Controlled Flight Into Terrain, Era Aviation, Sikorsky S-76A++, N579EH, Gulf of Mexico, About 70 Nautical Miles South-Southeast of Scholes International Airport, Galveston, Texas, March 23, 2004

Micro-summary: **This Sikorsky S-76A crashed into the sea for undetermined reasons.**

Event Date: **2004-03-23 at 1918:34 CST**

Investigative Body: **National Transportation Safety Board (NTSB), USA**

Investigative Body's Web Site: **http://www.ntsb.gov/**

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Era Aviation
Sikorsky S-76A++, N579EH
Gulf of Mexico, About 70 Nautical Miles
South-Southeast of
Scholes International Airport, Galveston, Texas
March 23, 2004

Aircraft Accident Report

NTSB/AAR-06/02

PB2006-910402
Notation 7646B

National Transportation Safety Board
Washington, D.C.

Aircraft Accident Report

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Notation 7646B
Adopted March 7, 2006

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2006. ***Controlled Flight Into Terrain, Era Aviation, Sikorsky S-76A++, N579EH, Gulf of Mexico, About 70 Nautical Miles South-Southeast of Scholes International Airport, Galveston, Texas, March 23, 2004.*** **Aircraft Accident Report NTSB/AAR-06/02. Washington, DC.**

Abstract: This report explains the accident involving an Era Aviation Sikorsky S-76A++ helicopter, N579EH, which crashed into the Gulf of Mexico about 70 nautical miles south-southeast of Scholes International Airport (GLS), Galveston, Texas. Safety issues discussed in this report focus on terrain awareness and warning systems for helicopters, flight control system training, flight-tracking technology for low-flying aircraft in the Gulf of Mexico, and preflight testing and maintenance checks for cockpit voice recorders. Safety recommendations concerning these issues are addressed to the Federal Aviation Administration.

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Contents

5. Appendixes

Figures

Abbreviations

ADI	attitude direction indicator
ADS-B	automatic dependent surveillance–broadcast
agl	above ground level
ALT	altitude
ALT PRE	altitude preselect
AP	autopilot
ASOS	automated surface observing system
ASR	airport surveillance radar
ATT	attitude
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CAM	cockpit area microphone
CFIT	controlled flight into terrain
CFR	*Code of Federal Regulations*
CLTV	collective
CPL	couple
CPLT FD	copilot flight director
CRM	crew resource management
CVR	cockpit voice recorder
DAFCS	digital automatic flight control system
DCPL	decouple
DDAFCS	dual digital automatic flight control system
DFDR	digital flight data recorder
DH	decision height
EFIS	electronic flight instrument system
EMS	emergency medical services
FAA	Federal Aviation Administration

FD	flight director
FDR	flight data recorder
FOU	Port Fourchon, Louisiana
fpm	feet per minute
GLS	Scholes International Airport
GPS	global positioning system
GPWS	ground proximity warning system
HDG	heading
HSAC	Helicopter Safety Advisory Conference
HSI	horizontal situation indicator
IAS	indicated airspeed
IFR	instrument flight rules
LCH	Lake Charles Regional Airport
METAR	meteorological aerodrome report
msl	mean sea level
NAV	navigation
nm	nautical mile
NWS	National Weather Service
PIC	pilot in command
POI	principal operations inspector
RA	radar altitude
S/N	serial number
SAS	stability augmentation system
SBY	standby
TAWS	terrain awareness and warning system
UTC	coordinated universal time
VFR	visual flight rules
VHF	very high frequency
VMC	visual meteorological conditions
VS	vertical speed
VSI	vertical slope indicator

Executive Summary

On March 23, 2004, about 1918:34 central standard time, an Era Aviation Sikorsky S-76A++ helicopter, N579EH, crashed into the Gulf of Mexico about 70 nautical miles south-southeast of Scholes International Airport (GLS), Galveston, Texas. The helicopter was transporting eight oil service personnel to the Transocean, Inc., drilling ship *Discoverer Spirit*, which was en route to a location about 180 miles south-southeast of GLS. The captain, copilot, and eight passengers aboard the helicopter were killed, and the helicopter was destroyed by impact forces. The flight was operating under the provisions of 14 *Code of Federal Regulations* Part 135 on a visual flight rules flight plan. Night visual meteorological conditions prevailed at the time of the accident.

The National Transportation Safety Board determines that the probable cause of this accident was the flight crew's failure to identify and arrest the helicopter's descent for undetermined reasons, which resulted in controlled flight into terrain.

The safety issues discussed in this report focus on terrain awareness and warning systems for helicopters, flight control system training, flight-tracking technology for low-flying aircraft in the Gulf of Mexico, and preflight testing and maintenance checks for cockpit voice recorders. Safety recommendations concerning these issues are addressed to the Federal Aviation Administration.

1. Factual Information

1.1 History of Flight

On March 23, 2004, about 1918:34 central standard time,[1] an Era Aviation Sikorsky S-76A++ helicopter, N579EH, crashed into the Gulf of Mexico about 70 nautical miles (nm) south-southeast of Scholes International Airport (GLS), Galveston, Texas. The helicopter was transporting eight oil service personnel to the Transocean, Inc., drilling ship *Discoverer Spirit*, which was en route to a location about 180 miles south-southeast of GLS. The captain, copilot, and eight passengers aboard the helicopter were killed, and the helicopter was destroyed by impact forces. The flight was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 135 on a visual flight rules (VFR) flight plan.[2] Night visual meteorological conditions (VMC) prevailed at the time of the accident.

The accident helicopter had been operated out of Era Aviation's flight and maintenance facility at Port Fourchon (FOU), Louisiana, as part of its contract with Union Oil Company of California for day and night aviation support operations. On March 22, 2004, two Era Aviation pilots repositioned the accident helicopter from FOU to GLS because the *Discoverer Spirit* was going to be operating from a location in the Gulf of Mexico that was closer to GLS. On March 22, the copilot drove his personal vehicle from FOU to GLS. On March 23, the captain drove his personal vehicle from his home to GLS.[3]

An Era Aviation captain stated that he saw the accident captain briefing the accident copilot and both pilots obtaining weather information from the Internet. The Era Aviation captain also stated that he saw the accident captain, in the right pilot seat,[4] taxi the helicopter to the site where the copilot and passengers would board.[5] The Era Aviation captain further stated that one box of cargo and the passengers' baggage were loaded on the helicopter.

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[1] All times in this report are central standard time based on a 24-hour clock.

[2] This flight plan was maintained by the company and was followed by the company dispatcher. The flight plan was not filed with the Federal Aviation Administration. See section 1.17.1.3 for more information.

[3] The accident captain, who normally worked the day shift, had been off duty during the previous 5 days but was aware that he would need to replace the on-duty night captain because of a scheduling conflict. During a postaccident interview, the captain's wife stated that he had changed his sleep pattern during the previous 72 hours so that he could handle the job requirements for this work assignment.

[4] The captain normally occupies the right seat in a helicopter.

[5] Each passenger viewed a videotaped safety briefing before boarding the helicopter.

A dispatcher located at Era Aviation's Gulf Coast headquarters was responsible for communicating by radio with the accident flight and entering information about the flight in a computerized log after each radio transmission. The dispatcher's records showed that the helicopter departed GLS at 1845 on an estimated 45-minute flight to an en route refueling stop at High Island A-557.[6] The records also showed that the helicopter had 2 hours of fuel on board at the time of departure. The cockpit voice recorder (CVR) recording began at 1847:42. The recording was mostly unintelligible, but conversational-tone voices were discernible during parts of the recording.[7]

Radar data from the Airport Surveillance Radar-9 (ASR-9) at the George Bush Intercontinental Airport in Houston, Texas,[8] showed that the helicopter flew on a south-southeasterly course after takeoff and climbed to 1,800 feet mean sea level (msl). The radar data also showed that the helicopter remained at 1,800 feet msl until about 1858:10 and then started to descend at a rate of about 300 feet per minute (fpm). A radar return that was received about 1900:21 showed that the helicopter was at an altitude of 1,100 feet msl and that its rate of descent was about 250 fpm. No radar returns were received after that time because the helicopter was no longer within the range of radar coverage.[9] At that point, the helicopter was about 35 nm south-southeast of GLS.

According to company procedures, the flight crew was responsible for providing the dispatcher with a position report every 15 minutes.[10] During its 1914 position report,[11] the flight crew told the dispatcher that the helicopter had enough fuel on board (1.6 hours) to continue directly to the *Discoverer Spirit*.[12] Also, the flight crew asked the dispatcher to provide updated coordinates to the *Discoverer Spirit*.[13] The dispatcher received no further

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[6] A lighted fixed oil and gas platform with refueling capability was located in *U.S. Gulf Coast VFR Aeronautical Chart* reference area High Island A-557, which was about 80 nm south-southeast of GLS and slightly to the east of a direct course from GLS to the reported location of the *Discoverer Spirit* (*U.S. Gulf Coast VFR Aeronautical Chart* reference area Alaminos Canyon 738).

[7] See section 1.11.1 for more information.

[8] The National Transportation Safety Board obtained these data from the U.S. Air Force 84th Radar Evaluation Squadron.

[9] ASRs are designed to provide short-range radar coverage within the general vicinity of an airport. The maximum radar coverage is about 60 nm. At the time of the last radar return, the accident helicopter was about 58 nm southeast of the Houston ASR-9 radar site.

[10] The standard position report at the time of the accident consisted of the helicopter's distance to its destination and the amount of fuel on board the aircraft. After the accident, the position reports also included the helicopter's altitude.

[11] The flight crew had provided two previous position reports—at 1850 and 1902. Both reports indicated that the helicopter would stop at High Island A-557 for refueling.

[12] The CVR recording captured the copilot stating, in part, "we [have] enough to ah fly to ah spirit."

[13] The *Discoverer Spirit* was lighted, and its helideck had refueling capability.

communications from the flight crew.[14] About 1918:25, the CVR recorded the sound of decreasing background noise. The CVR stopped recording about 1918:34.

The dispatcher's records showed that, at 1923, she tried to make radio contact with the flight crew to provide updated coordinates to the *Discoverer Spirit* but received no response from the crew. The records also showed that, at 1931, 1934, 1946,[15] and 2008, the dispatcher continued to try to make radio contact with the helicopter. The 1931 entry indicated that the dispatcher would call the *Discoverer Spirit* to see if someone aboard the ship could make radio contact with the helicopter,[16] and the 1934 entry indicated that someone aboard the ship was trying to contact the helicopter.

During a postaccident interview, the dispatcher stated that, in her communications with the flight crew, everything sounded normal with no strange background noises. Also, the dispatcher received no emergency or distress calls from the helicopter.

Seven vessels (from the U.S. Coast Guard and Union Oil) and nine aircraft (from the Coast Guard; Era Aviation; Petroleum Helicopters, Inc. [PHI]; and Evergreen Helicopters) were activated for search and rescue operations.[17] Pilots aboard these aircraft observed debris floating near the area that was believed to be the location of the helicopter after its last communication with the dispatcher. The helicopter wreckage was located about 70 nm south-southeast of GLS and 10 nm northwest of High Island A-557 at a depth of about 186 feet.

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[14] If a flight crew position report is not called in within 15 minutes of the last report, the helicopter's tail number on the flight plan line (which is displayed on the dispatcher's screen) turns from white to yellow. If the position report is still not called in within the next 5 minutes, the entire flight plan line turns to yellow. If the flight crew has not called in to close out or extend its flight plan at the estimated time of arrival for the helicopter's destination, the entire flight plan line turns red.

[15] The dispatcher's records indicated two entries for 1946.

[16] The *Discoverer Spirit* had two-way FM radio communications capability with the helicopter.

[17] According to an Era Aviation vice president, five aircraft were dispatched on the night of the accident for search and rescue operations: a helicopter from PHI was deployed from GLS about 2150; an Era helicopter was deployed from Houma, Louisiana, about 2209; two U.S. Coast Guard aircraft were deployed about 2210; and a helicopter from Evergreen Helicopters was deployed from GLS sometime before 2230. By 0515 on March 24, 2004, four vessels had joined the search and rescue operations. By 1000 on March 24, three additional vessels and four additional aircraft had joined the search and rescue operations.

1.2 Injuries to Persons

Table 1. Injury chart.

Injuries	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	2	0	8	0	10
Serious	0	0	0	0	0
Minor	0	0	0	0	0
None	0	0	0	0	0
Total	2	0	8	0	10

1.3 Damage to Aircraft

The helicopter was destroyed as a result of impact forces with the water.

1.4 Other Damage

No other damage was reported.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 50, held an airline transport pilot certificate with a rotorcraft-helicopter rating. The captain also held a Federal Aviation Administration (FAA) first-class medical certificate dated May 12, 2003, with a limitation that required him to wear lenses to correct for distant vision and possess glasses to correct for near vision.

The captain served in the U.S. Army from July 1977 to August 1988, during which time he graduated from Army flight training and became an Army pilot (December 1980). From October 1988 to October 1999, the captain served in the U.S. Coast Guard as a pilot. The captain was hired by Era Aviation in November 1999.

According to company records, the captain had accumulated 7,288 hours total flying time, including 5,323 hours as pilot-in-command (PIC) of multiengine helicopters, 1,489 hours aboard S-76 helicopters, and 1,028 hours at night. Company records also showed that the captain had accumulated 3,913 hours total flying time in the Gulf of Mexico. Further, the captain had flown in the Gulf of Mexico 389, 64, and 32 hours in the

12 months, 90 days, and 30 days, respectively, before the accident. The 32-hour flight time (for the 30 days before the accident) included about 3 hours at night.

Between March 1, 2003, and March 23, 2004, the captain accumulated 344 total flight hours (764 flights) in Era Aviation S-76A helicopters, 335 hours of which were flown during the day and 9 hours of which were flown at night. Of his 344 total flight hours, the captain flew 276 hours in S-76As with an analog flight control system and 68 hours in S-76As with a digital flight control system.[18] Of the 68 hours in a digital S-76A, 1 hour was flown at night, and 17 hours (43 flights) were flown in the accident helicopter (with 0.4 hour—the accident flight—at night).

The captain completed initial ground and flight training for the S-76A on November 17, 1999; a flight check on January 30, 2004, in an analog S-76A; recurrent instrument training on February 18, 2003; and recurrent ground training on February 26, 2004. The captain was also rated in the Bell 212/412 helicopter. FAA records indicated no accident or incident history or enforcement action, and a search of the National Driver Register indicated no record of driver's license suspension or revocation.

