first officer's hot microphone system diminishes]		
0141:03 **CAM-1a**	I don't mean you specifically, Adel. son, you are...		
0141:07 **CAM-2a**	I mean I like you.		
0141:07 **CAM-1a**	look, are you a youngster?		
0141:09 **CAM-2a**	no, he does whatever he pleases. some days he doesn't work at all.		
0141:11 **HOT-2**	[rustling sound heard through first officer's hot microphone system]		
0141:12 **CAM-1a**	that's why I'm saying. you see, it's just like you heard. when I told him about those who want to go back, what did he say? he said, "never mind, I have them covered."		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0141:20 **CAM**	[sound similar to cockpit door operating]		
0141:20 **CAM**	[whirring sound similar to electric seat motor operating]		
0141:24 **CAM-1a**	the conversation just happened in front of you.		
0141:26 **CAM**	[sound of click]		
0141:28 **CAM-2a**	doesn't he want to work with Raouf, or what?		
0141:30 **CAM-1a**	it's possible, it's possible, God knows. look, you don't have a male or female camel tied up in this situation [figuratively meaning: you have no personal interest at stake], as they say. right? by the Prophet, he's just talking nonsense.		
0141:44 **CAM**	[sound similar to cockpit door operating]		
0141:45 **CAM-1a**	that's it.		
0141:46 **CAM-?**	enter, Monsieur.		
0141:47 **CAM-2a**	please, sir, do you need these, sir?		
0141:51 **CAM**	[sound similar to cockpit door operating]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		0141:52 **CTR2**	EgyptAir nine ninety, I have your oceanic when you're ready.
0141:55 **CAM-1a**	oceanic is ready? go ahead.		
		0141:57 **RDO-2a**	go ahead nine nine zero.
		0142:00 **CTR2**	EgyptAir nine ninety, you're cleared to Hotel, Echo, Charlie, Alpha, via after DOVEY, NAT TRACK Zulu, SANTIAGO. maintain flight level three three zero. maintain Mach point eight zero.
		0142:13 **RDO-2a**	EgyptAir nine nine zero, cleared to Cairo Zulu, TRACK Zolo, SANTIAGO three three zero, eight zero Mach, TRACK (message) identification, three zero four.
		0142:24 **CTR2**	EgyptAir nine ninety, readback correct.
		0142:26 **RDO-?**	[sound similar to brief unmodulated radio transmission]
0142:31 **CAM-2a**	everything's under control.		
0142:32 **CAM-2b**	what?		
0142:33 **CAM-2a**	everything's under control, Haj.		
0142:34 **CAM-2b**	okay, chief.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0142:35 **CAM**	[whirring sound similar to electric seat motor operating]		
0142:35 **CAM-1a**	thanks, Addul. [nickname for Adel]		
0142:39 **HOT-2**	[sound of clicks similar to seat belt buckle operating]		
0142:41 **CAM-2a**	** these things.		
0142:42 **CAM-2b**	all right, all right, go rest.		
0142:43 **CAM**	[sound of click]		
0142:43 **CAM-1a**	***.		
0142:44 **CAM-?**	[sounds similar to clearing of throat]		
0142:46 **CAM**	[sound of clunk]		
0142:47 **CAM-2a**	how many do you want ** ?		
0142:56 **CAM**	[sound of thump]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0142:59 **CAM-1a**	how are you, Jimmy?		
0143:00 **CAM-2b**	why did you bring up this subject again?		
0143:04 **CAM-1a**	look, it's the same story with these number threes... [reference to additional repositioning crewmembers]		
0143:07 **CAM**	[sound of click]		
0143:08 **CAM-1a**	... so when they fly as active crew... what are they going to do?		
0143:09 **CAM**	[whirring sound similar to electric seat motor operating]		
0143:11 **CAM-1a**	you tell me.		
0143:12 **CAM-2b**	it's disorganized.		
0143:13 **CAM-1a**	no, that's why I mentioned it to him.		
0143:14 **CAM-2b**	and you...		
0143:15 **CAM-1a**	weren't you sitting there listening to me?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0143:16 **CAM-2b**	I mean, you don't... don't...		
0143:18 **CAM-1a**	no.		
0143:19 **CAM-2b**	he's trying to please them. just so you know.		
0143:22 **CAM-1a**	oh yes, didn't he say if somebody made a mistake...		
0143:24 **CAM-2b**	yeah.		
0143:25 **CAM-1a**	you know, I don't harm anyone, I will cover for him.		
0143:28 **CAM-2b**	like I'm telling you.		
0143:29 **CAM-1a**	I told him it's all right.		
0143:30 **CAM-2b**	he's trying to please them.		
0143:31 **CAM-1a**	did you give the instructions that they should come aboard? he said to me, "I always send telex messages." that's it.		
0143:37 **CAM**	[sound of click]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0143:38 **CAM-2b**	he's trying to please them. as long as he pleases them, don't worry your head.		
0143:47 **CAM**	[sound of two thumps]		
0143:50 **CAM**	[sound of two clicks]		
0143:52 **CAM-1a**	since when do I worry my head...		
0143:53 **CAM**	[two consecutive whirring sounds similar to electric seat motor operating]		
0143:54 **CAM-1a**	I mean, you know.		
0143:56 **CAM-2b**	they, they... the word is that @ @ @ is making trouble. you are making trouble, that's what's being said by everyone. just so you know.		
0144:06 **CAM-1a**	I don't care.		
0144:09 **CAM-2b**	these guys are a bunch of #. and what's more, they are being controlled by the guy named, under the leadership of, of the guy named, the # named @, you know?		
0144:22 **CAM-1a**	***.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0144:24 **CAM-2b**	don't worry your head. you're good hearted.		
0144:26 **CAM-1a**	I mean... you know me, it doesn't make any difference to me. but when kids start that way...		
0144:35 **CAM**	[sound of two clicks]		
0144:37 **CAM-1a**	I told him, I told him later that if I saw anyone aboard that didn't get permission from anybody and who also keeps going back and forth, even with permission, he won't fly with me. I won't fly with him, I'm not willing. I don't want to fly with anyone, even if it comes to me not flying, and if they can prevent me from flying, that's fine, what can I say to them?		
0145:04 **CAM-2b**	these kids are forming a clique with each other, just so you know, under the leadership of @ @. @ @ controls that group. he has @ ear, as well as... this kid is clever and cunning.		
0145:10 **CAM**	[brief interruptions in audio on all CVR channels]		
0145:25 **CAM-1a**	who?		
0145:27 **CAM-2b**	that's him.		
0145:29 **CAM**	[sound of click]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0145:30 **CAM-1a**	which one?		
0145:35 **CAM-2b**	that's enough.		
0145:35 **CAM-2b**	don't you have the flight report with you, Adel?		
0145:37 **CAM-2a**	I've got it, sir, I've got it.		
0145:41 **CAM-1a**	what's with you, why did you get all dressed in red like that?		
0145:47 **CAM**	[sound similar to cockpit door operating]		
0145:48 **CAM-1a**	when do you have simulator?		
0145:49 **CAM-5**	Wednesday.		
0145:50 **CAM-1a**	what's today?		
0145:51 **CAM-5**	Sunday... Saturday.		
0145:56 **CAM**	[sound of two clicks]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0145:59 **CAM-1a**	hey guy, why didn't you take tomorrow's plane?		
0146:00 **CAM-5**	I tried (because the plane is the plane named thousand).		
0146:03 **CAM-1a**	why burn yourself out?		
0146:05 **CAM-5**	because I'm a pilot (thousand). I made three (trips). I'm sick and taking medication.		
0146:10 **CAM-?**	maybe tomorrow?		
0146:11 **CAM-6**	* do you all want something else?		
0146:12 **CAM-2b**	no, no, no.		
0146:13 **CAM-6**	***.		
0146:15 **CAM-2b**	that's really, really fantastic.		
0146:17 **CAM-6**	***.		
0146:18 **CAM-2b**	thanks a lot.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0146:18 **CAM**	[sound similar to cockpit door operating]		
0146:20 **CAM-2b**	not at all, sir.		
0146:23 **CAM**	[several clicks]		
0146:30 **CAM**	[unintelligible background conversation]		
0146:37 **CAM-?**	(I know @ @)		
0146:40 **CAM-1a**	where is @ @?		
0146:42 **CAM-?**	(he's in a hotel in Dubai)		
0146:44 **CAM-1a**	what?		
0146:45 **CAM-?**	(he's in a hotel in Dubai) [sound of chuckle]		
0146:46 **CAM-1a**	why, where did he go?		
0146:48 **CAM**	[sound similar to two hand claps]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0146:49 **CAM-1a**	eh?		
0146:49 **CAM-?**	*.		
0146:51 **CAM-1a**	did he leave like @ @, or what? [sound of chuckle]		
0146:52 **CAM**	[sound similar to three hand claps]		
0146:53 **CAM-?**	no, no, no.		
0146:54 **CAM-?**	that @.		
0146:55 **CAM-2b**	@ left for good?		
0146:56 **CAM-1a**	they say @ came back again.		
0146:56 **HOT-2**	[whirring sound similar to electric seat motor operating]		
0146:58 **CAM-?**	he came back? I wish.		
0147:00 **CAM-1a**	Adel, weren't you the one who told me that he came back?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0147:03 **CAM-2a**	yes, yes, I heard.		
0147:08 **CAM**	[sound similar to cockpit door operating]		
		0147:19 **CTR2**	EgyptAir nine ninety change to my frequency one two five point niner two.
		0147:25 **RDO-1a**	one two five nine two, good day.
0147:31 **CAM-?**	***.		
0147:34 **CAM**	[sound similar to cockpit door operating]		
		0147:40 **RDO-1a**	New York, EgyptAir ah, nine nine zero heavy, good morning.
		0147:45 **CTR2**	EgyptAir nine ninety, roger.
0147:51 **CAM-1a**	is that the route? even if it/she didn't want * ...		
0147:55 **CAM-2b**	* look, here's the new first officer's pen. give it to him please. God spare you.		
0147:58 **CAM-?**	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0148:01 **CAM-2b**	to make sure it doesn't get lost.		
0148:03 **CAM-1a**	excuse me, Jimmy, while I take a quick trip to the toilet...		
0148:04 **CAM**	[whirring sound similar to electric seat motor operating, heard only using digital filter]		
0148:04 **CAM**	[sound of click]		
0148:05 **CAM**	[sound similar to cockpit door operating]		
0148:08 **CAM-2b**	go ahead please (go ahead please).		
0148:09 **CAM**	[sound of several clicks]		
0148:10 **CAM-1a**	...before it gets crowded. while they are eating, and I'll be back to you.		
0148:18.55 **CAM**	[sound similar to cockpit door operating]		
0148:22.70 **CAM**	[sound of thunk]		
0148:23.30 **CAM**	[sound of clink]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0148:30.69 **CAM-?**	*** [The five Arabic speaking members of the group concur that they do not recognize this as an Arabic word, words, or phrase. The entire group agrees that three syllables are heard and the accent is on the second syllable. Four Arabic speaking group members believe that they heard words similar to "control it". One English speaking member believes that he heard a word similar to "hydraulic". The five other members believe that the word(s) were unintelligible.]		
0148:34.80 **CAM**	[sound of click and thump]		
0148:39.92 **CAM-2b**	I rely on God. [heard faintly]		
0148:49.30 **CAM**	[sound of thump]		
0148:53.10 **CAM**	[sound of faint, muffled thump]		
0148:56.31 **CAM**	[sound of thump]		
0148:57.93 **CAM**	[series of thumps and clicks starts and continues for approximately seventeen seconds]		
0149:18.30 **CAM**	[sound of light thump]		
0149:18.37 **CAM**	[whirring sound similar to electric seat motor operating, also heard through first officer's hot microphone system]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0149:30.16 **CAM**	[sound of two faint thumps and one louder thump]		
0149:47.54 **CAM**	[sound of two clicks and two thumps]		
0149:48.42 **CAM-2b**	I rely on God.		
0149:53.32 **CAM**	[one loud thump and three faint thumps]		
0149:57.33 **CAM-2b**	I rely on God.		
0149:58.75 **CAM-2b**	I rely on God.		
0149:58.78 **CAM**	[four tones similar to Master Caution aural beeper]		
0150:00.15 **CAM-2b**	I rely on God.		
0150:01.60 **CAM-2b**	I rely on God.		
0150:02.93 **CAM-2b**	I rely on God.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0150:04.42 **CAM-2b**	I rely on God.		
0150:04.72 **CAM**	[sound of loud thump]		
0150:05.89 **CAM-2b**	I rely on God.		
0150:06.37 **CAM-1a**	what's happening? what's happening?		
0150:07.07 **CAM-2b**	I rely on God.		
0150:07.11 **CAM**	[sound of numerous thumps and clinks continue for approximately fifteen seconds]		
0150:08.20 **CAM**	[repeating hi-low tone similar to Master Warning aural starts and continues to the end of recording]		
0150:08.48 **CAM-2b**	I rely on God.		
0150:08.53 **CAM-1a**	what's happening?		
0150:11.50 **CAM-?**	*.		
0150:15.15 **CAM-1a**	what's happening, Gamil? what's happening?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
0150:19.51 **CAM**	[four tones similar to Master Caution aural beeper]		
0150:24.92 **CAM-1a**	what is this? what is this? did you shut the engine(s)?		
0150:25.00 **HOT2**	[change and increase in sound, heard only through first officer's hot microphone system]		
0150:26.55 **CAM-1a**	get away in the engines. [translated as said]		
0150:28.85 **CAM-1a**	shut the engines.		
0150:29.66 **CAM-2b**	it's shut.		
0150:31.25 **CAM-1a**	pull.		
0150:32.75 **CAM-1a**	pull with me.		
0150:34.78 **CAM-1a**	pull with me.		
0150:36.84 **CAM-1a**	pull with me.		
0150:38.47 **END OF RECORDING** **END OF TRANSCRIPT**			