The captain's wife reported that he was in good health and that his financial situation was good. She also reported that he was not taking any prescription or nonprescription medications. In addition, she stated that he did not smoke and that he consumed alcohol occasionally at home.

The captain normally worked the day shift (0530 to 1930). The captain was on duty from March 4 to 17, 2004,[19] and was off duty from March 18 to March 22, 2004. Before the captain went off duty, he was made aware that he would need to cover the upcoming night shift. On March 23, 2004, the captain drove his personal vehicle from his home to GLS (about 30 miles) and reported for duty about 1700. The accident flight was his first flight. The accident flight was also the first one that paired the captain and the copilot.

The captain's wife stated that, during the 72 hours before the accident, his activities included doing yard work and "stuff around the house." She also stated that, on the morning of the accident, the captain slept until 1100. The captain's wife further stated that she spoke with him during the afternoon and indicated that he sounded fine.

An Era Aviation captain (who was formerly the company's chief pilot) stated that the accident captain was always an extremely conscientious pilot and that he trusted him implicitly. The captain also stated that he never heard any complaints about the accident captain.

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[18] All Era Aviation S-76A pilots are trained to fly both the analog and digital flight control system versions of the helicopter. The accident helicopter had a digital flight control system. See section 1.17.1.1 for information about the S-76A analog flight control system and sections 1.6.3.2 and 1.17.1.1 for information about the S-76A digital flight control system.

[19] Era pilots were generally scheduled to be on duty for 2 weeks and then off for 2 weeks.

1.5.2 The Copilot

The copilot, age 46, held a commercial pilot's license with a rotorcraft-helicopter rating. The copilot also held an FAA first-class medical certificate dated March 15, 2004, with a limitation that required him to wear corrective lenses while exercising the privileges of the certificate.

The copilot received flight training at Versatile Aviation, Ardmore, Oklahoma, from August 1999 to April 2000, during which time he received his flight instructor certificate (October 1999). From April 2000 to March 2001, the copilot was a flight instructor at Versatile Aviation. From March to June 2001, he was a line pilot at Kenai Helicopters, Grand Canyon, Arizona. The copilot was hired by Era Aviation in August 2001.

According to company records, the copilot had accumulated 1,941 hours total flying time, including 1,371 hours as "PIC Helicopters," 534 hours as "SIC (second-in-command) Helicopters," 483 hours aboard S-76 helicopters, and 63 hours at night. Company records also showed that the copilot had accumulated 1,027 hours total flying time in the Gulf of Mexico. Further, the copilot had flown in the Gulf of Mexico 678, 14, and 4.5 hours in the 12 months, 90 days, and 30 days, respectively, before the accident. The 4.5-hour flight time (for the 30 days before the accident) included 3.6 hours at night.

Between March 1, 2003, and March 23, 2004, the copilot accumulated 451 total flight hours (608 flights) in Era Aviation S-76A helicopters, 434 hours of which were flown during the day and 17 hours of which were flown at night. Of his 451 total flight hours, the copilot flew 314 hours in S-76As with a digital flight control system and 137 hours in S-76As with an analog flight control system. Of the 314 hours in a digital S-76A, 9 hours were flown at night, and 79 hours (97 flights) were flown in the accident helicopter (with 5.4 hours flown at night between January 20 and March 23, 2004).

The copilot completed initial ground and flight training for the S-76A on December 12, 2002, and his first S-76A flight occurred on February 11, 2003. The copilot completed recurrent ground training on February 12, 2004; recurrent instrument training on February 17, 2004; and a flight check on February 20, 2004, in the accident helicopter (a digital S-76A). The copilot was also rated in the Bell 212/412 helicopter. FAA records indicated no accident or incident history or enforcement action, and a search of the National Driver Register indicated no record of driver's license suspension or revocation.

The copilot had been assigned to the night shift during his previous several duty periods, the last of which ended on March 3, 2004. The copilot had been off duty from March 4 to 17, 2004. He began his most recent duty schedule on March 17, 2004. From March 18 to 20, the copilot attended training (ground school for the Boelkow 105 helicopter)[20] at Lake Charles Regional Airport (LCH), Lake Charles, Lousiana, from 0800

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[20] Era Aviation training records showed that the copilot was in the process of upgrading to PIC of the Boelkow 105 helicopter, which has analog instrumentation and no autopilots or flight directors.

to 1700. On March 21, the copilot drove his car from LCH to FOU (about 230 miles); on March 22, he drove his car from FOU to GLS (400 miles). The copilot returned to the night shift on March 23, and the accident flight was his first flight during the duty period.

An Era Aviation captain who shared an apartment with the copilot when they were scheduled for duty indicated that he and the copilot would arrive at work about 1630 and that the night shift would begin about 1700 and end about 0500. The captain also indicated that he and the copilot would typically go to sleep immediately after their shift ended and that they would wake up about 1400. The captain described their schedules as “eat, sleep, work, eat, sleep, work for 14 days and then you go home.”

The Era Aviation captain stated that the copilot’s health was excellent and that his financial situation was unremarkable. The captain also stated that, on the day of the accident, the copilot was not suffering from a cold or allergies, and his mood was fine. Another Era Aviation captain stated that the copilot smoked and that he consumed alcohol only outside of work.

The Era Aviation captain who shared an apartment with the copilot when they were on duty stated that the copilot did not have any problems flying the S-76A and that he was interested in moving up in the company. The captain had previously flown 11 hours with the copilot and stated that the copilot had volunteered to do all of the flying. The captain further stated that he knew of no complaints about the copilot’s flying abilities and that he had not experienced any emergencies or other problems during previous flights with the copilot. In addition, the Era Aviation captain who was formerly the company’s chief pilot stated that the copilot was very keen and very conscientious, and another Era Aviation captain stated that the copilot was extremely competent.

1.6 Aircraft Information

The accident helicopter, a Sikorsky S-76A++, serial number (S/N) 760274, was a transport-category, twin-engine, single main rotor helicopter that was configured to carry 2 pilots and up to 12 passengers. Aircraft records showed that the helicopter was manufactured in 1984 and was issued an export airworthiness certificate to Court Aviation Company of South Africa. Aircraft records also showed that the helicopter was transferred to Era Aviation in June 2001, at which time the helicopter received a new registration number, and that the helicopter received its U.S. airworthiness certificate in August 2001. At the time of the accident, the helicopter had accumulated 10,075 total flight hours and 2,882 total cycles.[21]

1.6.1 Main Rotor and Tail Rotor Systems

The S-76A main rotor system provides the aerodynamic forces that make the helicopter fly. The main rotor system includes the main rotor drive shaft, which is attached

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[21] An aircraft cycle is one complete takeoff and landing sequence.

to a main transmission gearbox and a main rotor head,[22] and four main rotor blades, which are installed on a main rotor hub. Three hydraulic actuators (forward, aft, and lateral) control the movement of the swashplate, which changes the pitch angle of the main rotor blades.

The S-76A tail rotor system is used to control torque (that is, the tendency of helicopters with a single main rotor system to turn in the opposite direction of the main rotor rotation). The tail rotor system includes a tail rotor drive shaft with five sections that run through the tail cone, an intermediate gearbox, a tail rotor gearbox, and four tail rotor blades. The tail rotor drive shaft is attached to the main transmission gearbox. The tail rotor blades are integrated into two paddles so that each paddle has one blade on each end.

1.6.2 Powerplants

Aircraft records showed that the accident helicopter was initially installed with two Rolls Royce (formerly Allison) 250-C30 engines. The records also showed that, on June 19, 1998, Keystone Helicopters of West Chester, Pennsylvania, installed two Turbomeca Arriel 1S1 engines aboard the helicopter. (The designation for S-76A helicopters that are equipped with Arriel 1S1 engines is S-76A++.) At the time of the accident, the left engine, S/N 3015, had accumulated 4,519 hours and 7,633 cycles, and the right engine, S/N 15109, had accumulated 2,052 hours and 3,161 cycles.

1.6.3 Flight Control Systems

1.6.3.1 Cyclic, Collective, and Tail Rotor Pedal Control Systems

The accident helicopter was equipped with cyclic, collective, and tail rotor pedal control systems. Moving the cyclic forward or aft causes the helicopter to pitch up or down;[23] moving the cyclic left or right causes the helicopter to roll in the commanded direction.[24] Raising or lowering the collective results in a simultaneous increase or decrease, respectively, in the lift produced by the main rotor blades. Moving the tail rotor pedals (which are similar to airplane rudder pedals) positions the tail rotor blades to cause the helicopter to yaw.[25] Either pilot can control the cyclic, collective, and tail rotor pedal control systems.

1.6.3.2 SPZ-7000 Dual Digital Automatic Flight Control System

The accident helicopter was equipped with a Honeywell SPZ-7000 Dual Digital Automatic Flight Control System (DDAFCS), which was specifically designed for helicopters to provide full four-axis (longitudinal, lateral, vertical, and yaw) flight control. The DDAFCS includes the autopilots (see section 1.6.3.2.1); flight directors (see

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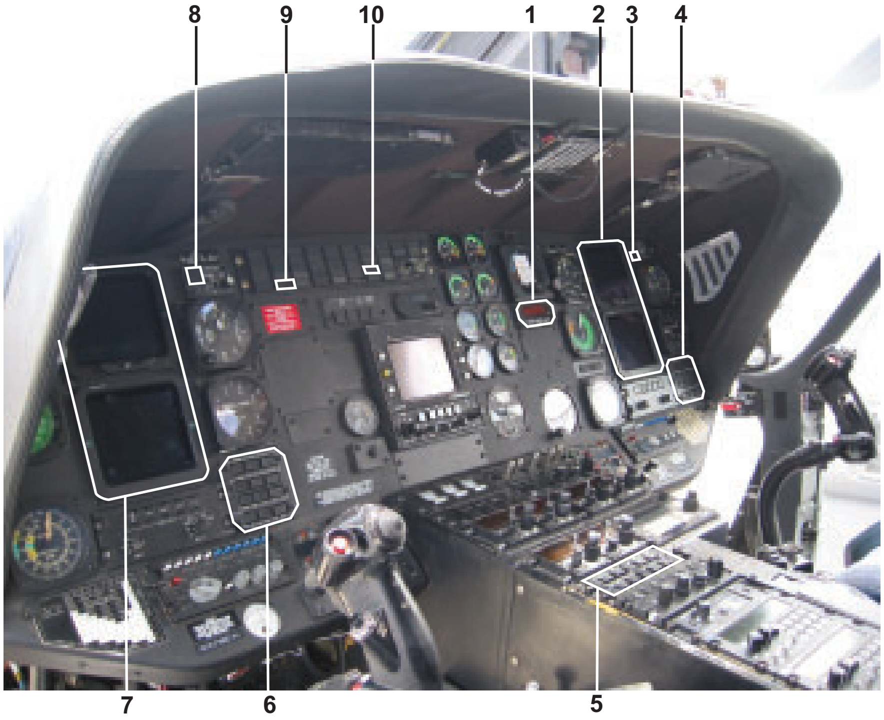
[22] The main rotor head has four spindles and four blade dampers.

[23] Pitch is the movement of the helicopter about its lateral (side to side) axis.

[24] Roll is the movement of the helicopter about its longitudinal (nose to tail) axis.

[25] Yaw is the movement of the helicopter about its vertical axis.

section 1.6.3.2.2); flight control computers, which provide all computations for autopilot and flight director operation; air data components,[26] which provide the flight control computers with information about the helicopter's airspeed, altitude above sea level, vertical speed, and radar altitude (that is, the helicopter's altitude above the surface);[27] and an autotrim system. Figure 1 is a preaccident photograph of the helicopter's cockpit that shows the location of DDAFCS components and indications.



1. Air data command display (AL-300)
2. Captain's electronic flight information system (EFIS) displays
3. Captain's digital automatic flight control system (DAFCS) caution panel and decouple (DCPL) indication
4. Captain's flight director mode selector
5. Autopilot controller
6. Copilot's flight director mode selector
7. Copilot's EFIS displays
8. Copilot's DAFCS caution panel and DCPL indication
9. Copilot's flight director indication
10. DAFCS indication

Figure 1. Location of DDAFCS Components and Indications in the Accident Helicopter's Cockpit
Source: Era Aviation.

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[26] The air data components include an air data command display known as the AL-300.

[27] Radar altitude is computed by the radar altimeter system. The radar altimeter receiver/transmitter box sends a signal to the ground through a transmitter antenna. The receiver/transmitter box receives an echo through a receiver antenna. The receiver/transmitter box then measures the phase or time difference between the two signals and transmits this information to the cockpit in terms of feet above the ground. Radar altitude is also referred to as radio altitude.

1.6.3.2.1 Autopilots

Dual autopilot systems provide stability to the S-76 helicopter through a stability augmentation system (SAS) and an attitude retention mode (ATT). Both SAS and ATT modes provide heading hold,[28] yaw damping and autotrim, and automatic turn coordination. The SAS mode provides short-term rate damping during manual flight and is selected when extensive maneuvering is required; this mode is commonly used during the initial and final phases of flight and while hovering. The ATT mode provides pitch and roll attitude retention, through the autotrim system, during manual flight. Thus, after an in-flight disturbance, the helicopter will automatically return to the reference attitude. The ATT mode engages automatically when either autopilot is selected. Upon initial ATT mode engagement, the helicopter's reference attitude is its current attitude. The reference attitude can be reset by pressing a button on the cyclic.

Only one of the stability modes (SAS or ATT) can be engaged at a time. The autopilot controller is used to engage SAS or ATT and autopilots No. 1 and No. 2 (AP1 and AP2). (Autopilot coupling, which refers to automatic flight, is discussed in section 1.6.3.2.3.) When selected, the SAS button illuminates in amber, the ATT button illuminates in green, and the AP1 and AP2 buttons illuminate in green and indicate "ON." Figure 2 shows the autopilot controller, which is located on the center pedestal (as shown by number 5 in figure 1).