Attachment B

Response of the Egyptian Civil Aviation Authority to the Draft Report of the National Transportation Safety Board

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EGYPTIAN CIVIL AVIATION AUTHORITY

RESPONSE TO DRAFT REPORT OF THE NATIONAL
TRANSPORTATION SAFETY BOARD CONCERNING
THE INVESTIGATION OF THE ACCIDENT INVOLVING
EGYPTAIR FLIGHT 990, A BOEING 767-300ER
SU-GAP, OCTOBER 31, 1999

Prepared pursuant to Annex 13
to the Convention on International
Civil Aviation

RESPONSE TO DRAFT REPORT OF THE NATIONAL TRANSPORTATION SAFETY BOARD CONCERNING THE INVESTIGATION OF THE ACCIDENT INVOLVING EGYPTAIR FLIGHT 990, A BOEING 767-300ER SU-GAP, OCTOBER 31, 1999

On April 19, 2001, the United States National Transportation Safety Board (NTSB) delivered a draft report regarding the investigation of the accident involving EgyptAir Flight 990, a Boeing 767ER, on October 31, 1999. Flight 990 was on a scheduled passenger flight from John F. Kennedy International Airport in New York to Cairo, Egypt when it crashed into the Atlantic Ocean approximately 60 miles southwest of Nantucket Island, Massachusetts.

The NTSB's draft report, prepared under a delegation from the Government of Egypt to the Government of the United States pursuant to the provisions of Annex 13 of the Convention on International Civil Aviation, reflects a limited and incomplete investigation and a corresponding inadequate analysis. More importantly, an objective consideration of the evidence accumulated during the investigation shows that the NTSB, in its draft report, used selected facts and speculative conclusions to support a predetermined theory, instead of determining what probable cause, if any, an unbiased evaluation of all of the evidence would support.

In particular, the NTSB's conclusion that the probable cause of the accident is the deliberate action of the relief First Officer is not supported by any evidence of intent or motive that would explain the First Officer's alleged conduct. Indeed, the NTSB omits any discussion of motive and intent and of the facts in the record that squarely contradict a theory of deliberate pilot action. Equally, if not more disturbing, is the NTSB's total disregard of the relevance of the unequivocal evidence of either sheared or deformed bellcrank rivets, not only on EgyptAir 990, but also on other Boeing 767 aircraft. Notably, neither the NTSB nor Boeing is able to explain the cause of these documented abnormalities. These sheared and deformed rivets are direct evidence of a potential defect in the airplane's elevator system and may well indicate either a full or partial jam of one or more elevator PCA's. Indeed, the NTSB acknowledges in its draft report that the internal damage to one of the right elevator PCA's of Flight 990 exhibited "unusual characteristics" that "<u>might or might not have been impact-related</u>" (emphasis added). It is inconceivable that the NTSB can credibly proffer a probable cause based on pilot action when it admits the existence of unexplained damage to a critical elevator component.

These shortcomings in both investigation and analysis compelled the Egyptian Civil Aviation Authority (ECAA) to prepare its own report and analysis, attached hereto as Appendix A, which is incorporated in the ECAA's response to the NTSB draft report. The ECAA's response, which includes the ECAA's comments, is submitted to the NTSB pursuant to the provisions of Annex 13.

In addition to setting forth the ECAA's own accident report, this response addresses three areas: (A) NTSB Procedural Irregularities and Adherence to Accident Investigation Standards; (B) Incomplete Investigation Actions/Missing Data; and (C) Discussion of Specific Issues in the NTSB Draft Report.

BACKGROUND

Immediately following the accident involving EgyptAir Flight 990, a Boeing 767-300ER, SU-GAP, in the Atlantic Ocean on October 31, 1999, the Government of Egypt sent an accident investigation team to participate with the NTSB. The Egyptian Investigative Team (the Egyptian Team or EIT) was led by the Egyptian Accredited Representative from the ECAA with experienced technical support from EgyptAir. The Egyptian Team participated in every phase of the investigation and on every NTSB working group for the entire 18-month period between the date of the accident and the delivery of the draft NTSB accident report.

The Egyptian Team made a formal presentation and submission on the accident issues to the NTSB on April 28, 2000. The Director General of the ECAA presented a detailed safety recommendation letter to the Administrator of the Federal Aviation Administration (FAA) on June 4, 2000. The letter contained three safety recommendations, addressing Boeing 767 bellcrank/elevator flight control, pilot training, and maintenance issues. The ECAA's safety recommendations resulted in two Airworthiness Directives by the FAA and a decision by the

Boeing Commercial Aircraft Company (Boeing) to evaluate design changes as the terminating action for the repetitive inspection of the bellcrank assembly on the Boeing 767. In January 2001, the Egyptian Team submitted a detailed report to the NTSB docket which outlined several technical inaccuracies in the accident submission that was made by Boeing. Finally, the Egyptian Team submitted numerous comments, reports and letters to the NTSB accident docket related to various aspects of the accident investigation and its factual record. The full record of Egyptian participation in the investigation serves as the foundation for the following comments.

I. The NTSB's Investigation Was Marked By Procedural Irregularities and the Failure to Follow Accepted Accident Investigation Standards

The investigation of the EgyptAir 990 accident was marked by early and ongoing "leaks" of information from the NTSB, and by public statements of the NTSB Chairman and "other sources close to the investigation." The early release of information, especially relating to the cockpit voice recorder (CVR) and the flight data recorder (FDR) and the statements by the NTSB Chairman and other NTSB officials, established in the minds of the media, the public, and the aviation industry that the accident was caused by a deliberate act of the First Officer. This became the so-called "suicide theory."

The release of selected CVR and FDR data, and the NTSB's public discussion of it as purportedly reflecting a deliberate act, occurred in November 1999, less than two days after the recorders had been recovered. Furthermore, the announcement by the NTSB that it was considering turning the investigation over to the FBI came after an incorrect translation of the conversations on the CVR which were in Arabic. CVR information was also released before there was any investigation by a CVR working group. Standard NTSB procedure is to convene a CVR working group, made up of representatives of the various parties, which then develops a transcript of the cockpit conversation, based on the technical and cultural knowledge of the group members. This did not occur. Instead, the NTSB staff listened to the Arabic conversations, accepted the incorrect translation of a non-Egyptian American translator, interpreted that translation without any cultural information, and then, less than 48 hours after the recorders were recovered, leaked information and made public statements concerning the CVR.

The NTSB's actions, unfortunately, resulted in an extraordinary waste of time, effort, and resources by the Egyptian Team, Boeing, and the NTSB. Instead of participating in an ongoing, objective investigation, focused on safety issues, the Egyptian Team was constantly forced to address the false issue of suicide. Despite the accumulation of substantial evidence showing that the suicide theory was incorrect and that there were serious airworthiness issues related to the Boeing 767 elevator bellcrank control system, the NTSB continued to make public statements which denied the existence of any mechanical issues and fueled speculation regarding the so-called suicide theory. In particular, the NTSB repeatedly asserted that it had found no mechanical cause for the accident. These statements -- not balanced by any corresponding comment that no non-mechanical cause had been found -- created a virtually unassailable public perception that the accident was attributable to the actions of the First Officer. The NTSB's actions were consistently contrary to their own procedures and to those contained in Annex 13.

The NTSB's persistent focus on the deliberate act scenario resulted in less than adequate investigation plans for other standard parts of the investigation. This was especially evident in the areas of the Systems Group, Aircraft Performance Group, and the Metallurgical Group. The Egyptian Team was forced to push for broader investigation plans and expanded tasks and schedules just to assure that basic aircraft accident issues were addressed. One example of the NTSB's failure to pursue basic investigative steps was its refusal to conduct any metallurgical examination of any elevator bellcrank rivets or power control actuators (PCA) until an Egyptian Team member, in January 2000, insisted that this be done. The result was a full-scale metallurgical analysis. The focus on the bellcrank issues and the Boeing inspection procedure, which the ECAA brought to the FAA's attention, led to a special investigation by the FAA in July 2000 and two Airworthiness Directives related to sheared bellcrank rivets and the inadequate Boeing inspection procedure.

A second example of the NTSB's limited investigation was its reluctance to conduct comprehensive aircraft performance testing in the flight simulators at Boeing. The superficial level of the first simulator tests led to further testing, but only at the insistence of the Egyptian Team. As late as March 2001, a new series of simulator tests was scheduled by the NTSB to resolve selected technical questions. Even after these latest tests, many issues remain concerning the validity of the simulator tests.

Another example was the NTSB's continuous refusal to conduct any analysis or tests concerning the recorded behavior of the ailerons of the accident aircraft. This was despite the FDR data which showed that Flight 990, while seemingly under control and in the process of recovery from the initial steep dive, suddenly experienced "split" elevators and abnormal aileron movements. The NTSB theorized that the abnormal aileron movement was caused by shock waves or other extraordinary aerodynamic phenomena as the airplane approached the speed of sound. However, the NTSB refused to consider these same shock waves as the possible explanation for the FDR data showing a "split" in the elevators. Instead, with no proof whatsoever, the NTSB concluded that the split of the elevator surfaces was due to opposite control forces in the cockpit – in other words, a fight between the Captain and the relief First Officer for control of the airplane. Although there was no evidence of a struggle, the NTSB used the elevator data to support its deliberate act scenario -- while, at the same time, it ignored any serious investigation of the unexplained behavior of the ailerons.