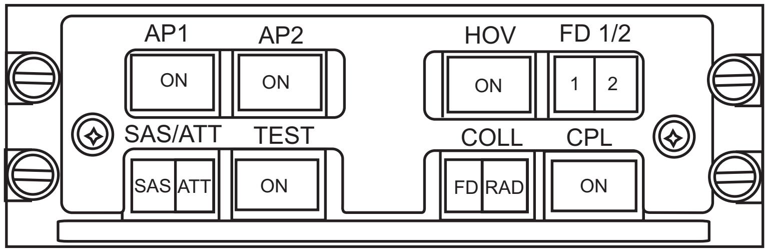

Figure 2. Autopilot Controller

Note: The "FD1/2" button allows the pilot to select flight director 1 or 2 (as discussed in section 1.6.3.2.2). The "CPL" button automatically illuminates when the autopilot and the flight director are coupled (as discussed in section 1.6.3.2.3). The "HOV" button allows the pilot to select the hover mode. The "COLL" button allows the pilot to select either the flight director or the radar altimeter to provide collective commands. The "TEST" button allows the pilot to test the autopilots before they are engaged.

Source: Honeywell.

1.6.3.2.2 Flight Directors

The flight directors assist pilots in maintaining a specified flightpath or attitude through the presentation of command cues[29] on the attitude director indicators (ADI).[30]

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[28] SAS provides heading hold when the helicopter's airspeed is below 60 knots; ATT provides heading hold at all airspeeds.

[29] Additional information about command cues appears in section 1.18.5.

[30] The ADIs are the top screens of the EFIS displays (as shown by numbers 2 and 7 in figure 1). Information about the ADIs appears in section 1.6.3.3.

Flight director 1 is used when the left seat pilot is flying the helicopter, and flight director 2 is used when the right seat pilot is flying the helicopter. Flight director selection is made on the autopilot controller (see figure 2) with the FD1/2 button, which illuminates in white and indicates "1" or "2" depending on which flight director was selected. (Each press of the FD1/2 button alternates between flight directors 1 and 2.) When FD1 is selected, a "CPLT FD" light illuminates in green on the caution/advisory panel on the front instrument panel (see number 9 in figure 1). No light illuminates on the caution/advisory panel when FD2 is selected.

The command cues that are presented on the ADIs generally correspond to the selected flight director modes, which include heading (HDG), vertical speed (VS), altitude (ALT), navigation (NAV), altitude preselect (ALT PRE), and standby (SBY). Figure 3 shows the flight director mode selector, which is located on the front instrument panel (as shown by numbers 4 and 6 in figure 1).

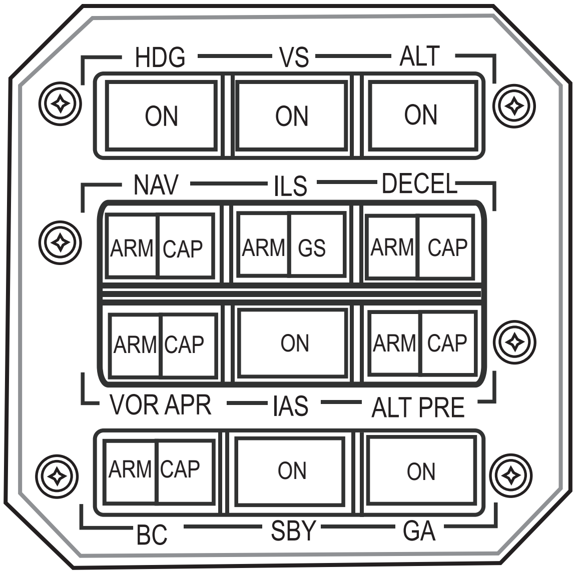

Figure 3. Flight Director Mode Selector

Note: Other buttons on the flight director mode selector are ILS, instrument landing system mode; DECEL, deceleration mode; VOR APR, very high frequency omnidirectional range approach mode; IAS, indicated airspeed mode; BC, instrument landing system backcourse; and GA, go-around mode.

Source: Honeywell.

1.6.3.2.3 Coupling Function

For the SPZ-7000 DDAFCS, whenever a flight director mode is selected, FD1 or FD2 becomes automatically coupled to the autopilot as long as AP1, AP2, and the autopilot's ATT mode are engaged. Coupling allows the flight director's computed pitch and roll attitude corrections to be input to the autopilot so that the pilot does not have to manually control the helicopter according to the command cues on the ADIs. The CPL button on the autopilot controller (see figure 2) automatically illuminates in green and indicates "ON" when the autopilot and the flight director are coupled.[31] The primary method to decouple the autopilot and the flight director is by pushing the CPL button.[32] Once decoupling occurs, the pilot is required to fly the helicopter manually. No aural warning occurs when the autopilot and flight director become decoupled.

During normal operations, the illumination, or absence of illumination, of the CPL button is the only direct annunciation of the status of the couple function.[33] Because of its location on the center pedestal, the CPL button is out of the pilots' routine instrument scan. During abnormal operations,[34] a DCPL (decouple) warning indicator on the pilots' digital automatic flight control system (DAFCS) caution panels[35] illuminates in amber whenever the autopilot and flight director are not coupled for an activated mode.[36] The DAFCS caution panels are located in front of the pilots above the barometric altimeters (as shown by numbers 3 and 8 in figure 1).

1.6.3.3 Electronic Flight Information System

The DDAFCS interfaces with an analog electronic flight information system (EFIS), which receives inputs from attitude, heading, navigation, and flight director sources to provide information to four cathode-ray tube flat-panel screens on the front instrument panel (two for each pilot position). The top screens are the electronic ADIs, which display pitch and roll attitudes via a blue and brown sphere that moves with respect to a stationary aircraft symbol to display actual pitch and roll attitudes. The bottom screens are the electronic horizontal situation indicators (HSI), which display the helicopter's position in relation to the selected course and heading or actual heading.

The ADIs display numerous items in addition to the attitude sphere and command cues (if selected). For example, the ADIs annunciate, at the top of the display, the flight director mode (or modes) that has been selected. The ADIs also annunciate the radar altitude

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[31] During postaccident interviews, Era Aviation S-76A pilots indicated that the CPL button had to be selected to couple the autopilot and flight director. However, pressing the CPL button actually decouples the two systems.

[32] An alternate method of decoupling is by pressing a quick release button on the bottom of the cyclic. When this button is pressed, the CPL button's ON annunciation no longer illuminates, all modes selected on the flight director mode selector disengage and return to standby, and command cues are no longer shown on the ADI.

[33] Indirect indications of the couple function are shown by course deviation on the ADIs and the horizontal situation indicators and changes displayed on mechanical instruments, such as the barometric altimeter, heading indicator, and vertical speed indicator.

[34] Abnormal refers to an aircraft-induced decouple resulting from a malfunction of a sensor, which causes an activated mode to decouple.

[35] The DAFCS caution panels annunciate malfunctions related to the autopilot and coupling function. The panel has three other warning indications besides DCPL: AP1, AP2, and CLTV (collective). The AP1 and AP2 warnings illuminate in amber when an autopilot failure, a hardover, or an oscillatory malfunction occurs. The CLTV warning illuminates in amber when the collective trim switch is off or the collective command limit has been exceeded.

[36] Whenever any DAFCS caution panel warning is annunciated, the abbreviation "DAFCS" illuminates in amber on the caution/advisory panel (see number 10 in figure 1), and a red "MASTER WARNING" light under the glareshield panel (the top rim portion of the front instrument panel) illuminates.

in blue in the lower right corner[37] and the pilot-selected decision height[38] in blue in the lower left corner.[39] Figure 4 shows an electronic ADI and its various displays. The ADIs do not show which flight director has been selected or whether it has been coupled to the autopilot.

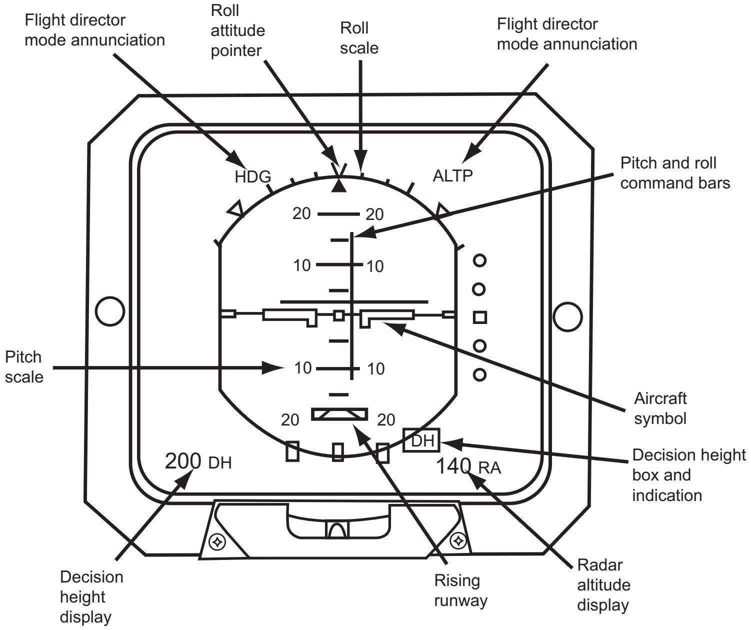

Figure 4. Electronic Attitude Director Indicator

Source: Honeywell.

1.6.4 Maintenance Records

Maintenance records for the accident helicopter indicated that it was being maintained in accordance with an FAA-approved Continuous Airworthiness Maintenance Program. This program consists of regularly scheduled inspections, parts replacements, and tests and uses a computer database to track an aircraft's flight and maintenance activities. The database also tracks the requirements for inspections, overhauls, retirement of components, airworthiness directives, service bulletins, and survival equipment.

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[37] The radar altitude readouts, which range from -20 to 2,500 feet, appear numerically in 10-foot increments between 200 and 2,500 feet and 5-foot increments below 200 feet.

[38] The decision height is the height at which a decision must be made either to continue the approach or execute a missed approach. The decision height is selected in 5-foot increments from 0 to 200 feet and 10-foot increments from 200 to 990 feet. The decision height knob is located on a display controller on the center pedestal.

[39] According to Era Aviation's Operations Manual (Operating Procedures section, chapter 5, page 11, dated December 23, 2002), "an operating radar altimeter is required for all night flights and for all day flights when the ceiling is less than 400 feet and/or the visibility is less than 2 miles. The DH [decision height] shall be set to 200 feet."

On March 22, 2004, a main rotor blade inspection (performed every 300 hours) was conducted at LCH. On March 23, 2004 (the accident date), a tail rotor spar inspection (performed every 25 hours) was conducted at GLS. The aircraft maintenance log for March 22 and 23, 2004, indicated "preflight inspection made this date, A/C [aircraft] deemed Airworthy and Satisfactory for operational flight."

The last recorded flight control maintenance action occurred on March 15 and 16, 2004. The maintenance action involved replacing the helicopter's trim relay assembly (a minimum equipment list [MEL] item)[40] because of an inoperative relay, performing an operational check, and clearing the helicopter for flight. The replacement of the helicopter's trim relay assembly was the final corrective action for a series of discrepancies concerning the flight director that occurred between March 9 and March 16, 2004.[41]

1.6.5 Previous Flights

On March 22, 2004, two Era Aviation pilots repositioned the accident helicopter from FOU to GLS. During a postaccident interview, the copilot who repositioned the accident helicopter stated that the captain of the repositioning flight tested the DDAFCS before departure and found it to be functioning properly. This copilot also stated that the DDAFCS was engaged during the flight and that the flight director ALT mode had been selected. Further, the copilot stated that he did not recall anything being wrong with the helicopter during the flight and that the helicopter performed as expected.

On March 23, 2004, the helicopter flew 5.4 hours before the accident flight with no reported discrepancies. The captain of these flights stated, during a postaccident interview, that the helicopter flew well and experienced no problems. The DDAFCS was used during this flight.

1.7 Meteorological Information

Weather observations at GLS are made by an automated surface observing system (ASOS), which is maintained by the National Weather Service (NWS). The ASOS records

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[40] According to the FAA, an MEL is an inventory of instruments and equipment that may legally be inoperative with the specific conditions under which an aircraft may be flown with such items inoperative.

[41] On March 9, 2004, the aircraft maintenance log indicated that the copilot's flight director did not hold altitude when the navigation and heading modes were selected and that the helicopter pitched nose down and descended when the collective was lowered manually. The log also indicated that, to correct this discrepancy, the pilot's and copilot's flight control computers were swapped; however, because this action only transferred the problem to the pilot's side, the flight control computers were switched back, and the copilot's computer was replaced. An operational check was performed, but the copilot's flight director still responded as before. On March 10, 2004, the copilot's flight director was placed on the MEL. To address the problem, the pitch trim actuator was replaced on March 12, 2004. A ground check of the pitch trim actuator was then performed, which was successful. On March 15, 2004, the trim relay assembly was replaced because of an inoperative relay. On March 16, 2004, paperwork was updated to indicate that the trim relay assembly had been replaced and that this corrective action had cleared the discrepancy. As a result, the flight director was removed from the MEL, and the helicopter was cleared for flight.

continuous information on wind speed and direction, cloud cover, temperature, precipitation, and visibility[42] and transmits an official meteorological aerodrome report (known as a METAR) each hour in coordinated universal time (UTC). (Central standard time is 6 hours behind UTC time.) The 0052Z[43] METAR (1852 local time), which was issued 7 minutes after the helicopter departed from GLS, indicated the following: winds 110º at 11 knots, visibility 10 miles, few clouds at 2,800 feet, overcast at 4,000 feet, temperature 19º C (66º F), dew point 16º C (61º F), and altimeter setting 30.25 inches of mercury.

The NWS surface analysis chart for 0000Z (1800 local time) showed a ridge of high pressure extending over the area with winds from the east-southeast at 10 to 20 knots. Buoy reports indicated winds from the east-southeast to southeast at 17 to 21 knots. Satellite imagery depicted no cumulonimbus clouds or thunderstorms over the region but depicted a scattered to broken layer of low stratiform clouds over the Gulf of Mexico south of GLS. The Galveston weather service radar identified no weather echoes near the accident site.

Sunset occurred about 1833, and the end of evening civil twilight[44] was about 1856, which was 11 minutes after the flight's departure from GLS. According to the U.S. Naval Observatory, 8 percent of the moon disk was illuminated at the time of the accident.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

During a postaccident interview, the Era Aviation dispatcher reported that the flight crew called her after takeoff. The dispatcher stated that she was able to hear the pilots but that they were unable to hear her, even after they changed frequencies. The dispatcher thought that the reason for this lack of communication was because the helicopter had just taken off and had not reached a sufficient altitude. No other communications problems between the dispatcher and the flight crew were reported.

No audio record of the conversations between the dispatcher and the accident flight crew was available.[45] Such conversations are normally recorded on a very high

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[42] Cloud cover is expressed in feet above ground level. Visibility is expressed in statute miles.

[43] The "Z" designation that follows the time in a weather observation stands for Zulu, which indicates UTC time.

[44] The U.S. Naval Observatory explains evening civil twilight as follows: "to end in the evening when the center of the Sun is geometrically 6 degrees below the horizon. This is the limit at which twilight illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished...Complete darkness, however...begins sometime after the end of evening civil twilight."

[45] The only record of the communications between the dispatcher and the pilots was a three-page printout containing nine entries (as described in section 1.1). The printout was generated from the dispatcher's computerized log at Era Aviation's Gulf Coast headquarters.

frequency (VHF) tape deck system in Era Aviation's Gulf Coast headquarters operations center; however, on the night of the accident, the tape deck system was not working.[46]

1.10 Airport Information

Not applicable.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The helicopter was equipped with an L-3 Communications solid-state model FA2100 CVR, S/N 118739. The exterior of the CVR did not appear to have any heat or structural damage, but it had been submerged in salt water. The CVR memory module was removed, restacked using dry components, and installed on a Safety Board FA2100 CVR chassis in the Board's audio laboratory. The CVR audio data was successfully downloaded.

The CVR recording contained four channels of audio data. The first audio channel, which was not required by Federal regulations, did not contain any usable audio information. The second and third audio channels recorded information from the pilot and copilot stations but did not contain any usable audio information. The fourth audio channel contained poor quality[47] audio information from the cockpit area microphone (CAM). A transcript was prepared of the entire 30-minute 52-second digital recording (see appendix B), but most of the recording was obscured by a high level of background noise.

The manufacturer of the CVR evaluated the main chassis to determine if the CVR was functioning properly at the time of the accident. The evaluation determined that the CVR was operating within its design specifications.

The Safety Board evaluated the internal communications system units from the pilot (captain) and copilot stations. On the left side of each unit was a white notched switch, labeled model 105/103, that could slide up or down to be set in the top (105) or the bottom (103) positions. According to CVR installation documentation provided by Era

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[46] During a postaccident interview, Era Aviation's director of operations stated that the system had been unhooked 1 or 2 days earlier for the installation of new furniture but that the system was accidentally not hooked up again. Once the problem was discovered, the system was hooked up again. In addition, a computer-based backup system for audio recordings was installed a few weeks after the accident.

[47] The Safety Board rates the quality of CVR recordings according to a five-category scale: excellent, good, fair, poor, and unusable. Poor quality CVR information is characterized by the following traits: extraordinary means had to be used to make some of the crew conversations intelligible. The transcript that was developed may indicate fragmented phrases and conversations and may indicate extensive passages where conversations were missing or unintelligible. This type of recording is usually caused by a combination of a high cockpit noise level with a low voice signal (poor signal-to-noise ratio) or by a mechanical or electrical failure of the CVR system that severely distorts or obscures the audio information.

Aviation, the switches determine the internal configuration for the CVR output, and failure to set the switches to the correct model position results in a lack of audio input to the respective CVR channels. The helicopter's CVR installation required that the switches be set to the bottom (103) position, but the switches were found set to the top (105) position. (These switches were not visible to the pilots.) After this accident, Era Aviation checked the CVRs installed on its remaining S-76A helicopters and found that the switches were set to the correct position.

According to FAA Form 337, "Major Repair and Alteration," the installation of the CVR and the pilot and copilot audio panels on the accident helicopter was performed at an FAA-certified repair station and was approved by the FAA on August 2, 2001. FAA Form 337 also stated, "an operational test of the CVR system was complied with."

1.11.2 Flight Data Recorder

The accident helicopter was not equipped with a flight data recorder (FDR) because, in August 2003, the S-76A became permanently exempt from Federal regulations requiring the helicopter to be so equipped. Before the permanent exemption was granted, Era Aviation had petitioned the FAA for an exemption from 14 CFR 135.152, "Flight Recorders," paragraph (a), to permit the company to operate two of its newly acquired S-76A helicopters—N575EH and N579EH (the accident helicopter)—under Part 135 without an FDR installed.[48] Section 135.152(a), stated the following at the time of the petition:

> No person may operate under this part a multi-engine, turbine-engine powered airplane or rotorcraft having a passenger seating configuration, excluding any required crewmember seat, of 10 to 19 seats, that was either brought onto the U.S. register after, or was registered outside the United States and added to the operator's U.S. operations specifications after October 11, 1991, unless it is equipped with one or more approved flight recorders that use a digital method of recording and storing data and a method of readily retrieving that data from the storage medium.

In its June 11, 2001, letter, Era Aviation stated that operations without FDRs "do not degrade safety." The letter also stated that the Safety Board's accident data for rotorcraft operated under Part 135 with seating of 10 to 19 passengers do not indicate "that the cause of accidents is in question or that the investigative process would have been improved by the requirement for a DFDR [digital flight data recorder]."

In an August 17, 2001, letter to Era Aviation, the FAA stated that it had previously issued grants of exemption to petitioners with circumstances similar to those presented in Era's petition. The letter referred to Grant of Exemption No. 6785, dated June 12, 1998, in which the FAA (specifically, the Director, Flight Standards Service) stated that the petitioners had demonstrated "valid reasons" for exempting several helicopter models,

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[48] In its letter, Era Aviation stated that it currently operated 37 other helicopters (with seating for 10 to 19 passengers) without FDRs installed.

including the S-76A, from the FDR requirements,[49] but the letter did not explain what these reasons were. The letter also stated that the FAA had found that "exempting certain helicopters from the FDR requirements would be in the public interest and would not adversely affect safety." The letter further stated that Era Aviation's reasons for requesting an exemption did not materially differ from those presented by the petitioner in Grant of Exemption No. 6785. As a result, the FAA granted Era Aviation an exemption from 14 CFR 135.152(a) for N575EH and N579EH (Grant of Exemption No. 7605), which allowed the company to continue to operate the helicopters without an FDR installed. The FAA's letter stated that the exemption would terminate on January 31, 2004, unless it was superseded or rescinded sooner.

On August 18, 2003, the S-76A helicopter became permanently exempt from the requirements of 14 CFR 135.152. Title 14 CFR 135.152(k) stated the following:

> For aircraft manufactured before August 18, 1997, the following aircraft types need not comply with this section: Bell 212, Bell 214ST, Bell 412, Bell 412SP, Boeing Chinook (BV-234), Boeing/Kawasaki Vertol 107 (BV/KV-107-II), deHavilland DHC-6, Eurocopter Puma 330J, Sikorsky 58, Sikorsky 61N, Sikorsky 76A.[50]

The final rule, which was issued on July 18, 2003 (and became effective 1 month later), focused primarily on 14 CFR Part 121 parameter accuracy issues with large transport-category Boeing and Airbus airplanes. The Safety Board commented on those issues before the issuance of the final rule. The FAA did not notify the Board of its intent to include the rotorcraft exemptions as part of the final rule and did not provide a comment period for the final rule.[51] Thus, the Board did not have the opportunity to formally state its position on the rotorcraft exemptions before the issuance of the final rule.

The Era Aviation S-76A accident highlighted the problems associated with rotorcraft exemptions from FDR requirements. As a result, on March 7, 2006, the Safety Board issued Safety Recommendation A-06-18, which asked the FAA to remove the current rotorcraft exemptions to 14 CFR 135.152(a). This recommendation is further discussed in section 1.18.6.2.

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[49] The FAA stated the following in Grant of Exception No. 6785: "following the August 18, 1997, effective date of Amendment No. 135-69, 'Revisions to Digital Flight Data Recorder Rules; Final Rule' (62 FR 38362, July 17, 1997), the FAA received requests from several helicopter operators for exemption from the new DFDR requirements. The FAA found that the petitioners demonstrated valid reasons for exempting the following helicopters from the DFDR requirements: Bell 212, Bell 214ST, Bell 412, Bell 412SP, Sikorsky 61N, and Sikorsky 76A. Because the material presented by the petitioners concerning those helicopters supported the FAA's finding of an exception to the rule, the exemptions were issued until §135.152(k) could be changed to include the affected helicopters as exceptions to the DFDR requirements."

[50] After the accident, Sikorsky began voluntarily equipping all of its new commercial aircraft, including the S-76, with FDRs.

[51] Title 14 CFR 11.29 states that the FAA may issue a direct final rule without first issuing a notice of proposed rulemaking (NPRM) if (1) an NPRM is "impracticable, unnecessary, or contrary to the public interest" or (2) the agency does not expect any adverse comments to the changed rule.

1.12 Wreckage and Impact Information

The helicopter wreckage was found on March 25, 2004. The wreckage was recovered from the sea floor (a depth of about 186 feet) at a location about 70 nm south-southeast of GLS in *U.S. Gulf Coast VFR Aeronautical Chart* reference area High Island A-508.

The helicopter fuselage showed severe accordion-type crushing. The fuselage was fragmented with pieces of structure attached to helicopter components. About 95 percent of the structure was recovered. The structure showed no evidence of bird strikes, fatigue fractures, or other anomalies. The nose cone had separated from the fuselage and showed minor damage. The lower fuselage showed upward compression fractures. The tailboom (the structure that connects the helicopter's fuselage to its tail rotor) had separated from the helicopter fuselage. Inward crushing was found on the lower part of the structure that attached the fuselage and tailboom, and tearing was found on the upper part of the attachment structure. The bottom of the tailboom was undamaged.

The front instrument panel was intact, and most instruments remained in their respective mounting areas. The EFIS displays were shattered. No useful instrument data were available.

Continuity of the cyclic, collective, and tail rotor pedal control systems could not be established because of the breaks in the systems. All of the breaks were examined, and no evidence of malfunction or failure was found.

1.12.1 Main Rotor and Tail Rotor Systems

The main rotor drive shaft remained attached to the main transmission gearbox and main rotor head. Two of the five sections of the tail rotor drive shaft were fractured, and the other three sections of the tail rotor drive shaft were attached to the tail cone structure.

All four main rotor blades were found fractured and with their blade roots still attached to the main rotor hub. All blade fracture surfaces were consistent with static bending overload and showed no evidence of fatigue. The rotor tips had separated from the blades but were recovered in the main debris field.

Two of the tail rotor blades separated from the tail rotor just outboard of the rotor cuff.[52] The third tail rotor blade remained intact on the spar but had a flatwise spar fracture near the root. The fourth tail rotor blade had fractured, and the outboard portion of the blade was not recovered.[53]

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[52] The rotor cuff is located at the root end of the blade spar and attaches the blade to the rotor head.

[53] Because a tail rotor blade is much smaller and flatter than a main rotor blade, the underwater recovery of a tail rotor blade can be more difficult than that for a main rotor blade.

The main, intermediate, and tail rotor gearboxes were examined at Sikorsky's facility. The gearboxes showed no evidence of malfunction or failure, and none of the components showed evidence of heat distress, warping, discoloration, or other signs of stress.

1.12.2 Powerplants

The left and right engines were found attached to the helicopter structure that surrounds the engine compartment. The engines were found in their normal operating position but had separated from their engine mounting points. The engines showed no evidence of fire damage.

The left and right engines were examined at the Turbomeca facility in Grand Prairie, Texas. The examination revealed torsion fractures to both drive shafts.[54] Evidence (turbine blades on the left engine that had completely shed from the disk) showed that the right engine had sensed an overspeed condition and activated its overspeed protection, which included shutting down the fuel to the right engine and removing all overspeed protection for the left engine. According to Turbomeca, during an accident sequence in which both engines become decoupled from the transmission, one engine will overspeed, and the other engine will not overspeed.

Examination of the overspeed protection boxes found that both boxes had minor external damage. One of the boxes (referred to as box A) was inscribed with the number 2, but the wiring bundle connected to the box was labeled with the number 1. The other box (referred to as box B) had no inscribed number to indicate its position, and no wiring bundle was connected to the box. The boxes' electrical connecting pins were tested for continuity, and the pins indicated that both boxes were not in an overspeed condition.

The overspeed protection boxes were disassembled and examined at Turbomeca's facility in Tarnos, France. The internal examination of both boxes found no evidence of soot, arcing, or overheating but found damage that appeared to be the result of seawater immersion. A pin continuity test of box A showed that it was not in the overspeed position but that its relay was found in the overspeed position. A pin continuity test of box B showed that it was not in the overspeed position and that its relay also was not in the overspeed position.

1.12.3 Landing Gear

The main landing gear was found intact but heavily damaged. The main landing gear doors were pushed upward and showed fractures that were consistent with the doors being closed at impact. The main landing gear floats were folded inside the wheel wells, and the floats were ripped. The main landing gear wheels, tires, and brakes were intact. The nose landing gear was attached to its respective mounting area but had severe structural deformation throughout the assembly. The nose gear support structure was in the up position. The landing gear control valve was intact and in the up position.

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[54] The drive shafts transmit power from the engines to the main rotor blades.

The electrical wiring for the landing gear warning system was examined for proper routing, component placement, and evidence of anomalies. The wiring matched the manufacturer's schematic drawing, which showed that the landing gear warning system was configured to activate red "LDG GEAR UP" lights under the glareshield panel and an aural warning (a gear warning horn) over the pilots' headsets when (1) the helicopter's height above the ground, as measured by the radar altimeter, decreased below a pilot-set decision height[55] with the gear up or (2) the helicopter's airspeed was at or below 60 knots indicated airspeed with the gear up.

The landing gear warning relay was found with damage that appeared to be the result of seawater immersion. The relay was not functional and thus could not be tested after the accident. A postaccident test flight aboard an Era Aviation S-76A helicopter showed that its landing gear warning system (which was similar to that installed on the accident helicopter) worked as indicated on the manufacturer's wiring diagram. Specifically, the aural tone sounded until one of the LDG GEAR UP warning lights was pressed, and the lights remained illuminated until the landing gear was lowered.[56] The test flight also demonstrated that the landing gear warning system's lights were among the brightest, and the aural warning was among the loudest, in the cockpit.

The landing gear warning lights were examined at the Safety Board's metallurgical laboratory in Washington, D.C. The light bulb filaments showed no evidence of stretching.[57]

1.13 Medical and Pathological Information

Remains of both pilots and all eight passengers were recovered. Autopsies were performed on both pilots, and no drugs of abuse were detected in either pilot.

1.14 Fire

The helicopter wreckage showed no evidence of an in-flight or a postcrash fire.

1.15 Survival Aspects

According to the County of Galveston Medical Examiner's Office, the cause of death for the flight crew and passengers was multiple blunt force trauma injuries.