Along these same lines, the Egyptian Team continually requested that the NTSB and Boeing perform wind tunnel tests on the Boeing 767 flight control systems at the same speeds experienced by Flight 990 -- up to .99 Mach. There is no validated Boeing data on the 767 airplane above .91 Mach; consequently, any conclusions about the performance of the airplane at higher speeds are necessarily based upon the extrapolation of .91 Mach data -- an extremely speculative technique when dealing with transonic speeds. The requests for wind tunnel testing to obtain accurate performance data were denied. Consequently, a thorough aircraft performance analysis to explain the meaning of the FDR data and the forces working on the airplane has not been accomplished. Curiously, at the same time that Boeing refused to conduct any wind tunnel tests[1] for this accident, it announced on March 15, 2001, that it had just completed wind tunnel tests on the new Boeing 767-400ER at speeds up to .97 Mach. The tests were completed in February 2001 at the U.S. Air Force Arnold Engineering Development Center at the Arnold Air Force Base in Tennessee.

The Egyptian Team repeatedly requested a more detailed spectrum analysis of certain sounds recorded on the CVR in the period just before the accident event started. This included the unexplained phrase "Control it." Chairman Hall, early in the investigation, suggested bringing in a Russian spectrum analysis expert to assist in this area. Although the NTSB had used this expert previously, it never sought his services and never explained its decision to the Egyptian Team. Nevertheless, the Egyptian Team continued to make requests for other spectrum analysis of CVR voices and sounds that the NTSB refused to undertake. This is contrary to what is required in a thorough accident investigation -- and is inconsistent with the NTSB's procedures in accident investigations where U.S. carriers have been involved.

Other areas where the investigation was incomplete and/or where requests from the Egyptian Team were not addressed include:

- There was a perfunctory treatment of the recorded radar data of Flight 990. Only after the Egyptian Team insisted was there any effort to analyze the radar data. In addition, the investigation of radar issues was hampered by the absence of certain critical data. For example, 18 requests were made by the Egyptian Team for specific radar data and information. To date, eight of the requests have been refused with the explanation that the data is classified and is not available to the FAA or to the NTSB investigation. The Egyptian Team complained to U.S. Government officials that this is contrary to ICAO standards which require that

[1] Through Boeing meeting with Egyptian Investigation Teem on late May 2001, Boeing presented some limited wind tunnel test data regarding aileron and elevator.

such information be made available to accident investigation authorities. The Egyptian Team also volunteered to take whatever steps might be necessary to protect any sensitive information. The Egyptian requests for further radar analysis were based on the appearance of high-speed radar returns on tracks converging with Flight 990. The official response from the NTSB and the FAA was that the returns in question were "clutter or strobing," although no work was done to verify this speculative conclusion.

- There were constant inaccuracies in the FDR data. On five occasions, the NTSB presented the "final" FDR data to the Egyptian Team and each time sufficient errors were identified to require the "final" report to be withdrawn and recomputed.
- Key aircraft components were not recovered even though a second effort was conducted to recover more wreckage. The second effort, scheduled for 10 days, lasted only 2 days and was initiated and undertaken without any consultation with the Egyptian Team. Critical components that were not recovered include two elevator PCA's, one bellcrank assembly, the RAT, the QAR and portions of the elevators.
- The Egyptian Team was hampered by the inability to communicate and coordinate directly with Boeing, Honeywell and other component manufacturers. All communications were required to go through the NTSB which, often at the group chairman level, filtered, modified, or in some cases, denied the Egyptian request.

The most serious shortcoming of the NTSB investigation was the failure to seek out and address all the related safety issues. Once fixated on the deliberate act theory, the NTSB virtually ignored the airworthiness issues that subsequently emerged relative to the Boeing 767 elevator bellcrank assemblies. These matters were brought to the attention of the FAA only after the ECAA took the initiative.

The Egyptian Team attempted to have the bellcrank issue thoroughly investigated by the NTSB Systems Group. Failing in this effort, the Egyptian Team took the unusual step of preparing a safety recommendation letter from the Director General of the ECAA directly to the FAA Administrator. The letter described the factual findings and the safety problems that had been identified in the EgyptAir 990 accident investigation. The three recommendations, sent to the FAA on June 4, 2000, stated:

1. Require a cockpit indication in the Boeing 767 that would alert the flight crew to abnormal PCA operation wherein a single fault in the elevator could result in uncommanded elevator movement. Until such a cockpit indicator is installed, require operators of Boeing 767 airplanes to perform daily -- rather than 400-hour -- checks of the elevator system to identify faults in the elevator system;
2. Review the Boeing 767 elevator control system design and conduct further examination of the causes of the reported discrepancies found in the elevator actuator bellcrank, and;
3. In conjunction with Boeing, develop cockpit crew procedures to aid the flight crew in identifying, isolating, and negating an uncommanded elevator hard-over condition.

These safety issue recommendations prompted action by the FAA which requested that Boeing undertake specific tests on the Boeing 767 elevator control system. The NTSB did not participate in this testing even though the issues arose from the Flight 990 accident investigation and appeared to be relevant to the accident. In any event, the identification and resolution of these safety issues should have come through the NTSB to the FAA.

The tests initiated by the FAA resulted in dramatic safety findings. In a July 20, 2000, Boeing message to all operators, Boeing stated that the test " . . . results revealed that the Elevator Power Control Actuator, Maintenance Planning Document Item Number 27-31-00-5B test, which is required at a 400-hour interval, may not detect a failed hydraulic." As a result, ". . . the single system hydraulic test passed even though there was a sheared bellcrank in one system." The Boeing document further advised that "a representative of the FAA witnessed the sheared bellcrank test and advised that an Immediate (emergency) Adopt Airworthiness Directive will be released concerning this issue. . . ." The Emergency Airworthiness Directive was issued in August 2000.

As a result of the findings of this Emergency Airworthiness Directive which required the prompt inspection of elevator bellcrank rivets, a second Airworthiness Directive was issued on March 20, 2001 which imposed a more comprehensive and frequent inspection of elevator components. This AD called for ". . . repetitive testing of the elevator control system to determine if an elevator power control actuator (PCA) is rigged incorrectly due to yielded or failed shear rivets in a bellcrank assembly for the elevator PCA, and follow-on actions, if necessary. This action is necessary to prevent continued operation with yielded or failed shear rivets in a bellcrank assembly for the elevator PCA, which could result in reduced controllability of the airplane. This action is intended to address the identified unsafe condition."

Finally, Boeing has announced that it is in the process of evaluating design changes to the Boeing 767 elevator control system related to the bellcrank.

Clearly, a thorough and objective investigation by the NTSB would have identified this safety issue. Instead, the issue was addressed only after the NTSB refused to do the requisite analysis and after the Director General of the ECAA went directly to the FAA. Of primary significance to the accident investigation is that the dual elevator PCA failure identified by the Egyptian Team in January 2000 produces a flight profile very similar to that of the EgyptAir Flight 990 accident.

Finally, the NTSB's decision to include raw, unverified U.S. Federal Bureau of Investigation (FBI) reports in the EgyptAir accident docket illustrated the NTSB's preoccupation with a deliberate act theory to the exclusion of a thorough consideration of the potential mechanical deficiencies acknowledged by Boeing. The FBI had conducted an investigation of the First Officer's background and had concluded that there was no evidence of a criminal act – no evidence of a deliberate act or a suicide – by the First Officer. The anonymous FBI reports had no place in an NTSB aircraft accident safety investigation; yet, the NTSB decided to include them in the public docket just days before the docket was opened. The result was the publication of unsubstantiated reports which slandered the First Officer and his family, had no bearing on the First Officer's ability to fly and provided no evidence that the First Officer intended to crash the airplane. At the same time, the NTSB deliberately ignored evidence provided by the Captain of an earlier flight on the accident airplane where he had experienced autopilot problems that had caused him to disconnect the autopilot. The NTSB not only failed to conduct any investigation of autopilot anomalies, it also excluded the evidence of these problems from the public docket.

From the beginning of this investigation, the Egyptian Team has insisted on only two things: First, that the investigation be complete and thorough; and second, that the evidence receive objective and unbiased evaluation. Unfortunately, the NTSB's draft report shows that neither of these objectives has been achieved.

II. Status Of Investigations Actions

As described above, during the course of the investigation, there were numerous instances where the NTSB was reluctant to pursue standard accident investigation issues except at the insistence of the Egyptian Team. In other instances, either the NTSB or Boeing failed to provide satisfactory information relevant to the accident investigation.

From November 1999 through August 2000, the NTSB directed the Egyptian Team to make its investigative requests directly to the NTSB. After the Technical Review meeting in October 2000, the parties agreed that any additional technical requests would be submitted directly to Boeing. A summary of the current status submitted by the Egyptian Team is presented below. This information is divided into two parts. Part1 lists requests submitted directly to the NTSB, and part 2 reflects requests made to Boeing.

1. Requests submitted directly to NTSB

Reference	Egyptian Investigation Team Requests	Reason of request and current status
Exhibit 9- Systems		
Elevator Hardware examination and analysis.	EIT asked for more studies and data to explain the abnormalities that were found in one of the right elevator power control actuators. EIT showed its disagreement with delivered Boeing study. (EIT comments has been officially submitted to NTSB on June 29, 2000)	To support the analysis of the anomalies observed with one of the recovered PCA's. Status: Boeing provided two letters: - Dynamic Analysis right PCA B-200-17066-ASI, 29-Sep-00 - Dynamic Analysis right PCA B-200-17066-ASI, 20-Oct-00 These studies are still considered to be incomplete.
	EIT requested recovery of the following components: • RAT (Ram Air Turbine). • QAR (Quick Access Recorder). • The elevator remaining surfaces. • One elevator input bellcrank. • The following flight control actuators: ▪ Two elevator power control actuators (PCA). ▪ One elevator autopilot servo actuator. ▪ Two outboard aileron actuators. ▪ Two outboard spoiler actuators. ▪ One inboard aileron actuator. Only the inboard aileron actuator was recovered during the second wreckage recovery effort, March 2000.	To acquire more data to support the investigation analysis Non of the requested component has been recovered yet.
Boeing letter, "Split Elevator Failure Scenario" dated July 21, 2000.	EIT requested an answer from Boeing regarding the discrepancies between the Ground Test results and Boeing analysis for the elevator PCA's failure. (EIT request has been officially submitted to NTSB on June15, 2000)	To validate Boeing analysis of the "Split Elevator Failure Scenario". Boeing presented the following letters: 767 elevator control System Operation with Regard to Column Splits, Aft quadrant splits, and column jam B-H200-17026-ASI, B-H200-17026-ASI-R1, B-H200-17083-ASI-R1, dated 2-Aug-00, 14-Sep-00 and 20-Oct-00 respectively - Explanation of two 767 elevator system Characteristics observed during dual PCA Fault ground testing, B-H200-17027-ASI, dated 4 Aug-00. - 767 Elevator control friction and hysteresis, B-H200-17028-ASI dated 7-Aug-00 EIT commented about these letters during the Boeing Meeting, Nov 2000.
	EIT requested: • Additional information regarding ADC/ IRS	To visualize the cockpit indication during the dive, and to support investigating pressurization system

Reference	Egyptian Investigation Team Requests	Reason of request and current status
	• additional information regarding the effect of aircraft high rate of descent on the operation of the pressure controllers. (EIT request has been submitted to Boeing through an E-mail on July 14, 2000 with a copy to the NTSB, on July 21, 2000)	EIT did not receive Boeing response. Items are still opened.
Exhibit 13 Aircraft Performance Group Chairman's Performance Study.	The EIT asked for some more studies relevant to accident and not included in the performance study (when, where and why engine separation occurred, radar interference study, …)	To support the performance analysis and the study of possible aircraft disintegration. The NTSB presented Aircraft Performance Addendum #4, "Engine separation study", dated 03 April 01, and revised version on April 09,2001. EIT disagrees with the study conclusion
Group Chairman's Performance Study. Addendum # 1	EIT asked the NTSB to apply the same methodology used for the elevator split study on the Aileron split (Study has been made by the EIT) EIT did not receive NTSB answer	To support the analysis for the split elevator movement at the end of the dive. Boeing presented the letters: - Aileron Behavior, B-H200-17216-ASI, dated 12 April 2001. - Elevator Behavior, B-H200-17219-ASI, dated 16 April 2001. These letters contain descriptive information without any analysis.
	EIT requested to conduct wind tunnel tests to examine the ailerons and elevators behavior at speeds near the sonic speed (EIT request has been officially submitted to NTSB on June 22, 2000)	To investigate the abnormal behavior of the ailerons and elevators during the dive EIT received some incomplete data during Boeing presentation in Cairo, May 2001.
Exhibit # 12 Cockpit Voice Recorder Sound Spectrum study	EIT asked the NTSB to: Record the cockpit door operation and the cooling pack switches sounds during a flight test at an altitude of 33000 ft (EIT request has been officially submitted to NTSB on May 2000 and August 11, 2000) Do proper spectrum study for the word "Control It" and the following sounds. (Egyptian Civil Aviation submission August, 2000)	To support the analysis for identifying the unknown sounds in the cockpit before and during the dive. EIT did not receive NTSB answer yet To identify the persons occupying the cockpit before and during the dive. EIT did not receive NTSB answer yet
Exhibit # 3 ATC	The following requests have been made to the FAA and assistant secretary of state for answers to questions that continue to be critical to the	To support identifying the radar returns that were observed in the vicinity of EgyptAir 990 before beginning of the dive.

Reference	Egyptian Investigation Team Requests	Reason of request and current status
	investigation of EgyptAir Flight 990: 1. Letter of agreement between FAA and the US armed forces concerning special use of warning area W506 2. The list of the activated warning areas during October 1999 (conditions period of releasing back to FAA) 3. Multiple radar coverage charts for New York and Boston Centers at FL 50, 100, 200 and 300. 4. Multi radar tracking mosaic clutter and interference study for radar sites. 5. The configuration of the ZNY ATC system including radar and flight data processors, radar and voice data recorders, voice communication switching systems and the relevant radar sites. 6. The radar coverage charts, the last flight check reports, the interference and clutter charts and the antenna radiation patterns (PSR & NSSR) for GIBBSBORO (GIB), Riverhead NY, {RIV), North Truro, MA (NOR), Bucks Harbor, ME (BUC) and Nantucket radar sites (ARSR-4 & ASR-9). 7. The explanation of why the targets of Squawk 5606, 1216, 3835 & 6757 are existing in the navy file and do not exist in the Airforce file while the source of both files is the Riverhead NY radar site. 8. The radar data of the following targets: - The target of squawk 2655 which was detected by five radars up to 06:18:25 UTC in the same area and date of the accident and no data shows after that time, albeit it was still at flight level 330 and within the radar coverage of the five radars (more information was received later but only up to 06:22:15 UTC}. - The military aircraft ARISE 57, squawk 1625 which was in the radar contact with the same controller (R86) of MSR990. - The Royal Jordanian aircraft RG262 NYC/AMC 9. The clutter and interference studies for the radar sites, RIV, ZNY, and NOR. 10. Available technical data to analyze any	This request was submitted to the NTSB, the FAA and the State Department, no response is provided to the EIT on the basis of “Classified Information”.

Reference	Egyptian Investigation Team Requests	Reason of request and current status
	interference affecting RIV. 11. Complete file of Riverhead Radar from Airforce from 06:30 to 07:05 UTC including: Mode C validity Mode 3 validity Radar measured altitude Decimal Latitude/longitude Range and Azimuth angles from Radar site	
Exhibit # 10 Flight_Data Recorder	EIT requested an explanation for inner marker signal which was recorded at the final phase of dive. EIT requested a complete analysis for the elevator behavior after autopilot disconnect events through the last 25 hours recorded data.	To find the explanation for the inner marker signal recorded at the end of the dive. Boeing comment on Action items received on October 20, 2000, contained description for the event. Item is still opened To support the study regarding the causes for autopilot disconnect. Boeing presented the letters: - Autopilot disconnects on DFDR B-H200-17114-ASI, dated 22 Nov, 2000 - Autopilot disconnects evaluation B-H200-17201-ASI, dated 22 March, 2001 EIT does not agree with the conclusions

2- Requests submitted directly to Boeing

Reference	Egyptian Investigation Team Requests	Reason of request and current status
Action 2: wreckage analysis	EIT requests the elevators PCA's vendor (Parker Hannifin) to review the contents of Boeing letters B-H200-17066-ASI and B-H200-17082-ASI for concurrence relative to remarks made by Parker representative (Steve Weik) during the June 28th Systems Group meeting at the NTSB about the hypothetical position of the spring coil adjacent to the outside diameter of the spring guide. EIT requests Boeing to evaluate Page 15 photo marks relative to the scenarios considered in the referenced letters. Also, the EIT would like to know if these marks are consistent with a bellcrank shear for number 3 PCA?	To support the analysis of the anomalies observed with one of the recovered PCA's. EIT did not receive Boeing answer yet.

Reference	Egyptian Investigation Team Requests	Reason of request and current status
Action 4: autopilot disconnect	EIT in its response on the Boeing submission to NTSB dated 31 October 2000, showed its disagreement with Boeing conclusion regarding elevator behavior in the events of auto pilot disengagement.	Refer to B.1 Exhibit #10 Flight Data Recorder, B
Action 5: elevator failure scenario	EIT requests clarification of the conditions causing elevator pogo deflection during both single and dual valve jams (reference Boeing letter B-H200-17032-ASI).	To support the analysis of possible mechanical failure. Boeing presented the letter “Column forces required to deflect elevator input pogo”, B-H200-17030-ASI, dated 11-Aug-2000
Action 7: inner marker	EIT requests Boeing to study the reason for having “inner marker bit” appearing in the FDR at the end of the dive. Boeing indicated that it would confirm this condition by checking the CVR for marker aural warning associated with this condition.	Refer to B.1 Exhibit # 10 Flight Data Recorder
Action 10: Air Data System	For the purpose of verifying instruments behavior during the dive, EIT requested Boeing to perform pitot static test using FDR data on a B767 airplane. Boeing refused to perform this test at Boeing claiming that it has not a similar Boeing 767-300 airplane. EIT offered to perform the test on the MS sistership airplane on condition that Boeing would provide the test plan, pitot static test equipment, and that the test should be supervised by Boeing.	EIT did not receive Boeing answer yet.
Action 12: elevator failure scenario	EIT requests an explanation of the reason why the elevator model presented by Boeing (Boeing report B-H200-17026-ASI-R1, dated 14 Sept 2000, 767Elevator System Operation with Regard to Column Splits, Aft Quadrant Splits, and Column Jams), does not accurately predict the effects of single and dual PCA failures. Boeing is also requested to provide an explanation for the large deflection of the elevator surface associated with the column being held at neutral and how it is consistent with normal column sweep test data in the Failure Analysis Report.	Refer to B.1 Exhibit #9 systems, split elevator
Action 14: high rate column inputs	EIT requests the tabular data (e-fi1e) that support Boeing study regarding the effect of high rate column inputs (letter B-H200-17065-ASI))	EIT did not receive Boeing answer yet.

Reference	Egyptian Investigation Team Requests	Reason of request and current status
Action 18: ailerons behavior	EIT repeats request for Boeing to study the behavior of the inboard and outboard ailerons using high-speed data. EIT also requests the control surfaces hinge moment at speeds near sonic speed as derived from wind tunnel tests. EIT did not receive Boeing answer yet.	Refer to B.1 Appendix #13, Performance, Addendum #1
Action 20: elevator failure scenario	Regarding Boeing failure scenario (Boeing report B-H200-17027-ASI, dated 4 August 2000, Explanation of Two767 Elevator System Characteristics Observed During Dual PCA Fault Ground Testing) Egyptian Investigation Team requests the following: - Explanation for the mismatch in the elevators/ Columns gearing ratio. - The reason for ignoring the three factors inf1uencing the elevator surface def1ection mentioned in Boeing relevant study, with regard to Boeing study concerning Split Elevator Failure Scenario (B-H200-16968.ASI.R1, dated 21 July 2000), and its impact on the study when these factors are included. - Explanation for the variation in the left-to-right elevator difference with regard to the Failure Analysis Report	To acquire more precise information for the possible mechanical failure. EIT did not receive Boeing answer yet.
Action 21: elevator system friction and hysteresis	With regard to 767 Elevator System Friction and Hysteresis (Boeing report B·H200-17028-ASI, dated 7August 2000), EIT requests Boeing to provide a study showing the impact of the conclusion in the above mentioned report on its failure analysis report.	To support the analysis of possible mechanical failure. Boeing presented the letter “767 elevator control friction and Hysteresis “ B-H200-17028-ASI dated 7-Aug-2000
Action 22: elevator response with power On	EIT requests the tabular data (e-file) that supports Boeing letter concerning elevator system response to hydraulic power On (letter B-H200-17076-ASI)	To support the analysis of possible mechanical failure. EIT did not receive Boeing answer yet.
Action 23: elevator failure scenario	EIT requests documentation of the expected tolerances of the analytically-developed elevator traces for the dual PCA valve jam scenario and a comparison of these tolerances with the tolerances of the FDR elevator traces.	To establish the match criteria between the analytically predicted results and the FDR data. EIT did not receive Boeing answer yet.

Reference	Egyptian Investigation Team Requests	Reason of request and current status
Action 24: elevator hysteresis	EIT requests an example of a hysteresis curve for an autopilot driven elevator	To support the analysis of possible mechanical failure. EIT did not receive Boeing answer yet.
Action 25: elevator failure scenario	With regards to Elevator System Friction and Hysteresis (Boeing letter B-H200-17028.ASI), EIT requests Boeing evaluation of the impact of the contents of this letter with Boeing letter concerning Split Elevator Failure Scenario (letter B-H200-16968-ASI-R2)	To support the analysis of possible mechanical failure. EIT did not receive Boeing answer yet.
Action 26: elevator split	EIT requests Boeing to evaluate the aileron required to match the bank angle during the elevator split.	To support the analysis of possible mechanical failure. EIT did not receive Boeing answer yet.

III. Specific Comments Regarding The NTSB's Draft Report, Which Is Based Upon an Incomplete Investigation, Unverified Data, and Unsupported Conclusions

As stated previously, the ECAA prepared a separate report:

a) Pursuant to section 5.3 of Annex 13, it was anticipated that the investigation would be conducted as a partnership between equals. However, it soon became apparent that the NTSB leadership did not regard the Egyptian delegation as an equal partner and shared its processes, if at all, on a selective and seemingly random basis. Often the Egyptian delegation read about the NTSB's views in the press without prior communication.

b) Because of the flawed and biased NTSB investigation; and because the NTSB draft report is specifically dedicated to proving the deliberate act (suicide) theory. Under these circumstances, the ECAA's "comments" on the draft could never be adequate to correct all of the deficiencies of the NTSB draft or to provide input for meaningful revisions to the report. The draft NTSB report would require a major revision to include an expanded analysis of critical issues and, most importantly, an objective assessment of the evidence.