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[55] Because it is possible for the pilots to select different decision heights, the landing gear warning system will activate at the higher of the two decision heights.

[56] The aural tone and the warning lights could also be cleared if the helicopter's airspeed increased above 60 knots and the helicopter's altitude increased above the higher pilot-selected decision height.

[57] Stretching is the elongation of individual coils in light bulb filaments when the filaments are hot and subjected to impact forces.

1.16 Tests and Research

1.16.1 Cockpit Voice Recorder Study

The Safety Board conducted a CVR study to detect any aircraft system noise on the recording, including the noise produced by the helicopter's rotor, engine, and transmission. Numerous signals were evident on the CAM, but the following five signals were prominent: tail rotor, bull gear mesh (in the main rotor transmission), piston passing frequency of the hydraulic pump, bevel gear mesh (in the main rotor transmission), and input helical mesh (in the main rotor transmission). These five signals remained constant in frequency throughout the recording, which indicated that the system producing the noise remained at a constant speed throughout the recording. The amplitudes of the bull gear mesh and the bevel gear mesh changed toward the end of the recording, which indicated a change in the signal strength.[58]

The signals that were evident in the recording indicated that, at the time of the accident, the main rotor and the tail rotor were operating at a constant rotor speed. According to Sikorsky Aircraft, the simultaneous changes in signal strength of the bull and bevel gear meshes (at 1918:15) indicated that an increase in torque was applied to the transmission.

The Safety Board's CVR study was also conducted to evaluate the background noise recorded on the CAM channel. Generally, the noise of air flowing over the fuselage directly influences the loudness (amplitude) of the broadband background noise of a CAM recording. About 1918:25, the overall background noise level recorded on the CAM decreased.[59] The decrease in the background noise level continued until the end of the CVR recording at 1918:34.

1.16.2 Actuator Testing

The Safety Board identified airworthiness concerns about S-76 actuators during the investigation of the August 2005 accident involving an S-76C that crashed into the Baltic Sea shortly after takeoff from Tallin, Estonia.[60] As a result, the Safety Board examined the three main rotor actuators installed on the Era Aviation S-76A accident helicopter at HR Textron (the actuator manufacturer), Santa Clarita, California. The examination showed that most of the actuator seals were intact with no damage[61] and that

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[58] Specifically, the signal for the bull gear mesh began to decrease in strength until the signal disappeared into the background noise at 1917:28. The signal reappeared at 1917:43 and increased in strength at 1918:15. The signal for the bevel gear mesh decreased in strength beginning at 1918:15.

[59] It was not possible for the Safety Board to correlate the noise level to a specific airspeed because the accident CVR recording levels could not be calibrated to an external source.

[60] In accordance with the provisions of Annex 13 to the International Convention on Civil Aviation, the Safety Board has been assisting the Aircraft Accident Investigation Commission of Estonia with this accident investigation. For more information, see DCA05RA089 and Safety Recommendations A-05-33 through -35 at the Safety Board's Web site at <http://www.ntsb.gov>.

[61] Only the forward actuator's balance tube seals were worn, and one of the actuator's seal caps had fractured.

the control valves moved freely with no blockages or restrictions. The piston head's plasma coating was not flaked. Because of the condition of the actuators, they could not be functionally tested.

1.17 Organizational and Management Information

1.17.1 Era Aviation

Era Aviation, LLC, is headquartered in Anchorage, Alaska.[62] Era Aviation began operations in the Gulf of Mexico in 1979. The accident helicopter was based at GLS, and its operations and maintenance were managed by the company's Gulf Coast headquarters at LCH. At the time of the accident, Era Aviation had 7 S-76A helicopters in its Gulf of Mexico fleet[63] (including the accident helicopter) and employed 87 pilots who flew in the Gulf of Mexico (including the accident flight crew).

1.17.1.1 S-76A Configurations

At the time of the accident, four of the seven S-76A helicopters in Era Aviation's Gulf of Mexico fleet, including the accident helicopter, were digital and were configured with an EFIS and a DDAFCS (as described in section 1.6.3).[64] These helicopters provided pilots with landing gear warnings when the helicopters' airspeed was at or below 60 knots or when the helicopter was at or below the decision height with the gear retracted.[65] The other three S-76A helicopters in Era Aviation's Gulf of Mexico fleet were analog and were equipped with a Phase II automatic flight control system that was installed by the manufacturer.[66] These helicopters provided pilots with landing gear warnings only when the helicopters' airspeed was at or below 60 knots with the gear retracted.[67]

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[62] At the time of the accident, Era Aviation, Inc., was a subsidiary of Rowan Companies, Inc., of Houston. In January 2005, Era Aviation, LLC, became a subsidiary of SEACOR Holdings, Inc., of Houston.

[63] Other helicopters in the company's Gulf of Mexico fleet at the time of the accident included the Sikorsky 61, Bell 212/412, Boelkow 105, Agusta 109, and Eurocopter 332L (Super Puma) and 350.

[64] The accident captain completed EFIS-DDAFCS training in December 2001. The accident copilot received EFIS-DDFACS training as part of initial training. For information about Era Aviation's training program, see section 1.17.1.2.

[65] As stated in section 1.12.3, the accident helicopter's landing gear warning lights were located under the glareshield panel. The landing gear warning lights for the other three digital helicopters were located at the bottom of the front instrument panel near the center pedestal.

[66] The Phase II automatic flight control system maintains selected attitudes and provides stabilization in the pitch, roll, and yaw axes. The Phase II system consists of two separate but identical systems that introduce signals into the flight control system through the pitch, roll, and yaw operational channels to correct any difference between a preset flight attitude and the actual flight attitude. The helicopters equipped with a Phase II automatic flight control system do not have EFIS or flight directors.

[67] The landing gear warning lights on two of the analog helicopters were also located under the glareshield panel. The warning lights on the other analog helicopter were located above each pilot's airspeed indicator.

1.17.1.2 Ground and Flight Training

Era Aviation's S-76A initial ground training consisted of 40 hours of classroom training during a 5-day period. During a postaccident interview, Era Aviation's director of training at LCH stated that the primary instructors for initial ground training were check airmen, who followed the FAA-approved curriculum and prepared a syllabus, lesson plans, pilot training manuals, PowerPoint presentations, and other needed materials. The director of training stated that he was responsible for overseeing the format of the training information.

The initial ground training syllabus listed 14 lessons that were presented during the course "to provide the ground training necessary to familiarize and train each crewmember in the operation of the Sikorsky S76 helicopter and to assure that the crewmember can completely and safely perform his/her assigned duties." The 14 lessons included 4 hours of instruction for the flight control and automatic flight control systems; 2 hours of instruction for the avionics system; 3 hours of instruction for familiarization with aircraft flight manuals; and 4 hours of instruction on the caution warning, electrical power, and lighting systems. A quiz was given at the end of each lesson, and an examination was given at the end of the course; each pilot had to receive a minimum score of 80 percent on all of the quizzes and the examination.

Initial ground training was delivered in lecture format using information from Era Aviation training manuals and PowerPoint presentations. The Era Aviation S-76 Pilot Training Manual included detailed descriptions of the analog and digital flight control systems, and the Era Aviation S-76 Training Flight Manual included all operating handbooks and required supplements. Pilots were provided with copies of the manuals during the training. The PowerPoint presentations included schematics and photographs of the various components of the analog and digital flight control systems. The training included limited information on flight director and coupling status annunciations and command cue presentations.

During initial ground training, pilots also received a copy of Era Aviation's Operations Manual. This manual contained guidelines for Era Aviation's operations, which were not specific to any aircraft type in the company's fleet. Pilots receive revisions to the manual as they are printed.

Part of initial ground training was dedicated to controlled flight into terrain (CFIT)[68] and crew resource management (CRM). All Era Aviation pilots were required to watch a 30-minute videotape on CFIT prepared by Boeing. The videotape emphasized the importance of communication and crosscheck procedures in preventing CFIT. The director of training at LCH stated that, during the CFIT portion of his training, the accident captain spoke about his flight experiences with the Coast Guard, discussed the risk factors associated with flying to an offshore platform at night, and was "the most vocal and active participant in the class." Also, Era Aviation pilots were required to view a 45-minute PowerPoint presentation on aeronautical decision-making. The presentation cautioned pilots about becoming overly confident with increased experience and provided information about various helicopter

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[68] For more information about CFIT, see section 1.18.4.

accidents. In addition, pilots watched three videotapes about pilot decision-making, one of which discussed the human factor considerations present in aviation safety.

Initial flight training consisted of 10 hours of flight time. This flight time was divided into six 90-minute periods and one 2-hour period during which pilots were given a Part 135 flight check.[69]

Era Aviation's S-76A recurrent ground and instrument training was conducted at its headquarters during a 6-day period (6 hours each day). The training was presented along with recurrent ground and instrument training for the Sikorsky S-61 and the Bell 412. Topics covered during the training for all three helicopter models included aircraft flight manual and flight standards guide information, systems training (flight control and hydraulic systems), navigation, meteorology, instrument flight rules (IFR) procedures, maintenance, CFIT, CRM, situational awareness, and safety (accident and incident review). Examinations were given for each training subject.

Era Aviation required its S-76A pilots to attend a minimum of 6 hours of recurrent simulator flight training each year. This training was conducted during four 1.5-hour sessions at FlightSafety International, West Palm Beach, Florida, in an S-76A simulator equipped with an EFIS and a DDAFCS. The first session consisted of simulator familiarization, including normal approaches to oil rigs, and selected malfunctions and emergencies. The second session consisted of instrument procedures and weather considerations. The third session consisted of a review of VFR and IFR procedures and CRM procedures. Each of these sessions concluded with a debriefing. The fourth session consisted of a Part 135 flight check and a question-and-answer period. An Era Aviation captain stated that the simulator sessions included at least 2 hours of night flying under IFR. He also stated that at least two offshore approaches to an oil rig were conducted down to 200 feet with 0.6 mile visibility.

Era Aviation's simulator coordinator (who was also an S-76A check airman) stated that, before the accident, coupling indications and related issues were not a focus of the DDAFCS portion of ground or simulator flight training. He also stated that, after the accident, Era Aviation focused the DDFACS portion of the training on improving a pilot's situational awareness regarding the system and decreasing the possibility of confusion between pilots.

Era Aviation's check airmen provided annual flight checks to company PICs. According to an Era Aviation vice president, the flight checks generally involved flights to offshore platforms or ships or flights near LCH for checks of emergency procedures.

1.17.1.3 Visual Flight Rules Flight Plans

As stated in section 1.1, the accident helicopter's VFR flight plan was not filed with the FAA. In a July 12, 2004, letter to the Safety Board, an Era Aviation vice president

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[69] These flight checks were conducted pursuant to 14 CFR 135.293, "Initial and Recurrent Pilot Testing Requirements," 14 CFR 135.297, "Pilot in Command: Instrument Proficiency Check Requirements," and/or 14 CFR 135.299, "Pilot in Command: Line Checks: Routes and Airports."

stated that about 600 helicopters fly in the Gulf of Mexico, many of which fly numerous flight segments each day, and that it would therefore be "impractical" and "overwhelming" to file every VFR flight plan with the FAA. This vice president stated that the company adhered to 14 CFR 135.79(a), "Flight Locating Requirements," for its VFR flight plans. Title 14 CFR 135.79(a) states the following:

> Each certificate holder must have procedures established for locating each flight, for which an FAA flight plan is not filed, that – (1) provide the certificated holder with at least the information required to be included in a VFR flight plan; (2) provide for timely notification of an FAA facility or rescue facility, if an aircraft is overdue or missing; [and] (3) provide the certificate holder with the location, date, and estimated time for reestablishing radio or telephone communications, if the flight will operate in an area where communications cannot be maintained.

1.17.2 Federal Aviation Administration

The principal operations inspector (POI), assistant POI, principal maintenance inspector, and principal avionics inspector at the FAA's Anchorage office provided oversight for Era Aviation. Flight checks for check airmen at Era Aviation's Gulf Coast headquarters were conducted by the assistant POI or by designated examiners from the FAA's Baton Rouge, Louisiana, office. Era Aviation's director of operations stated that the flight checks were performed on shore and near LCH.

1.18 Additional Information

1.18.1 Flight Simulations

Safety Board staff members evaluated the flight characteristics of the accident helicopter using a full-motion, FAA-certified flight check S-76A simulator at FlightSafety. The simulator's cockpit configuration replicated, as much as possible, that of the accident helicopter (as determined by preaccident photographs of the helicopter's front instrument panel).[70] The simulator's mechanical radar altimeter indicator was not used because the accident helicopter was not equipped with a mechanical radar altimeter indicator. Also, the simulator's landing gear warning system triggered only when airspeed decreased below 60 knots with the gear up.[71]

The Safety Board examined numerous possible scenarios that could lead to an inadvertent descent to understand the systems and annunciations that were available to the

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[70] Although the simulator's cockpit configuration did not exactly replicate that of the accident helicopter, the simulator's flying characteristics closely resembled those of the accident helicopter.

[71] As stated in section 1.17.1.2, Era Aviation S-76A pilots received recurrent training using this S-76A simulator. Even though this simulator had a landing gear warning system that triggered only when the helicopter's airspeed was 60 knots or below with the gear retracted, the predominant method of flight training was actual flights aboard company helicopters, during which the pilots would have been trained on helicopters with both landing gear warning system configurations.

flight crew. As shown in figure 5, the following indications of descent were seen on the pilots' ADIs during the scenarios:

- The radar altitude appeared in blue at the bottom right of the ADIs followed by an "RA" indication in white.
- The decision height was displayed in blue at the bottom left of the ADIs followed by a DH indication in white. A white square box appeared above the radar altitude (at the bottom right of the ADIs) when the helicopter was 100 feet above the decision height (based on the radar altimeter). When the decision height was reached, an amber DH indication appeared inside the box and remained there as the helicopter continued to descend.
- A yellow rising runway symbol appeared at the bottom center of the ADIs at 180 feet (based on the radar altimeter). As the helicopter's altitude decreased, this symbol ascended until it met the aircraft symbol at 0 feet.

Figure 5. Indications of Descent on the Attitude Direction Indicator

Other indications of descent seen on the pilots' instrumentation during the scenarios were the following:

- The barometric altimeters showed decreasing altitude by the counterclockwise rotation of the needle.[72]
- The vertical speed indicators (VSI) showed a rate of descent of 250 to 300 fpm, which placed the needle below the centerline position.[73]

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[72] The barometric altimeters are located directly to the right of the ADIs (see figure 1).

[73] The VSIs are located directly below the barometric altimeters and directly to the right of the HSIs (see figure 1). The VSI tick marks between 0 and 1,000 feet represent increments of 100 fpm, and the tick marks between 1,000 and 3,000 feet represent increments of 500 fpm.

In addition, for one scenario, an altitude of 900 feet was selected on the air data command display (the AL-300).[74] At an altitude of 600 feet (300 feet below the preselected altitude), an amber altitude alert light at the top left of the barometric altimeters illuminated,[75] and a 1-second aural tone sounded over the pilots' headsets. The light remained illuminated for the rest of this simulation.[76] Figure 6 shows the amber altitude alert light on one of the simulator's barometric altimeters.

Figure 6. Altitude Alert Light

Of the numerous possible scenarios that could lead to an inadvertent descent, the Safety Board focused on the four scenarios that were deemed to be the most likely to have occurred during the accident flight if the flight crew had engaged the DDAFCS. For detailed information about each of the four scenarios, see appendix C.

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[74] The altitude preselect value is entered by turning the "set" knob until the AL-300 shows the desired value. The selected altitude is shown on the display until the altitude is captured. The AL-300 also displays commanded vertical speed, airspeed, and radar altitude depending on the mode (VS, IAS, or ALT) selected on the flight director mode selector. The parameters are displayed during the time that each is being adjusted by the pilot and for 7 seconds after the adjustment.

[75] When the helicopter is descending, the altitude alert light illuminates at 1,000 feet above the preselected altitude. The light does not illuminate from about 300 feet above the preselected altitude to about 300 feet below the preselected altitude. Afterward, the light illuminates again until the helicopter descends beyond 1,000 feet below the preselected altitude, at which point the light is no longer illuminated.

[76] The accident helicopter was equipped with two barometric altimeters, but only the captain's barometric altimeter had an altitude alert light at the top left of the instrument.

1.18.2 Gulf of Mexico Helicopter Operations

According to the latest statistics from the Helicopter Safety Advisory Conference (HSAC),[77] 561 oil industry helicopters (single engine, light twin, medium twin, and heavy twin) operated in the Gulf of Mexico during 2004, transporting more than 2.3 million passengers aboard 1.3 million flights. Table 2 shows the 2004 Gulf of Mexico oil industry helicopter accident rate and fatal accident rate per 100,000 flight hours compared with the same information for all U.S. air carrier operations under on-demand Part 135 (charter and air taxi).[78] (Even though the FAA's General Aviation and Air Taxi Survey[79] distinguishes between fixed-wing airplane and rotorcraft flight hours, the survey estimates of flight hours for rotorcraft do not reliably compare to HSAC's flight hour estimates for offshore helicopter operations. Thus, only the overall rates for on-demand Part 135 accidents are reported.) Table 3 shows this information for the 5-year period between 2000 and 2004. Appendix D provides a list of Gulf of Mexico helicopter accidents from March 2000 to February 2006.

Table 2. 2004 Accident Rates for Gulf of Mexico Helicopter Operations and On-Demand Part 135 Air Carrier Operations

Operation	Number of flight hours	Accident rate per 100,000 flight hours	Fatal accident rate per 100,000 flight hours
Gulf of Mexico helicopters	362,000[a]	2.77	1.11
On-demand Part 135 aircraft[b]	3,238,000	2.10	0.74

[a] The Gulf of Mexico estimate of flight hours was obtained from the HSAC's Gulf of Mexico Offshore Helicopter Operations and Safety Review.

[b] Accident rate calculations for on-demand Part 135 operations (fixed-wing airplanes and rotorcraft) were estimated using data from the FAA's General Aviation and Air Taxi Survey.

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[77] According to its Web site, the HSAC was formed in January 1978 to promote improved communication and safe practices within the Gulf of Mexico offshore community. The HSAC consists of representatives from major petroleum companies; drilling companies; helicopter operators; oil industry service companies; helicopter manufacturers; and U.S. Federal agencies, including the FAA, the Army, the Air Force, the Navy, the Coast Guard, the Department of the Interior, and the Customs Service. Since 1998, HSAC has annually surveyed 22 helicopter operators that provide on-demand Part 135 helicopter services in the Gulf of Mexico. The survey compiles operational and flight activity data, including fleet size and characteristics; number of passengers, flights, and flight hours; and accident statistics. These data are published annually in HSAC's Gulf of Mexico Offshore Helicopter Operations and Safety Review.

[78] On-demand Part 135 air carrier operations include rotorcraft and fixed-wing airplanes.

[79] Data for the General Aviation and Air Taxi Survey are compiled annually by the FAA based on voluntary data from Part 135 operators.

Table 3. Accident Rates for Gulf of Mexico Helicopter Operations and On-Demand Part 135 Aircraft Operations for 2000 Through 2004

Year	Gulf of Mexico helicopters[a]		On-demand Part 135 aircraft[b]	
	Accident rate per 100,000 flight hours	**Fatal accident rate per 100,000 flight hours**	**Accident rate per 100,000 flight hours**	**Fatal accident rate per 100,000 flight hours**
2000	2.04	0.68	2.04	0.56
2001	1.77	0.22	2.40	0.60
2002	1.49	0.25	2.06	0.62
2003	3.93	1.84	2.56	0.61
2004	2.77	1.11	2.10	0.74
Average	2.40	0.82	2.22	0.62

[a] The Gulf of Mexico accident rates were calculated using estimates of flight hours from the HSAC's Gulf of Mexico Offshore Helicopter Operations and Safety Review.

[b] Accident rate calculations for on-demand Part 135 operations (fixed-wing airplanes and rotorcraft) were estimated using data from the FAA's General Aviation and Air Taxi Survey.

Safety Board staff members visited two Gulf of Mexico helicopter operators—PHI of Lafayette, Louisiana, and Air Logistics of New Iberia, Louisiana—to compare and contrast their operations with Era Aviation's operations. Although each company's fleet consists of similar helicopter models, PHI and Air Logistics operate a larger fleet of helicopters than Era Aviation (more than 220 at PHI and more than 170 at Air Logistics compared with about 100 helicopters at Era Aviation). Also, PHI and Air Logistics operate both domestically and internationally, whereas Era Aviation operates domestically in Alaska, the West Coast, and the Gulf Coast. All three operators' helicopters fly at low altitudes while en route.

All three operators have dispatchers at their Gulf Coast headquarters (Era Aviation has 3 dispatchers, PHI has between 8 and 12 dispatchers, and Air Logistics has 2 dispatchers), but only Air Logistics has additional dispatchers at all of the locations where the company's helicopters are operating (one dispatcher per location). All three operators currently use flight-tracking software and hardware purchased from commercial vendors.[80] The software displays chevrons to indicate aircraft in flight and their direction along with weather overlays, and the hardware allows company pilots and dispatchers to relay text messages to each other. As with Era Aviation pilots, Air Logistics pilots call a company dispatcher to provide a position report every 15 minutes and to close out the flight plan; PHI pilots do not call a company dispatcher with position reports unless the

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[80] At the time of the accident, Era Aviation did not have this flight-tracking capability. As stated in section 1.1, dispatchers at Era Aviation's Gulf Coast headquarters entered information about company flights in a computerized log after each radio transmission. This information was displayed on a screen showing each helicopter's tail number in black, the departure location in yellow, the destination location in red, and the helicopter's flight plan between the two locations.

customer requests so, but the pilots do call the dispatcher to close out the flight plan. All three operators stated that they did not receive weather information or flight-tracking services from the FAA.

All three companies conduct training at their headquarters and at FlightSafety. Era Aviation does not have simulators on site, but PHI and Air Logistics have two fixed-base simulators on site that have similar instrumentation and performance capabilities as most of the aircraft in their fleets. All three companies conduct daily maintenance at their bases of operation and heavy maintenance at their headquarters.

1.18.3 Automatic Dependent Surveillance–Broadcast Technology

In 1998, the FAA developed an initiative under the Safe Flight 21 program for the Gulf of Mexico. The Safe Flight 21 program focused on providing pilots with radar-like information (navigation, air traffic, terrain, and weather) in the cockpit and enabling air traffic controllers and operators to provide surveillance of low-flying aircraft in those areas with limited or no radar coverage.

The Safe Flight 21 Gulf of Mexico initiative included plans to provide a ground- and satellite-based infrastructure called automatic dependent surveillance–broadcast (ADS-B), which relies on position information that is transmitted by individual aircraft based on global positioning system (GPS) technology. Each ADS-B-equipped aircraft has the capability to broadcast its position using a digital data link that provides information on the aircraft's airspeed and altitude and an indication of whether the aircraft is turning, climbing, or descending. This information can be directly transmitted from one aircraft to another, or the information can be transmitted to an ADS-B ground station,[81] combined with other aircraft data, and transmitted back to any aircraft within range of an ADS-B ground station. The information can also be transmitted by landlines or other means to air traffic controllers in distant locations. In addition, ADS-B can be used as the enabling technology that will allow weather, traffic, conflict alert, and other information available to personnel on the ground to be provided to pilots.

The Safe Flight 21 Gulf of Mexico initiative also included a network of ADS-B ground stations that were tested on offshore platforms. These ground stations transmitted and received high accuracy, radar-like flight-tracking information for ADS-B-equipped aircraft. In addition, data received by these ground stations were transmitted and processed at the Houston Air Route Traffic Control Center and the Lafayette Terminal Radar Approach Control so that controllers at these locations had real-time positional data on test ADS-B-equipped aircraft operating in the Gulf of Mexico. This test was conducted by the National Aeronautics and Space Administration between 2001 and 2004 with the use of

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[81] A ground station is a site equipped with a device that transmits and receives signals.

several ADS-B-equipped aircraft,[82] and the test data were provided to the FAA. The ADS-B infrastructure in the Gulf of Mexico was removed in 2005 because of the lack of funding.

Another initiative under the Safe Flight 21 program was the Capstone program in Alaska, which was developed to improve aviation safety in areas of Alaska with a high accident rate. The FAA planned to implement the Capstone program in three phases (based on geographic area). According to the FAA, at the beginning of March 2006, 341 aircraft in Alaska had been equipped with ADS-B technology during the first two phases of the program. The FAA also indicated that the final Capstone phase was currently under development with funding for site surveys but not construction.

Information from the FAA's November 2005 Flight Technologies and Procedures New Technologies Workshop showed that the FAA did not plan to implement the Safe Flight 21 Gulf of Mexico initiative until fiscal year 2013. In January 2006, the FAA announced that the Safe Flight 21 program was being transitioned to the National ADS-B Program. Although the content of both programs was basically the same, the implementation dates for the National ADS-B Program were moved forward. Specifically, the FAA proposed fiscal year 2007 to begin implementation of the program and fiscal year 2010 to complete the first segment of ADS-B infrastructure deployment. On March 1, 2006, the FAA informed the Safety Board verbally that the Gulf of Mexico would be among those areas in the first segment of ADS-B deployment. The FAA also informed the Board that it planned to seek budget approval for the National ADS-B Program in June 2006.

1.18.4 Controlled Flight Into Terrain

CFIT occurs when a controlled, serviceable aircraft is flown into terrain, obstacles, or water with no prior awareness by the flight crew of the impending collision.[83] Between 1987 and 2004, 56 (25 percent) of the 226 worldwide fatal accidents involving large commercial jet aircraft were classified as CFIT, resulting in 3,631 fatalities.[84] Most CFIT accidents occurred with poor visibility conditions and during the approach and landing phases of flight.[85] Although the number of CFIT accidents has markedly declined in recent years for U.S. transport-category airplanes,[86] CFIT remains a major aviation problem in foreign countries and for general aviation aircraft and helicopters.

A Flight Safety Foundation study indicated that about 75 percent of all CFIT accidents in commercial aircraft occurred in those that were not equipped with a

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[82] These aircraft were an FAA Boeing 727, an FAA Convair, a Piper Aztec from the Department of Transportation's Volpe National Transportation Systems Center, and a PHI helicopter.

[83] E.L. Weiner, "Controlled Flight Into Terrain: System Induced Accidents," *Human Factors Journal* Vol. 19 (1977).

[84] Boeing Commercial Airplane Group, "Statistical Summary of Commercial Jet Aircraft Accidents, Worldwide Operations 1959-2004," (Seattle, WA: May 2005).

[85] R. Khatwa and R. Helmreich, "Analysis of Critical Factors During Approach and Landing in Accidents and Normal Flights," *Flight Safety Digest* (November 1998–February 1999): Flight Safety Foundation.

[86] The Safety Board issued numerous safety recommendations to prevent CFIT.

traditional ground proximity warning system (GPWS).[87] A traditional GPWS uses the radar altimeter to calculate closure rate with terrain to predict a potential collision threat. Although a traditional GPWS can help prevent CFIT, a traditional GPWS cannot provide a timely warning to the flight crew if the terrain rises steeply. As a result, on October 16, 1996, the Safety Board issued Safety Recommendation A-96-101,[88] which asked the FAA to do the following:

> Examine the effectiveness of the enhanced ground proximity warning equipment and, if found effective, require all transport-category aircraft to be equipped with enhanced ground proximity warning equipment that provides pilots with an early warning of terrain.

Enhanced GPWS is also referred to as a terrain awareness and warning system (TAWS). These systems have the ability to look ahead of an aircraft to determine the terrain or other obstruction along the flightpath, thereby providing pilots with more time to determine the necessary corrective actions than with a traditional GPWS.

When used for helicopter operations, TAWS can include a forward-looking terrain awareness display, which provides aural alerts and visual indications of terrain and obstacles. The aural alerts are “caution terrain,” “warning terrain,” “caution obstacle,” and “warning obstacle.” The visual indications of terrain and obstacles can be displayed on one or two screens on the front instrument panel or can be incorporated into EFIS displays. In addition, TAWS for helicopters can include aural alert modes 1 through 6, which are excessive descent rate, excessive terrain closure rate, descent after takeoff, terrain clearance, deviation below glideslope, and autorotation and altitude,[89] respectively.

The accident helicopter was not equipped with a TAWS and was not required by Federal regulations to so be equipped.[90] Specifically, a March 23, 2000, final rule issued by the FAA required all U.S.-registered turbine-powered airplanes configured with six or more passenger seats to be equipped with a TAWS by March 29, 2002 (new-production airplanes), and March 29, 2005 (existing airplanes). As a result of the FAA’s action, Safety Recommendation A-96-101 was classified “Closed—Acceptable Action” on February 15, 2001.