Consequently, the ECAA was compelled to develop a separate report concerning the EgyptAir Flight 990 accident. However, it is important to underscore the following major deficiencies in the draft NTSB report in order to highlight those shortcomings which hampered the accident investigation, and which now are incorporated into the draft NTSB report.

- The draft NTSB report selectively uses the facts of the investigation to develop, support and "prove" the findings of the deliberate act scenario which appears to have been predetermined since November 1999. The NTSB's most glaring omission is its failure to discuss any evidence of the motive or intent that would have caused the relief First Officer to take the "deliberate act" that the NTSB alleges. Similarly, the NTSB fails to account for specific facts in the record that refute the possibility of an intentional act by the First Officer. In addition, the NTSB ignores the significance of critical internal PCA damage, which it admits, “might or might not have been impact-related.”

- The NTSB uses airplane performance data, often supplied by Boeing, and performance data developed in the Boeing E Cab simulator, to reach conclusions about the performance of EgyptAir Flight 990 without addressing the proven inaccuracies and errors in the data. Additionally, the NTSB does not account for the absence of airplane performance data or characteristics for the flight regime of Flight 990 in the areas above .91 Mach. The NTSB draft report, nevertheless, reaches specific findings about the Boeing 767 and Flight 990. The fact that many of these conclusions are either speculative or are based upon data that has not been validated, supports the view that the NTSB’s conclusions were predetermined.
- The NTSB downplays and ignores critical safety issues related to the Boeing 767 elevator system. In part, the draft NTSB report uses its analysis of performance data to discount the existence of safety deficiencies that were illustrated by the two FAA Airworthiness Directives related to the Boeing 767 elevator system, while ignoring the ongoing incidents of failed components in the bellcrank assembly and a recently reported incident of a jammed elevator on an American Airlines Boeing 767.

As shown in the comments below, because of these general errors and shortcomings, the NTSB draft report creates a false view of the evidence and an inaccurate determination of probable cause. The following comments, set forth with reference to the page numbers in the draft report, must be addressed by the NTSB before the issuance of any final report. Each comment is separately numbered, with the page numbers of the draft report set forth in parentheses at the beginning of each comment.

1. **(Pages 3-5)** The NTSB’s deliberate act theory is based, in part, on establishing that the Relief First Officer (RFO) took various unusual means to “clear the cockpit” so that he alone would be in control of the airplane. The implication in the quoted statements from the CVR is that the RFO “ordered” the Command First Officer (CFO) out of his seat and off the flight deck. In making this argument, however, the NTSB failed to account for the literal nature of the CVR translation and failed to interpret the literal translation with appropriate Egyptian cultural nuances and references. Although the NTSB quotes a substantial portion of the CVR transcript, several facts and statements are omitted. In light of the apparent bias of the NTSB's draft report, it is not possible to conclude that these omissions were either unintentional or inadvertent.

After some discussion of changing places, the CFO told the RFO at 0140:35 "… if you want to sit here, there's no problem." The RFO then said, "I'll come back to you, I mean, I will eat and come back, all right?" Out of the entire CVR transcript on the subject, the NTSB omitted this exchange. In doing so, the NTSB left the reader without the critical evidence that the CFO advised that changing places would be "no problem" and that the RFO offered to eat and come back later -- an offer that the CFO refused, suggesting, instead, that the RFO eat his meal in the cockpit.

Moreover, without considering either the tone or cultural context of the discussion, the NTSB created the erroneous impression that the RFO was improperly "pulling rank." According to the Egyptian Team investigators who listened to the CVR, the RFO was not ordering the CFO out of the cockpit, but rather, was simply asking to take an early turn on the flight deck -- a procedure that is not contrary to any EgyptAir policy or ECAA regulation. Presumably, if any adverse inference should be drawn from the RFO's conduct, the Captain would have intervened and made his views known. The fact that the Captain did not intervene is the best evidence that the RFO's request was not improper.[2]

The draft report also highlights the RFO's statement at 0147:55 "Look here's the new first officer's pen. Give it to him. God spare you." The only conceivable purpose in picking this one statement from the otherwise normal, routine cockpit conversation is, again, to imply

[2] Further, the CFO's subsequent comments at 0140:57 and 0141:09 that the RFO "does whatever he pleases" indicated that the RFO's request to work early was in keeping with his past actions and was not part of a plan to crash the airplane.

that the RFO was trying to make others leave the cockpit. More important, however, is that the NTSB report does not reflect that at the time the RFO asked that the pen be returned, the CFO was still in the cockpit, and that he was still present at 0147:03 -- seven minutes after he agreed to change seats with the RFO.

The draft report fails to point out that the RFO never asked the CFO or anyone else to leave the cockpit. In fact, the transcript identifies a number of different voices in the cockpit and numerous times when the cockpit door is "operating," suggesting that there was substantial traffic in and out of the cockpit. Consequently, it would have been extremely difficult for a crew member seeking to be alone to be sure that would occur when others were so freely -- and frequently -- present in the cockpit. Further, there is no evidence even if the RFO were alone -- as the NTSB contends -- that he took any action, such as locking the door, to prevent other crewmembers from entering the cockpit.

These facts neither reflected in nor commented upon in the draft report present a picture of a busy cockpit with people coming and going in response to their own desires and not as part of the RFO's coordinated plan.

2. (Page 5, footnote 10) The meaning of "Tawakkalt ala Allah" is critical to the investigation. The Egyptian Team presented a substantial report about the cultural and religious meanings of this statement, and specifically made the point that this statement would never be used by a person who was about to do an evil deed. This aspect of the CVR and the cultural basis for the explanation of the actions of the RFO were generally ignored in the draft report. The NTSB should include in its report the cultural evidence regarding the circumstances when this expression would and would not be used.

3. (Pages 6-10) This section of the draft report addresses the actions of the RFO and the Captain and the manner in which the airplane maneuvered up until the end of the CVR and FDR recordings. The section is replete with the selective use of FDR data and CVR statements. The following points either are not raised or are minimized:

- The draft NTSB report does not discuss the important fact that there was no argument between the Captain and the RFO when the Captain re-entered the cockpit at 0150:06 after the accident event started. The Captain did not say to the RFO “What are you doing?” “Why are you pushing the controls of the airplane forward?” “Let go of the controls.” There is absolutely no indication that the Captain thought the RFO had any part with the condition of the airplane. None of this is addressed in the draft report. Instead, the Captain said five times, “What’s happening?” There is no indication from the Captain’s words that he believed the RFO was acting improperly.
- The cockpit door was left open. The RFO would have closed and locked the door if he had a plan to deliberately place the airplane into a dive.
- There is no mention of the following FDR data:
  - Only 6 degrees of TED elevator was used even though 15 degrees of TED elevator were available;
  - The computed control column position was less than 4 degrees forward although 11 degrees of forward movement was available;
  - Throughout the maneuver, the airplane was never rolled more than 10 degrees, and each time a roll started, it was corrected back toward a wings level attitude;
- The engines were not cut off as part of the initial dive;
- The FDR contains 25 hours of data detailing the airplane’s performance prior to the accident. In particular, this data shows an unusual pattern of 11 autopilot disconnects. These autopilot disconnects shed light on the unique behavior of EgyptAir 990. Of special note is that most of the time the autopilot was disengaged, there was an obvious downward movement of elevators, with the right elevator showing a greater deflection than the left.

  To analyze this data, EgyptAir test flew another 767 and performed a series of autopilot disconnects and reviewed the FDR data from those test events. This set of test autopilot disconnects was performed during cruise on a flight from Cairo to Rome. As was expected, the data recording these disconnects showed no significant movement of the elevator between autopilot and manual operation at the moment the autopilot disconnected. This is in contrast to the data for the EgyptAir 990 airplane where there ware downward elevator deflections when the autopilot was disengaged.

4. **(Page 9, footnote 22)** This footnote is devoted to asserting that during the dive as reproduced on the simulator, the airplane's controls could be worked without difficulty. The NTSB notes, however, that the zero g loads recorded on the FDR could not be duplicated in the simulator. This is typical of the NTSB's approach in other areas -- identify a potential problem and then totally ignore it.

The inability to simulate zero g may be critical in any evaluation of the potential recoverability of the airplane; yet, the NTSB suggests that identifying the problem is all that it must do. The issue is important where, as here, the control column force needed to recover the airplane is much higher than normal and must be sustained by the crew for longer than normal. Under zero g conditions, it may be difficult, if not impossible, for an unrestrained crewmember to exert sufficient force on the controls to affect the same recovery demonstrated in the simulator. Consequently, no conclusions as to probable cause should be based on the purported recoverability of the airplane.

5. **(Page 15, footnote 32)** The routing of the cable in Figure 1a appears to be the opposite of the routing described in the footnote.

6. **(Page 21-22)** The NTSB mischaracterizes the report of the EgyptAir Captain on the outbound flight to Los Angeles regarding the operation of the autopilot. The important fact is not that the autopilot could not be reengaged, but rather why Captain Arram disconnected the autopilot in the first place. With respect to that question, Captain Arram reported that he observed movement in the control column, as if the autopilot was "hunting." Because of the abnormal movement in the control column, he disengaged the autopilot. It is entirely possible that the RFO also observed unusual movement in the control column and, like Captain Arram before him, decided to disconnect the autopilot.

7. **(Page 22)** The NTSB states that all of the previous elevator movements on autopilot disconnect -- which were “primarily in the trailing-edge-down (TED) direction” -- were consistent with “normal operation.” The ECAA is not aware of any Boeing supplied data that shows a TED movement is expected consistently upon autopilot disconnect and has not been shown any data or studies to confirm that movement of .88 degrees or less is “normal.”

8. **(Page 23)** The discussion of Boeing 767 bellcrank anomalies minimizes the critical safety aspects represented by these findings and is presented in such a way as to convince the reader that these types of failures never happened on EgyptAir Flight 990. The report does not point out that the Egyptian Team was responsible for the identification of the possibility of bellcrank assembly failures due to rivet shears and PCA jams. The NTSB Systems investigation refused to address these issues or to bring the safety deficiencies to the attention of the FAA. The draft report does not discuss the cumulative findings that were developed which suggest that there was a similar bellcrank/PCA failure associated with EgyptAir Flight 990.

The facts are that, as a result of the safety issues raised during the EgyptAir Flight 990 investigation, the FAA issued two Airworthiness Directives concerning the Boeing 767 bellcrank assemblies. More than 152 bellcrank assembly rivets were found defective. Of this number, 52 had to be replaced before the airplanes were allowed to fly again. The FAA determined that the approved Boeing inspection procedure for the rivets was inadequate. Boeing is evaluating design changes, as the potential terminating action, of the system.

The sheared elevator bellcrank rivets on an AeroMexico Boeing 767 (a fact acknowledged only in a footnote on page 23), along with the discovery of numerous defective rivets as a result of the FAA’s August 2000 Emergency AD, are ample proof of unusual and unexplained forces acting within the Boeing 767 elevator system. These anomalies may well be related not only to the Flight 990 accident, but also to three other incidents involving the improper functioning of the Boeing 767 elevator system.

In particular, the NTSB's assertion that there is no relevant FAA Service Difficulty Reports (SDR) is incorrect. The following incidents involving the Boeing 767 elevator system are included in the SDR's:

i. On September 12, 1994, United Airlines reported that a B767-300 airplane (serial number 27159) experienced a frozen elevator condition (while descending through 11,000 feet), which took 30 pounds forward pressure to pop the elevator free. A post-landing inspection revealed no discrepancies in the elevator control system.

ii. On June 20, 1996, the same airplane reported that it was "unable to hold altitude at 10,000 feet on autopilot which was disconnected and the elevator was stiff. After 5 to 10 minutes of using stabilizer trim, while pushing up and down on the control column, something let go at 4,000 feet and the airplane flew normal since." A post-landing inspection, once more, revealed no discrepancies in the elevator control system.

Finally, on March 27, 2001, American Airlines reported that one of its B767-300 airplanes experienced pitch control difficulties when descending through 6,000 feet on approach to Paris, France. A post-incident evaluation of the FDR confirmed that one of the elevators was frozen (believed to be the right elevator) in response to both autopilot and manual inputs. This event was described in the NTSB letter to the ECAA dated April 19, 2001 as a binding of the elevator aft quadrant. The pilots used the stabilizer trim to land the airplane. On the ground, the crew applied a higher force on the control column to break the elevator free. The post-landing inspection also revealed no discrepancies in the elevator system and the airplane was ferried back to Dallas, Texas. The incident is still under investigation by the NTSB, FAA, and Boeing.

Not only are these incidents significant because they provide documented evidence of malfunction in the Boeing 767 elevator system, they also conclusively demonstrate that such malfunctions can occur without leaving any obvious physical evidence. The NTSB's five-year investigation of the USAir 427 accident was made all the more difficult and prolonged precisely because the suspect valve left no physical evidence of a malfunction. In light of this evidence of previous incidents and of the physical anomalies found in the Flight 990 wreckage, the NTSB's contention that there is no evidence of a possible mechanical malfunction is neither accurate nor credible.

9. **(Page 23, footnote 40)** The footnote refers to the February 2000 incident involving an AeroMexico Boeing 767. The airplane experienced two failed bellcrank shear rivets. This prompted a March 15, 2000, Boeing letter to Boeing 767 operators which discussed the findings and explained that the bellcrank assembly rivets are designed to shear in the event of a jam of a PCA. Efforts by the NTSB and the Egyptian Team to examine components of the AeroMexico airplane were unsuccessful because the parts were not retained by Boeing. Consequently, the statement that the "examination of the elevator PCA's revealed no evidence of a PCA jam" is an unsubstantiated report from Boeing -- which has its own interest in the outcome of this investigation -- and was not verified by the NTSB. It would be helpful to describe exactly what Boeing examined and what it observed rather than simply repeat the conclusory statement that there was "no evidence of a PCA jam." Moreover, the NTSB should point out that the absence of evidence of a valve jam is not determinative as to whether or not a jam occurred.

10. **(Page 25)** There actually have been more than 152 reports of damaged shear rivets. The draft report understates the magnitude of this issue and the safety implications of the sheared rivets and the elevator control system failures.

11. **(Page 25)** Given the critical nature of the bellcrank assembly rivet issue and its possible involvement in the Flight 990 accident, it is irresponsible for the draft report to dismiss this issue with nothing more than the statement that "although the cause of the bellcrank shear rivet failures has not yet been determined, Boeing and the FAA are continuing to study the failures to identify the cause." What is not mentioned is that the FAA is discussing an elevator system design change with Boeing. Given the documented safety problems with the elevator control system and the ongoing, unresolved deficiencies, the dismissive treatment by the NTSB in the draft report is surprising. This lack of emphasis potentially could be justified if the cause of the sheared rivet failures were known and had been thoroughly analyzed. However, without knowing the cause of the failures, the NTSB cannot dismiss the issue as unrelated to the EgyptAir Flight 990 accident and still expect to maintain high standards of accident investigation credibility.

12. **(Page 25)** This section states that the airplane is controllable with a dual bellcrank failure. However, there is no discussion of the increased control forces a pilot would experience or the fact that there is no pilot training for this failure. This information is critical to a proper analysis of pilot actions.

13. **(Page 30)** Speech Pattern Information -- This entire section was developed without consideration to how a person would react if he were so shocked or ill-prepared by an unexpected airplane system failure that he reverted to a state of inaction. This behavior has been documented by the NTSB in the past, but is not accounted for here.

14. **(Page 32)** The purportedly "unintelligible" comment was interpreted by some in the CVR group as "control it." If "control it" was uttered by a crewmember in response to observed, unexplained, movement of the control column or the control wheel, it explains both the comment and the decision to disconnect the autopilot. Again, this comment is not included or discussed in the draft, especially within the context of the statement of the EgyptAir captain who observed this activity on the outbound flight.

It is puzzling that the NTSB repeatedly describes this phase as "unintelligible" when five of the nine CVR Group members were able to understand the words -- with four believing it to be "control it" and one thinking it was "hydraulic." In fact, it was only a minority of the group that found the speech "unintelligible." In light of these facts, it is wrong for the NTSB to label the utterance as unintelligible. The comment that these words "might have been an isolated declaration" of the RFO is sheer speculation. In fact, given the RFO's reported lack of comfort using English, it is highly unlikely that he was the speaker.

15. **(Page 34)** Here, the NTSB describes its review of the transcripts of other accidents and states that it "did not observe instances on these CVR recordings in which a pilot failed to exhibit surprise, alarm, or increased stress . . . ." The NTSB's purpose in making this comparison with Flight 990 obviously is to suggest that the absence of exclamations from the RFO indicates he was in control of the events and, therefore, was not surprised. First, the NTSB fails to note that the instances it uses for comparison all involved circumstances where there were two or more crewmembers in the cockpit at the beginning of the accident sequence. Consequently, many of the comments appear to have been made as part of the communication from one crewmember to another. Although there is no evidence to prove that the RFO was alone in the cockpit, the NTSB assumes this to be a fact. Therefore, the circumstances of Flight 990 are unlike any of those studied by the NTSB. Second, and more important, the NTSB provides no data or studies to show that the absence of an excited utterance is in any way meaningful, much less that it is indicative of an intent to crash an airplane. Consequently, there is no evidence in the record to support a view that the RFO was acting improperly.

In contrast to the lack of evidence concerning the meaning of the absence of an excited utterance, there is specific, expert evidence in the record that the NTSB ignores completely. An Egyptian psychiatrist, Dr. Adel Fouad, listened to the entire CVR tape and provided a detailed report substantiating his conclusion that the RFO was acting normally and interacted appropriately with the Captain. The NTSB surpressed this evidence in its report and provided no explanation as to why Dr. Fouad's opinion -- the only expert medical opinion obtained during the investigation -- was completely ignored.

16. **(Page 37)** The report should be clarified to reflect that it could not be determined if portions of either the right or left elevator surfaces were recovered or were present at either wreckage site.

17. **(Page 39)** Although the NTSB notes the unusual characteristics of the internal mechanisms of one of the right-side PCA's, nowhere does the NTSB discuss the fact that in the entire course of the five-year USAir Flight 427 investigation, it did not find any anomalies on the internal mechanisms of any of the PCA slides that it examined. In fact, the EgyptAir PCA slide anomaly is probably the first ever found by the NTSB. The absence of this background stands in stark contrast to the extensive historical context that the NTSB devotes to the review of CVR transcripts to show the uniqueness of the RFO's response compared to other flight crews.

In most NTSB reports the metallurgical investigation is reported in a separate section to provide detailed information about the metallurgical findings of the investigation. In the draft report, however, the NTSB puts the metallurgical work in the wreckage information section and provides virtually no detail about any findings. This is a critical oversight, since the metallurgical work is tied directly to the FAA Airworthiness Directives on the sheared bellcrank rivets, and is related to the Boeing inspection procedure for the rivets which was proved to be unsatisfactory.

Additionally, if the FAA and Boeing have not found the cause of the rivet shears, it is irresponsible for the NTSB to provide anything less than a full accounting of the EgyptAir 990 PCA and bellcrank rivet examinations. In fact, the findings were that two of the three bellcrank rivets on the right elevator sheared in a direction different from the third bellcrank assembly rivet on the same side. The draft report fails to identify the right elevator as the location of these conflicting shear patterns and makes only a very general (and vague) statement that some assemblies sheared in a direction opposite to the others.

18. **(Page 39)** The statement that there were no scrapes or abrasions on the bias spring is misleading and incomplete. The bias spring is composed of a metal that is harder than other PCA components and, therefore, would naturally resist any physical evidence of a jam. Moreover, in the USAir 427 accident investigation, the NTSB concluded that a jam could occur in a similar PCA without leaving any physical mark.

19. **(Page 40)** The statement that the fracture surfaces "were consistent with failures generated by high-speed impact" is misleading and incomplete. This statement is written not just to advise that the fracture surfaces are consistent with high-speed impact, but also to suggest that high-speed impact <u>caused</u> the fractures. There is no evidence that these fractures were, in fact, caused by a high-speed impact. In fact, the fractures are stress fractures that are just as consistent with low-speed forces as with high speed. This statement in the report needs to be corrected.

20. **(Page 41)** The NTSB states that the U.S. Air Force determined that unidentified radar returns "were caused by radio interference." For over 18 months, the Egyptian Team has been seeking the technical data that would either support or refute this conclusion and has consistently been refused access to this information. The data on which the Air Force relies should be disclosed and delivered to the Egyptian Team.

21. **(Page 44, footnote 70)** This note suggests that even a small sideslip angle or roll rate could produce large changes in the aerodynamic forces acting on the ailerons when approaching 1.0 Mach. If the NTSB believes that these same forces do not affect the elevators in a similar way, the difference must be explained.

22. **(Page 45, footnote 71)** The NTSB advises that for performance numbers higher than .91 Mach (the highest number for which Boeing has verified data), "the simulator's database was adjusted to reflect extrapolations . . . ." This reflects the inexact methodology relied upon by the NTSB to arrive at its conclusions. With respect to the use of extrapolated data to predict transonic airplane performance, the Egyptian Team is not aware of any study or analysis that validates this approach. The reason is that airplane performance and aerodynamic forces change in radical ways as the airplane's speed approaches 1.0 Mach as it did here. Consequently, without technical evidence that extrapolation produces valid results, none of the simulator results above .91 Mach can be considered reliable.

Furthermore, the validity of many of the simulator results is questionable for an even more fundamental reason. The simulator runs were based on published Boeing performance data and predictions. Various ground tests, using an actual Boeing 767, however, demonstrated that many of Boeing's predicted results did not reflect real-world airplane behavior. Nevertheless, Boeing refused to use the ground test results in the simulator experiments. Thus, there is empirical evidence that demonstrates the inherent unreliability of conclusions based solely on simulator results and Boeing's calculated predictions. Without further study, it is not possible to determine the margin of error. It is, however, clear that many of the NTSB's factual assertions are derived from faulty simulator tests.