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[87] R. Khatwa and A.L.C. Roelen, “An Analysis of Controlled-Flight-Into-Terrain (CFIT) Accidents of Commercial Operators, 1988 Through 1994,” *Flight Safety Digest* (April–May 1996): Flight Safety Foundation.

[88] This recommendation was issued in response to the December 20, 1995, accident involving American Airlines flight 965, which struck trees and crashed into a side of a mountain near Cali, Colombia, during night VMC. The airplane was equipped with a traditional GPWS. About 12 seconds before impact, the GPWS began issuing the aural warnings “terrain” and “pull up,” but these warnings were not provided in time for the flight crew to avoid crashing into the mountainous terrain.

[89] If a decision height is set, the mode 6 “altitude altitude” aural alert would occur at that height unless a higher priority alert, such as “caution terrain” or “warning terrain” takes precedent.

[90] In May 2004, Sikorsky announced that it would voluntarily equip its new S-76 helicopters with TAWS. Sikorsky subsequently announced that it would offer a TAWS/CVR/FDR retrofit program for all S-76 helicopters built before 2005.

As part of this investigation, the Safety Board requested that Honeywell (the manufacturer of TAWS for helicopters) perform simulations of a 150- and 250-fpm descent into water to determine what alerts could have been expected if a TAWS had been installed aboard the accident helicopter.[91] For a descent rate of 150 fpm, the simulation showed that the "caution terrain" alert would have occurred 97 seconds before impact, along with a water indication that changed from blue to yellow on the forward-looking terrain awareness display.[92] The simulation also showed that the "warning terrain" alert would have occurred 84 seconds before impact, along with a water indication that changed from yellow to red on the forward-looking terrain awareness display. For a descent rate of 250 fpm, the simulation showed that the caution terrain alert would have occurred 68 seconds before impact and that the warning terrain alert would have occurred 55 seconds before impact (along with the water indication color changes on the forward-looking terrain awareness display).

In January 2006, the Safety Board adopted a special investigation report on emergency medical services (EMS) aircraft accidents.[93] According to the report, 55 EMS accidents occurred between January 2002 and January 2005; these accidents involved 41 helicopters and 14 airplanes and resulted in 55 fatalities and 18 serious injuries. The Board found that TAWS might have helped pilots avoid terrain in 17 of the 55 accidents. (Thirteen of these 17 accidents involved helicopters.) As a result, the Board issued Safety Recommendation A-06-15, which asked the FAA to do the following:

> Require emergency medical services (EMS) operators to install terrain awareness and warning systems on their aircraft and to provide adequate training to ensure that flight crews are capable of using the system to safely conduct EMS operations.

1.18.5 Comparison of SPZ-7000 and SPZ-7600 Dual Digital Automatic Flight Control Systems

The SPZ-7000 DDAFCS, which was installed on the accident helicopter, is no longer in production. Its successor is the SPZ-7600 DDAFCS, which was originally designed for the S-76C.[94] Although the SPZ-7000 and the SPZ-7600 are similar, there are differences between the systems, including the display presentation of command cues for an unselected axis and the indications for system coupling and decoupling.

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[91] Radar data showed that the helicopter's descent rate at an altitude of 1,100 feet was 250 fpm. The Safety Board estimated that the helicopter impacted the water at a descent rate of 150 fpm.

[92] The color change would have occurred because the TAWS would have detected that the closure rate to the water was a concern.

[93] National Transportation Safety Board, *Special Investigation Report on Emergency Medical Services Operations*, Aviation Special Investigation Report NTSB/SIR-06/01 (Washington, DC: NTSB, 2006).

[94] The FAA issued a supplemental type certificate to allow the S-76A to be retrofitted with the SPZ-7600.

Both the SPZ-7000 and the SPZ-7600 have the capability to display pitch and roll command cues in either a dual- or a single-cue format. With the dual-cue format, pitch attitude is represented by a horizontal line, and roll attitude is represented by a vertical line, as shown in figure 7. With the single-cue format, angular bars integrate pitch and roll guidance, as shown in figure 8. When both pitch and roll commands are selected in either mode, the guidance provided by the command cues is intuitive and well understood by pilots who have been trained on either flight control system.

Figure 7. SPZ-7000 Dual-Cue Format

Figure 8. SPZ-7000 Single-Cue Format

Also, both the SPZ-7000 and the SPZ-7600 have the capability for the pilot to select a command cue for only one axis, either pitch or roll, at a time. The displayed cue for the selected axis is functionally the same as when command cues for both axes are selected. However, depending on the system and the command cue format, the command cue for the unselected axis may or may not be displayed. In addition, no annunciation appears on the ADIs regarding the source of guidance for the unselected command cue presented in the SPZ-7000 dual- and single-cue formats and the SPZ-7600 single-cue format.

Table 4 summarizes the command cues presented on the SPZ-7000 and SPZ-7600 DDAFCS and highlights the differences in attitude synchronization between the two systems. These differences, which are not intuitive, are analyzed in section 2.3.2.

Table 4. Command Cues Presented on the SPZ-7000 and SPZ-7600 DDAFCS With Single-Axis Command Selections

Display format	Axis selected	SPZ-7000 unselected axis	SPZ-7600 unselected axis
Dual cue	Pitch only	Roll indication is synchronized to the trimmed roll attitude.	Roll indication is not shown.
	Roll only	Pitch indication is synchronized to the trimmed pitch attitude.	Pitch indication is not shown.
Single cue	Pitch only	Roll indication is synchronized to the trimmed roll attitude.	Roll indication is centered.
	Roll only	Pitch indication is synchronized to the trimmed pitch attitude.	Pitch indication is centered at the horizon.

In addition, the indications for coupling and decoupling are distinctly different between the SPZ-7000 and SPZ-7600 DDAFCS. As stated in section 1.6.3, the SPZ-7000 does not annunciate the coupling status on the front instrument panel, and the SPZ-7000 DCPL warning indicator on the DAFCS caution panels illuminates only during abnormal operations. For the SPZ-7600, the DCPL warning indicator on each DAFCS caution panel illuminates during normal and abnormal operations whenever the autopilot and flight director become decoupled for an activated mode. Once the DCPL warning indicators are annunciated, annunciations can be cleared by either coupling the autopilot and flight director or resetting the couple logic by disengaging and reengaging one or both of the autopilots.

Finally, the SPZ-7600, as delivered from the manufacturer (Honeywell), is not equipped with an aural alert to indicate system decoupling under normal operations. Operators that use the SPZ-7600 can install an after-market product to provide this aural alert as either a chime or a verbal annunciation ("decouple").[95] One manufacturer (Sikorsky) installs this aural alert (manufactured by Keystone Helicopters) on all of its helicopters that are equipped with the SPZ-7600.

1.18.5.1 Federal Aviation Administration SPZ-7000 Evaluation

As a result of the Safety Board's investigation of this accident, and to ensure the safety of the S-76 fleet, the FAA evaluated the SPZ-7000 DDAFCS to determine whether "hazardously misleading" flight director data were being presented on EFIS displays. The evaluation was conducted during February 2005 in an S-76A simulator and helicopter that were similarly configured to the accident helicopter. The FAA provided notes about its evaluation to the Board. The notes indicated the following observations:

> There is no aural or visual annunciation of a pilot-induced decouple.
>
> The only cues that the flight director is not coupled on the selected side are the lack of FD mode selections and the disappearance of FD mode annunciations on the corresponding EADI [electronic ADI].
>
> With cross-needle FD cues selected on the EADI, single-axis FD modes (HDG only, ALT only, etc.) caused both pitch and roll cue needles to be displayed. With only HDG mode selected, the pitch cue bar apparently provides guidance only to retain the aircraft's existing pitch attitude when HDG mode was selected. It did not provide guidance to maintain a selected altitude. A vertical mode (ALT, VS, ILS) must be selected for the pitch bar to provide vertical navigation steering commands. This is apparently different from other S-76 DAFCS systems such as the SPZ-7600, and from some Part 23 or Part 25 fixed-wing flight director systems.
>
> In general, the indications of either a pilot-induced or self-induced FD decouple were not particularly compelling.

In its notes, the FAA recommended that the certification basis for the SPZ-7000 DDAFCS be reviewed to ensure that, at the time of certification, the system met all requirements for coupled flight director disconnect annunciations. Also, the FAA recommended that the presentation of single-cue flight director commands by the SPZ-7000 be further examined in the context of certification requirements and continued operational safety.

In November 2005 correspondence, the FAA stated that it reviewed the certification basis of the SPZ-7000 DDAFCS and determined that, at the time of certification, the system did meet the requirements of 14 CFR 29.1335 and 14 CFR 29.1329. Also, the FAA stated that it found no evidence to indicate that the SPZ-7000's disconnect annunciations were inadequate or that the SPZ-7000 was a factor in previous S-76 accidents.

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[95] This alert can be configured (according to customer preference) to provide an aural annunciation in pilots' headsets, the cabin, or both.

1.18.6 Previous Flight Recorder Safety Recommendations

1.18.6.1 Safety Recommendation A-02-25

On August 29, 2002, the Safety Board issued Safety Recommendation A-02-25 as a result of its long-standing concerns about the availability of CVR information after reportable accidents or incidents. Safety Recommendation A-02-25 asked the FAA to do the following:

> Require that all operators of airplanes equipped with a cockpit voice recorder (CVR) test the functionality of the CVR system prior to the first flight of each day, as part of an approved aircraft checklist. This test must be conducted according to procedures provided by the CVR manufacturer and shall include, at a minimum, listening to the recorded signals on each channel to verify that the audio is being recorded properly, is intelligible, and is free from electrical noise or other interference.

On December 12, 2002, the FAA responded that current regulations (14 CFR 23.1457 and 25.1457) require CVR equipment to have "an aural or visual means for preflight checking of the recorder for proper operation." The FAA also stated that it would survey current maintenance practices of air carrier and general aviation aircraft to determine if corrections to the operators' maintenance programs were necessary to ensure expected recorder reliability. On January 16, 2003, the Safety Board replied, stating its concern that the FAA's maintenance survey would address only one part of the CVR reliability problem. The Board's safety recommendation letter stressed that it was the flight crew's responsibility to check the CVR for proper operation each day before the first flight; consequently, the Board encouraged the FAA to include maintenance procedures and crew checklist operational procedures in its survey.

On March 5, 2004, the Safety Board reiterated Safety Recommendation A-02-25 as a result of its investigation of the January 8, 2003, Beech 1900D accident (Air Midwest flight 5481) in Charlotte, North Carolina.[96] The Board's investigation found that the captain's and the copilot's audio panel information was fair to poor quality with respect to the audio captured from the accident airplane's VHF radio systems. As a result, important CVR information from the accident flight might not have been available if the audio information from the captain's and the copilot's hot microphones had not been excellent to good quality.

On June 7, 2005, the FAA responded that, even though CVRs on all equipped airplanes were tested daily, the level of testing that the Safety Board was seeking could not be universally accomplished because of implementation or design limitations imposed by the regulations that govern CVR requirements. The FAA also stated that it issued Notice N8000.292, "Clarification of Recommendations for Cockpit Voice Testing"

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[96] For more information, see National Transportation Safety Board, *Loss of Pitch Control During Takeoff, Air Midwest Flight 5481, Raytheon (Beechcraft) 1900D, N233YV, Charlotte North Carolina, January 8, 2003*, Aircraft Accident Report NTSB/AAR-04/01 (Washington, DC: NTSB, 2004).

(January 18, 2005), for operators of those airplanes equipped with CVRs that can be tested before the first flight of the day. The FAA indicated that the intent of the notice was to persuade the operators to configure the CVRs during future major maintenance cycles so that flight crews would be able to test them. Further, the FAA stated that it made a change to FAA Order 8300.10, *Airworthiness Inspector's Handbook*, Chapter 143, "Monitor Cockpit Voice Recorders" (March 4, 2004). According to the FAA, the change tasked airworthiness aviation safety inspectors to evaluate maintenance programs that require maintenance technicians to perform a thorough test of the CVR at appropriate intervals. The FAA explained that the test should include listening to the recorder signals on each channel to verify that the audio is properly recording, is intelligible, and does not contain electrical noise or other interference.

On January 4, 2006, the Safety Board stated that, even though Notice N8000.292 asked for the recommended action, a notice was not a requirement, and it would expire after 1 year. The Board added that the need for a functional check of the CVR before the first flight of each day would remain after Notice N8000.292 was canceled. Also, the Board stated that the change to FAA Order 8300.10 would not ensure that a CVR functional test would be performed before the first flight of each day and that there must be a permanent change to the FAA's operational requirements to ensure this CVR functional test; such a change could be achieved by a revision to FAA Order 8400.10, *Air Transportation Operations Inspector's Handbook*. Pending this permanent change, Safety Recommendation A-02-25 was classified "Open—Acceptable Response."

1.18.6.2 Safety Recommendations A-06-17 and A-06-18

On March 7, 2006, the Safety Board issued Safety Recommendations A-06-17 and A-06-18, which asked the FAA to do the following:

> Require all rotorcraft operating under 14 *Code of Federal Regulations* Parts 91 and 135 with a transport-category certification to be equipped with a cockpit voice recorder (CVR) and a flight data recorder (FDR). For those transport-category rotorcraft manufactured before October 11, 1991, require a CVR and an FDR or an onboard cockpit image recorder with the capability of recording cockpit audio, crew communications, and aircraft parametric data. (A-06-17)
>
> Do not permit exemptions or exceptions to the flight recorder regulations that allow transport-category rotorcraft to operate without flight recorders, and withdraw the current exemptions and exceptions that allow transport-category rotorcraft to operate without flight recorders. (A-06-18)

2. Analysis

2.1 General

The captain and the copilot were properly certificated and qualified under Federal regulations. No evidence indicated any medical or behavioral conditions that might have adversely affected their performance during the accident flight. Flight crew fatigue was not a factor in this accident.

The accident helicopter was properly certified, equipped, and maintained in accordance with Federal regulations. The recovered components, with the exception of the CVR,[97] showed no evidence of any structural, engine, or system failures.

The engines were found attached to the helicopter with no evidence of fire, uncontainment, structural damage, or foreign object damage. The torsion fractures to the drive shafts and the water impact damage to the helicopter fuselage indicated that both engines were producing power at the time of impact. During the helicopter's impact with the water, the engines became decoupled from the transmission. As a result, the right engine sensed an overspeed condition, shut down, and removed the overspeed protection from the left engine, which, in turn, caused the left engine to overspeed.