23. **(Page 48)** The assertion that "calculations" showed that there would initially be 6 degree nose-down elevator deflection is accurate, but misleading. As noted above, this number was derived from Boeing calculations -- not from testing -- that could not be replicated on a real airplane, thus raising a significant question as to their validity. The simulator was then programmed to produce a 6 degree nose-down deflection as shown in NTSB figure 2. The clear implication of the NTSB's text and its charts is that the dual PCA jam testing produced certain results that did not "match" the FDR. This is simply not the case because the test parameters were nothing more than Boeing's calculations. Consequently, none of the testing confirmed Boeing's calculations. Indeed, it was just the opposite as shown by the ground tests. Therefore, the NTSB's assertions that a dual PCA jam would produce a deflection of 6 degree nose-down on the failed side and 4 degree nose-down on the non-failed side suggests a degree of precision not warranted by any of the tests conducted during the investigation. The error built into the simulator testing along with normal variations in airplane performance make it impossible to conclude (with any reasonable scientific certainty) that Flight 990 was not affected by a dual PCA jam.

24. **(Page 50)** In an effort to convince the reader that the simulation results were valid, the NTSB states (a) that the simulator reflected the flight characteristics "to the maximum extent possible," (b) that all flight conditions "were calculated correctly," and (c) that the out-the-window view replicated the visual cues during actual flight. Again, these statements are both misleading and inaccurate. Even if the simulator reflected the EgyptAir 990 characteristics "to the maximum extent possible," the NTSB has omitted any discussion of the inaccuracies in the modeling and whether those inaccuracies affected the test results. As noted previously, the ECAA believes that there were sufficient inaccuracies in the data used in the simulator which, when combined with the limitations of the simulator, produced inaccurate results. In particular, these inaccuracies do not support a definitive conclusion as to the amount of elevator deflection in the various failure scenarios. The degree of precision represented in the NTSB draft report is simply not a valid product of the simulator testing and misrepresents the reliability of the data obtained.

25. **(Page 50)** The NTSB acknowledges that in recovering the airplane during the dive, "additional forces" would be required beyond those necessary for recovery if a failure had not occurred. However, the NTSB omits any discussion the magnitude of those "additional forces" and of the impact that such forces have in the recovery of the airplane. Again, there was a marked difference in the additional forces demonstrated through ground testing and those predicted in the simulator -- with the ground testing forces being much higher. The actual demonstrated forces were never used in the simulator, making the NTSB's comments concerning recoverability speculative. Rather than simply identify an issue and then ignore it, the NTSB must discuss the additional forces needed for recovery, the duration that such forces must be applied, and the effect of zero or negative g on the crew's ability to apply such forces. Unless these issues are fully developed, there can be no meaningful conclusion regarding the recoverability of the airplane.

The numerous references in the draft report to the recoverability of the airplane reveal another "backdoor" through which the NTSB arrives at its probable cause determination. Presumably, the NTSB's logic is that if an airplane suffering a dual PCA jam can be recovered in the simulator, then the failure to recover Flight 990 means that it did not experience a dual PCA jam. The obvious flaw in this logic is that no matter how good the simulator is, it cannot reproduce the feelings, sensations, and emotions triggered by an unexpected upset, at night, over the ocean, during which the airplane and its contents experience a 40 degree nose down pitch and the crew and passengers experience negative g forces.

Further, in none of its references to "recoverability" does the NTSB ever define what it means by that term. If recovery were defined as a point at which an uncommanded descent has been arrested, the wings are level, and the pitch has almost reached zero, then the Flight 990 crew recovered the airplane because those were the flight characteristics when the FDR stopped recording. Precisely what happened after Flight 990 recovered is unknown because both the CVR and FDR stopped recording. It does appear, however, from the location and condition of the left engine, that pieces of the airplane, including the left engine, departed the airplane prior to the beginning of the second, fatal dive toward the ocean. The loss of the left engine -- likely due to an overstress of the airplane during the ascent back to 24,000 feet -- created an asymmetrical load on the airplane from which recovery was virtually impossible. Consequently, regardless of the reason that the airplane initially departed cruise flight, there is a substantial argument that the reason that Flight 990 crashed was because it lost a major component -- the left engine -- which rendered the airplane unstable and unrecoverable.

26. **(Page 58)** As a result of the EgyptAir's January 12, 2001 response to the Boeing submission, the NTSB was compelled to conduct further simulator tests and bench tests of the pressure relief valves of the elevator control assembly. These additional tests were required because of the incorrect data -- identified by EgyptAir -- that Boeing had submitted to the NTSB. The inaccuracies in the Boeing submission resulted in incorrect blowdown data for the elevator which was subsequently used as the basis for some of the airplane performance analysis. These facts should be included in the report to document the inaccuracies of the Boeing performance data relied upon by the NTSB. The variances in Boeing data demonstrate how easy it is to move the FDR flight profile towards, or away from, the E Cab simulator profile for a dual actuator failure. This aspect of the investigation underscores the manner in which the factual record and the subsequent analysis was selectively developed in the draft report.

27. **(Page 59)** The NTSB's assertion that there was "no evidence of any ATC problems or issues" is incorrect. The ATC transcript included in the docket shows that Flight 990 was "lost" in the ATC system during the handoff from New York TRACON to New York ARTCC. Further, the controller did not attempt to contact Flight 990 until six minutes after the accident sequence began and almost four minutes after the airplane crashed into the ocean. It appears that the light early morning air traffic may have lulled the controller into a period of inattention. It is neither acceptable nor explainable that an ATC controller does not notice the disappearance of an aircraft for more than four minutes after the last possible transponder radar return -- particularly when there are only a few airplanes in the air.

28. **(Page 60)** The analysis does not address in any way the reports of unexplained movements of the control column or the control wheel. These events on the outbound flight are possibly the reason the RFO disconnected the autopilot on EgyptAir Flight 990.

29. **(Page 60)** The discrepancy between the left and right elevators as recorded on the FDR prior to the event are not cited or analyzed. The position differences are indicative of an anomaly in the elevator control system and are critical to the analysis of the PCA jam/failure scenario

30. **(Page 61)** This sweeping generalization does not at all address the likelihood or possibility that the right elevator separated from the airplane about 0150:21. EgyptAir previously provided the NTSB with detailed calculations regarding the expected roll rate that would have occurred if the elevator were attached and in fact split from the left elevator to the extent indicated on the FDR. The NTSB must explain why the expected roll did not occur.

31. **(Pages 62-63)** The discussion of the recovered PCA's and the bellcrank assemblies provides no in-depth analysis or a description of the anomalies that have been documented. The Board again fails to note that the one PCA from EgyptAir Flight 990 with a sheared rivet, sheared slid pin and an improperly positioned coil spring is the only PCA ever examined by the NTSB with any observable anomalies. The NTSB's analysis does not address the shear patterns of the recovered elevator bellcrank assemblies except to attribute them in general to "high speed water impact and under water recovery." There are no facts in the docket to support, much less prove, this conclusion. This analysis is inadequate and speculative and, more importantly, appears intended solely to support the deliberate act scenario.

Further, the analysis completely avoids any discussion of the NTSB's statement on page 39 that the internal anomalies of the right elevator PCA "might or might not have been impact-related." If those anomalies were not impact-related, then they indicate a serious problem in

Flight 990's elevator system. Unless the NTSB can exclude non-impact causes for this observed damage, it is not correct to state that there is no evidence of a mechanical defect, and it is not appropriate to assert a probable cause based on purported flight control inputs by the RFO.

32. **(Page 63)** The shear rivets in the recovered elevator bellcrank assemblies were sheared in different directions; however, "the Safety Board considers it likely that the rivets sheared as a result of impact or recovery-related forces." The NTSB continues to ignore the history of the bellcrank shear rivets since this accident. The unexplained rivet failures have resulted in two FAA Airworthiness Directives, new airline inspection procedures for the rivets, and possible design changes of the system by Boeing. In addition, there was an unexplained elevator jam on an American Airlines Boeing 767 in March 2001. It is irresponsible for the NTSB to summarily dismiss this issue with a "considers it likely" assessment in the accident analysis. The existence of uncontroverted evidence of deformed rivets, suggesting a defect in the Boeing 767 elevator system, makes opinion "evidence" highly speculative and inappropriate. There is significant physical evidence that suggests that this type of failure was a factor in the accident.

As a relevant factor, however, the issue is not so much whether sheared rivets <u>caused</u> the uncommanded dive, but whether such shearing -- potentially evidenced by the opposing shear patterns on the recovered bellcranks -- is indicative of as yet unidentified problems elsewhere in the elevator control system. If nothing else, this investigation has shown that the Boeing 767 elevator system is extremely complex and that there is relatively little certainty as to its precise operation under various failure scenarios. Consequently, the mere existence of examples of rivet shearing and deformation, the cause of which is unknown, should be adequate evidence of the possibility of a mechanical malfunction relating to Flight 990. This possibility is all the more likely where, as here, the rivets in question are designed and intended to give way in the event of a PCA jam. It is hardly farfetched or speculative to suggest that the rivet defects that have been observed are attributable to intermittent PCA jams, which are sufficiently transient as to leave no direct evidence and are sufficiently random as to defy predictability. The ECAA also notes that there was no physical evidence observed on the PCA's of the USAir Flight 427 or United Flight 585 where the NTSB concluded that the PCA caused a malfunction of the rudder. In the EgyptAir accident, the NTSB has physical evidence of an anomaly with the PCA yet concludes that "… the absence or presence of a jammed or disconnected impact linkage or a jam in the servo valve in one of the airplanes elevator PCA's could not be established."

33. **(Page 64)** The centerpiece of the NTSB's argument that there was no evidence of a mechanical failure is that the elevators did not move to 6? TED at the beginning of the dive. As discussed previously, there are substantial reasons to question whether the calculated -- not demonstrated -- value of 6 degrees is accurate. Moreover, there is no discussion of whether this initial deflection value could be less if the crew were exerting back-pressure on the control column or if the failure were intermittent -- or at least not total -- at the beginning of the dive. Finally, there is no data in the docket showing the range of deflection that could be expected in the case of a dual PCA jam. Because the 6 degrees is a calculated number, it does not reflect real-world variances. If such variances were accounted for, the deflections observed on the Flight 990 FDR would likely be far closer to the NTSB's calculations for a dual PCA jam. Again, the NTSB's emphasis on the precise amount of deflection is misleading, not only because the testing did not validate that degree of precision, but also because it tends to obscure the physical evidence of a possible jam -- the oppositely sheared rivets, the sheared servo slide pin, and the differential bending in the PCA connecting rods. This physical evidence cannot be dismissed as impact damage when there is no evidence to prove it was impact-related.

34. **(Page 65)** Figure 2 shows a close correlation during the first 13 seconds between the accident aircraft FDR elevator profile and the dual jam failure scenario. Figure 2 also shows a close correlation between the accident aircraft elevator profile and all three failure scenarios if the RFO makes some limited control inputs once the accident sequence starts. However, the draft report does not address these issues and simply dismisses the possibility that any of the failure scenarios are consistent with the accident aircraft FDR data. Again, the NTSB's failure to include any discussion of the forces necessary to move the flight control surfaces creates a misleading impression. The NTSB's claim that "the nonfailed surface would have responded immediately to any nose-up flight control inputs" is not correct. The nonfailed surface would not respond to "any" nose-up input; it would only respond to nose-up input of a sufficient force to overcome the failed condition. As demonstrated in the ground testing, this force is considerably higher than the normal force. Whether the crew would immediately apply sufficient force to overcome a failure for which they were not trained is a matter of conjecture.

This same comment applies to the NTSB's wholly conclusory assertion that the lack of demonstrated nose-up movement proves that there was no attempt to recover the airplane (see p. 66). There is no evidence whatsoever to support this statement, which is made solely for the purpose of placing blame for the accident on the RFO. The fact is that the RFO could have been attempting a recovery, but failed -- or was not able -- to exert sufficient force to move the elevators in a failed condition. The question of the RFO's ability to exert the necessary force is significant when Figure 4 is examined. Figure 4 shows that the downward deflection of the elevators tracked exactly the decrease in load factor. This may indicate that as the load factor decreased, the RFO became less able to exert the force necessary for recovery and, thus, the force of the PCA failure overcame the force of recovery. Figure 4 also shows that when the load factor began to increase, the elevators also began to move TEU -- possibly in response to the increasing ability of the crew to gain the leverage necessary to exert recovery level forces.

35. **(Page 67)** The draft report seriously understates the limitations of the E Cab simulator and the Boeing aircraft performance data with the simple statement that "the Board is well prepared to take those limitations into account … In this case the Board determined that the differences were not significant …." This sweeping conclusion again indicates a preconceived conclusion by the Safety Board to not involve the airplane in the accident scenario. More importantly, the draft report omits any discussion explaining exactly how the NTSB took the simulator limitations into account, what differences were considered, and why those differences were deemed "not significant" in the context of this investigation.

36. **(Pages 67-68)** As part of its conclusion that there was no mechanical failure, the NTSB argues that the RFO "exhibited no audible expression of anxiety or surprise." This fact -- even if true -- does not mean that there was no PCA jam or that the elevator bellcrank rivets did not shear. By making this argument in the mechanical defect analysis section of the draft report, the NTSB illustrates the biased and predetermined nature of the report. Clearly, there are no scientific or behavior studies that link the existence of a surprised utterance with proof of a mechanical defect in an airplane.

In its apparent haste to place blame on the RFO, the NTSB has overlooked three other important considerations. First, when the Captain returned, he asked several times, in an excited way, "What's happening?" Presumably, if an excited utterance were the hallmark of the existence of a mechanical defect, the Captain's statements would tend to support that theory -- particularly when made under circumstances where it should have been obvious to the Captain if the RFO were trying to crash the airplane.

Second, the NTSB's contention that the RFO showed no audible anxiety fails to account for the rapid repetition of the phrase, "I rely on God." That repetition in itself is likely an indicator of stress. Moreover, the NTSB has failed to offer any evidence to support its theory that the lack of discernable stress or anxiety means that the RFO was intentionally diving the airplane. Without such evidence, the RFO's "passive behavior" is just that -- passive behavior. At worst, the RFO's behavior is unexplained -- a vastly different conclusion than that his behavior proves he intentionally dove the airplane.

Third, the NTSB's assessment that the RFO did not exhibit undue anxiety is based, in part, on its analysis of fundamental frequency characteristics, described on pages 29-30 of the draft report. The NTSB's assessment of the RFO was that he exhibited a 25 percent increase in fundamental frequency -- below the 30 percent threshold the NTSB identifies as the indication of "stage 1 level of stress." Interestingly, a similar study of the Captain when he returned to the cockpit and asked "What's happening?" showed an increase of only 29 percent -- still below the

NTSB's 30 percent threshold. Thus, neither the Captain nor the RFO met the NTSB's criteria for a stage 1 level of stress.

The relative comparability of the fundamental frequency increases for both the Captain and the RFO show that it is unfair to characterize only the RFO as purportedly failing to exhibit an audible indication of anxiety. Even at the most extreme point in the accident sequence, the NTSB attributes only a 47 to 65 percent increase in fundamental frequency to the Captain. This equates to a range of stress from stage 1 to a very low level of stage 2 (50 to 150 percent increase). Given the cascading problems aboard Flight 990, including a 40 degree nose-down pitch and zero g, it is remarkable that the Captain barely broke into stage 2 -- and, in fact, did so only toward the end of the descent.

These facts suggest that the NTSB's reliance on a change in fundamental frequency may not, in this case, be an accurate predictor of anxiety and stress. At a minimum, the NTSB must describe the range of variances from the norm that may be attributable to personality, training, and culture. In particular, the NTSB must validate its measurement techniques and analytical assessments for Egyptian persons speaking Arabic.

Finally, the NTSB provides no evidence to show the RFO's intent or motive or otherwise to explain his behavior. It is extraordinary to conclude that the evidence is so strong that it supports a determination of probable cause, yet fail to include any explanation for the allegedly intentional human action that had such tragic consequences. In fact, the total lack of any cogent explanation for the RFO's actions -- in contrast to the detailed scenario established in the Silk Air investigation -- is itself evidence that calls into question the validity of the NTSB's deliberate act theory. In spite of the crucial role that such evidence has in establishing the probable cause set forth by the NTSB, the draft report is silent on the subject. This alone is cause for the NTSB to withdraw its probable cause determination.

37. **(Page 68)** The ECAA maintains that the FDR shows that the crew did recover the airplane -- or, at a minimum, substantially recovered the airplane -- by the time the FDR stopped recording. While it is evident that the recovery could not be maintained, the NTSB draft report fails to discuss the reasons that such recovery was not ultimately successful. Again, without any analysis, the NTSB asserts that a successful recovery was possible. Not only does this conclusory statement substitute speculation for fact, it ignores the real possibility that the airplane, in passing through a range of g forces and approaching 1.0 Mach, experienced shock waves and aerodynamic forces that led to structural damage, including the loss of the right elevator and the left engine. Under those circumstances, the airplane would have been out of control and -- contrary to the NTSB's claim -- unrecoverable.

38. **(Page 69)** The entire Pilot Action Scenario is developed by selectively using information developed during the investigation to prove that the RFO deliberately crashed the airplane. The same information could be presented in a different manner to prove that the RFO had no idea what was happening and that the Captain did not suspect that the RFO was performing any actions that were contributing to the airplane dive. See comments in No. 36 above.

39. **(Page 70)** See previous comment No. 1.

40. **(Page 72)** The RFO could have disconnected the autopilot in response to unexplained movements of the control wheel or column. Further, all radar targets have not been adequately resolved. The Pilot Action Scenario does not account for the fact that the airplane maintained an essentially wings level attitude which would be unexplained if the RFO was trying to dive/crash the airplane or if a struggle was underway with the Captain. Further, the NTSB fails to note that if the RFO were intending to dive the airplane, he could have used an additional 9 degrees of nose down elevator authority. The fact that full elevator authority was not used indicates that the RFO was not intending to dive the airplane.

Similarly, the NTSB implies that retarding the throttles at the beginning of the dive indicates that the RFO intended to dive the airplane. The NTSB is wrong; this action implies precisely the opposite conclusion. If he had intended to crash the airplane, the RFO would have increased power to enhance the dive, rather than slowing the dive by retarding the throttles.

It is readily apparent from a comparison of Flight 990 data with that from Silk Air that the NTSB has manipulated the facts and corresponding analysis to fit its predetermined result. In Silk Air, the NTSB wrote that "physical evidence of a high engine power setting, a horizontal stabilizer trim setting positioned for maximum nose-down attitude, and the absence of any indication of an attempt to reduce the airplane's speed … strongly suggest the [diving] maneuver was intentional." In the case of Flight 990 where all of these factors are the opposite of those in Silk Air -- where the engines were throttled back to a low power setting, less than full elevator authority was used, there was no nose-down stabilizer trim, and various steps, including extended the speed brakes, were taken to reduce speed -- the NTSB still concludes it was an intentional act. It is impossible to believe that the NTSB conducted an objective and unbiased investigation of Flight 990 when it is plain that completely opposite data concerning key factors in two accidents, nevertheless, produced the same NTSB conclusion.

41. **(Page 74)** The NTSB makes several speculative statements without explanation or support. The NTSB hypothesis that the RFO was gripping the control column when he supplied "significant nose-down control column inputs" and that action also provided some input to the ailerons. First, the FDR does not record either control column movement or the forces exerted; consequently, control column movement is only implied from other parameters. There is no FDR data that confirms what action was taken by the RFO. Second, input to the ailerons could also be supplied when pulling on the control column in response to a dual PCA jam.

The NTSB also states that the RFO increased forward pressure on the control column "when he heard the captain returning to the cockpit." This statement demonstrates that the NTSB's intention to avoid an objective evaluation of all of the evidence extends to making up evidence. There is no evidence whatsoever that the RFO heard the Captain returning to the cockpit. The only reason to include this fabricated claim is to place the blame for the accident on the RFO and to provide an explanation for an event that the NTSB finds otherwise unexplainable.

42. **(Page 75)** The NTSB concludes that the Captain made the nose-up elevator movements when he returned to the cockpit. Once again, this statement reflects more the NTSB's conjecture than any supportable facts. Because there is no FDR record of control column movement or force, there is absolutely no basis to claim that the Captain rather than the RFO, or that the Captain alone and not along with the RFO, provided nose-up elevator inputs. As previously pointed out, the RFO could have tried to move the elevator nose-up, but those efforts may not have shown up on the FDR if the force applied was insufficient to overcome a dual PCA failure. The NTSB's failure to provide an objective analysis of the evidence shows its intent to support a predetermined probable cause.

43. **(Pages 75-76)** The contention that the elevators would be minimally affected by aerodynamic forces at .99 Mach is not supported by any validated test data. As noted previously, the extrapolation of airplane performance is not appropriate for the transonic speeds experienced by Flight 990. Consequently, the conclusion that the elevator split was caused by different inputs to each elevator surface is not supported by reliable evidence. More importantly, however, even if differing inputs were the cause of the split, there is no basis other than shear speculation to conclude that the different inputs were the result of a struggle between the Captain and the RFO. In fact, it is just as reasonable (and even more likely) that different control inputs were in response to differing perceptions as to the airplane's attitude and the input necessary to affect a recovery. If the RFO believed that the pitch was increasing too much, he would push the column forward. A split would occur if, at the same time, the Captain believed that the increasing pitch needed to be sustained, and he pulled back. Remarkably, within just a few seconds of the split, the Captain reversed course and reduced the nose-up deflection of the left elevator. It seems reasonable that this action was due to the Captain perceiving, as the RFO had, that the pitch needed to be moderated. There is no indication that the Captain's decreasing nose-up input was because the alleged struggle was "over."

44. **(Page 76)** The NTSB's statement that the Captain's actions just after the split "were consistent with an attempt to recover the airplane, and the relief first officer's were not" is totally unsupported opinion and not factual analysis. If the NTSB insists on this reasoning, then it must add that during the last 10 seconds of the recording, when the Captain moved the left elevator TED and the RFO moved the right elevator TEU, the RFO's actions were consistent with an attempt to recover the airplane, and the Captain's were not. In fact, the Captain's action is completely contrary to his request to the RFO to "pull with me."

45. **(Pages 80-81)** The NTSB provides an unnecessary summary of its analysis, based on the same erroneous facts and unsupported conclusions addressed by the comments set forth above.

CONCLUSION

In summary, it is obvious that the NTSB has not done the type of professional accident investigation expected by the Egyptian Government when delegation was convened in November 1999. Pursuant to section 5.3 of Annex 13, it was anticipated that the investigation would be conducted as a partnership between equals. However, it soon became apparent that the NTSB leadership did not regard the Egyptian delegation as an equal partner and shared its processes, if at all, on a selective and seemingly random basis. Often the Egyptian delegation read about the NTSB's views in the press without prior communication.

Therefore, the responsibility of the Egyptian Government for the integrity of air safety and to underscore the work the Egyptian Investigation Team has done in the past 17 months, obliges the Government of Egypt to prepare a comprehensive and objective report of accident. This report is an accurate, technical document for use by an aviation industry that is truly concerned with air safety and addressing the safety issue of the EgyptAir Flight 990 accident on October 31, 1999.