All four main rotor blades were found fractured but with their root ends still attached to the main rotor hub. All of the main rotor blade tips were recovered in the main debris field. Two of the tail rotor blades were fractured just outside of the tail rotor cuff, and a third tail rotor blade had fractured near the root but was still attached to the spar. The fourth tail rotor blade had an outboard portion that was not recovered. None of the tail rotor tips were recovered. However, because of the paddle design of the tail rotor blades, if a tail rotor blade tip had separated in flight, a whole paddle (two tail rotor blades) would be missing, which did not occur in this accident.

Weather was not a factor in this accident. The dispatcher who handled the accident flight provided appropriate flight-tracking services. The search and rescue effort for this accident was timely. The accident was not survivable for the helicopter occupants because they were subjected to impact forces that exceeded the limits of human tolerance.

This analysis discusses the accident sequence, cockpit systems, tracking of Gulf of Mexico helicopter flights, the lack of adequate CVR information for this accident investigation, and the lack of FDR data for helicopter operations.

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[97] This issue is discussed in section 2.5.

2.2 Accident Sequence

2.2.1 Accident Summary

The Era Aviation dispatcher's records showed that the accident helicopter departed GLS about 1845 with 2 hours of fuel on board. The helicopter's initial destination was High Island A-557, a refueling platform about 80 nm south-southeast of GLS, and its final destination was the *Discoverer Spirit*, a drilling ship that was en route to a location about 180 miles south-southeast of GLS. It is reasonable to assume that the captain was the flying pilot because, according to the CVR recording, the copilot was making the radio calls to the dispatcher (which is the duty of the nonflying pilot) through the time of the destination change. (The CVR did not record any pilot transmissions after that time.)

ASR-9 radar data showed that the helicopter began to descend from an altitude of 1,800 feet at 1858:10 at a rate of 300 fpm. The last radar return that was received while the helicopter was still within the range of radar coverage was at 1900:21; this return showed that the helicopter was at an altitude of 1,100 feet msl and that its rate of descent was 250 fpm. At the time, the helicopter was located 35 nm south-southeast of GLS. If the helicopter had continued its 250-fpm descent from 1,100 feet msl, it would have crashed into the water within 5 minutes. However, the helicopter flew for another 18 minutes.

During its 1914 position report, the flight crew told the dispatcher that the helicopter had enough fuel on board (1.6 hours) to continue directly to the location of the *Discoverer Spirit*. The CVR study for this accident found that, at 1918:15, an increase of torque was applied to the main rotor transmission and that the background noise level on the CVR recording decreased from about 1918:25 to the end of the recording at 1918:34 (the time of the accident). Although an increase in torque can be the result of a pilot input to the flight control system (increased collective or movement of the cyclic) and the decrease in background noise level can be directly related to a decrease in forward airspeed, the available evidence prevented further evaluation of the CVR study's findings.

Evening civil twilight (sometime after which complete darkness occurs) ended about 22 minutes before the accident. Also, the moon illumination (only 8 percent of the moon disk) and the starlight were affected by a scattered to broken layer of low stratiform clouds over the Gulf of Mexico south of GLS. The Safety Board concludes that, even though VMC prevailed at the time of the accident, few, if any, references outside of the helicopter would have been available to the flight crew.

The severe accordion-type crushing found on the helicopter fuselage was consistent with a water impact at a high airspeed. The upward compression fractures found on the lower fuselage were consistent with a level (or very shallow) bank attitude at impact. The lack of damage to the lower part of the tailboom was consistent with a shallow descent angle and pitch attitude at impact. The damage to the cyclic, collective, and tail rotor pedal control systems was consistent with static overload fractures as a result of water impact. As a result, the Safety Board concludes that the helicopter crashed into the water at a high airspeed, a shallow descent angle, and a near-level roll attitude. Also, because the main landing gear floats were found folded, which was consistent with the floats not being inflated and being in the stowed position inside the wheel wells at impact, and no emergency or distress calls were received by the dispatcher from the flight crew, the Safety Board concludes that the pilots were not attempting an emergency landing on the water. In addition, because of the inward crushing that was found on the lower part of the structure that attached the fuselage and tailboom and the tearing that was found on the upper part of the attachment structure, the Safety Board concludes that, after the helicopter crashed into the water, the fuselage pitched nose down, and the tailboom broke off in a downward direction.

Because no evidence showed any problems with the helicopter's engines, systems, or structures during the accident flight, the Safety Board's investigation focused on the pilots' actions during the 4 minutes between their last radio call to the dispatcher and the time of the accident. The Board did not have FDR, CVR, or air traffic control information[98] to help determine what transpired during that portion of the flight. However, with the use of an S-76A simulator that was similarly configured to the accident helicopter, the Board examined numerous possible scenarios in which the flight crew's actions could have inadvertently led to a controlled descent into water. The Board then focused on the four scenarios that were the most likely to have occurred (see appendix C). The scenario results, along with preaccident photographs of the accident helicopter's front instrument panel and manufacturer and company manuals, showed the indications of descent that would have been available to the flight crew. These indications are discussed and analyzed in section 2.2.2.

2.2.2 Indications of Descent and Proximity to the Water

Cockpit instrumentation at both pilot stations would have shown indications of the helicopter's descent and proximity to the water. These indications, which are shown in figure 9 and described in this section, were located in front of the pilots and within their routine instrument scan.

Three indications would have been available on a continuous basis throughout the flight and did not require previous pilot action. First, the VSI needles (numbers 4 and 6 in figure 9) would have been consistently below the centerline position, indicating a descent. Second, the barometric altimeter needles (numbers 3 and 8 in figure 9) would have been indicating a decreasing altitude. Third, the radar altitude readout on the ADIs (numbers 2 and 7 in figure 9) would have shown numbers that decreased in 10-foot increments through 200 feet and 5-foot increments afterward.

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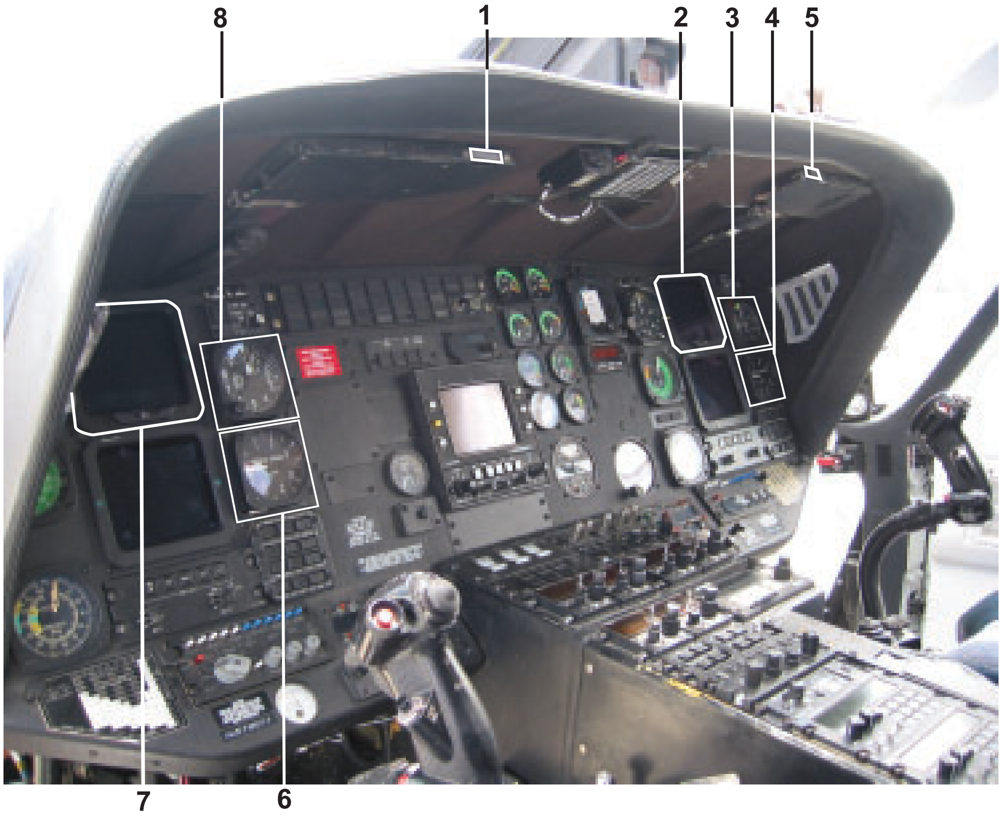
[98] As stated previously, the accident helicopter was not equipped with an FDR. Also, although the helicopter was equipped with a CVR, three channels (including the pilot and copilot stations) contained no usable information, and the fourth channel (the CAM) contained information that was mostly obscured by a high level of background noise. In addition, no radar data were available after the helicopter descended below 1,100 feet msl.



1. Landing gear warning light
2. Captain's ADI, showing radar altitude readout, rising runway symbol, decision height box, decision height indication, and command cues
3. Captain's barometric altimeter and altitude alert light
4. Captain's VSI
5. Landing gear warning light
6. Copilot's VSI
7. Copilot's ADI, showing radar altitude readout, rising runway symbol, decision height box, decision height indication, and command cues
8. Copilot's barometric altimeter

Figure 9. Indications of Descent in the Accident Helicopter's Cockpit

Source: Era Aviation.

Another indication, a rising runway symbol on the ADIs (numbers 2 and 7 in figure 9), did not require previous pilot action but would not have appeared until 180 feet above ground level (agl). The rising runway symbol would have continued upward until it met the aircraft symbol on the ADIs at 0 feet.

In addition to the indications of the helicopter's descent and proximity to the water that would have been present regardless of pilot action, several indications could have been present depending on the actions taken by the pilots during the accident flight. For example, if the flight crew had set a decision height above 0 feet (a decision height of

200 feet was required by Era Aviation for nighttime flights), two additional indications of the helicopter's descent and proximity to water would have been available. First, a decision height box would have appeared on the ADIs (numbers 2 and 7 in figure 9) at 100 feet above the set decision height. Second, the letters DH would have appeared inside the decision height box as the helicopter descended through the decision height. If the decision height was set to 0 feet, a decision height box would have appeared on the ADIs at 100 feet agl, and the letters DH would have appeared inside the decision height box about the time that the helicopter was contacting the water. If the pilots had set different decision heights, then the decision height box and the letters DH would have appeared when the helicopter descended through the higher of the two decision heights.[99]

Also, if either pilot had set a decision height above 0 feet, both pilots would have seen conspicuous (very bright) landing gear warning lights under the glareshield panel[100] (numbers 1 and 5 in figure 9) and would have heard a tone over their headsets when the helicopter descended below the decision height.[101] The aural tone was not detected on the CVR recording. However, as stated previously, audio information from the pilot and copilot stations was unusable because of the faulty installation of the CVR. Also, the CAM would not have recorded the aural tone because the tone is sent to the pilots' headsets only and not to a cockpit speaker.

In addition, if the pilots had entered a preselected altitude on the AL-300, an altitude alert light would have illuminated on the captain's barometric altimeter (number 3 in figure 9) at 1,000 feet above the preselected altitude. The light would have extinguished from about 300 feet above to about 300 feet below the preselected altitude. The light would again have illuminated from about 300 to 1,000 feet below the preselected altitude. The pilots would have also heard a 1-second tone over their headsets each time that the light illuminated.

Finally, if the pilots had selected an altitude-related flight director mode (altitude or altitude preselect and vertical speed)[102] but had not coupled the flight director to the engaged autopilot, the pitch command cue would have been displaced above the centerline on the ADIs (numbers 2 and 7 in figure 9). Displacement of the pitch command cue above the centerline would have indicated that the helicopter was below the desired altitude, and movement of the pitch command cue toward the top of the display would have indicated

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[99] If the accident flight crew had not changed the decision height from the previous flight, then the altitude at which the decision height box and the DH indication appeared would have been based on the decision height set by the previous flight crew.

[100] The results of the landing gear warning light bulb examination were inconclusive regarding whether the lights had illuminated. It is possible that the helicopter fuselage absorbed a large amount of impact energy at the time of the collision with the water and that a reduced amount of impact energy was transferred to the light bulbs within the helicopter. Thus, if the lights were illuminated at the time of impact, the impact might not have been severe enough to stretch the filaments.

[101] As stated in section 1.12.3, the landing gear relay could not be functionally tested after the accident to determine if the system did in fact trigger because of damage to the relay that appeared to be the result of seawater immersion.

[102] If the pilots had selected the altitude preselect and vertical speed modes, they would also have had to enter the desired altitude on the AL-300.

the helicopter's continued descent. Displacement of the pitch command cue in these cases would have occurred regardless of whether a flight director heading mode was engaged and the decision not to couple was intentional.

The Safety Board cannot determine the sequence of events that led to the helicopter's inadvertent descent.[103] It is clear, however, that the flight crew should have been actively monitoring cockpit instrumentation showing the helicopter's altitude, especially because of the lack of outside visual references. The flight crew would have been presented with salient cues to detect the helicopter's descent and proximity to the water. Thus, the Safety Board concludes that the flight crew was not adequately monitoring the helicopter's altitude and missed numerous cues to indicate that the helicopter was inadvertently descending toward the water.

2.2.3 Human Factors

The Safety Board examined possible factors to explain why the flight crew missed indications of the helicopter's descent and proximity to the water. Three of these factors—flight crew experience, crew coordination, and use of automated systems—are discussed in sections 2.2.3.1 through 2.2.3.3, respectively.

2.2.3.1 Flight Crew Experience

The accident flight crew had adequate experience in the accident helicopter and other similar S-76A helicopters in Era Aviation's fleet to safely conduct the accident flight. The captain and the copilot completed recurrent training and flight checks during the month before the accident. Even though the captain completed his flight check in an S-76A analog helicopter, he had line experience during the 12 months before the accident with the S-76A EFIS-DDAFCS configuration, including experience with the accident helicopter. The copilot completed his flight check in the accident helicopter and had additional line experience during the 12 months before the accident with the EFIS-DDAFCS configuration and the accident helicopter. Also, both pilots had adequate experience at night to safely conduct the accident flight. In addition, both pilots received adequate CFIT training.

2.2.3.2 Crew Coordination

The accident occurred about 4 minutes after the flight crew notified the dispatcher of the change in destination. Under most conditions, a change in destination increases pilot workload depending on the tasks that need to be completed and the flight conditions. The accident flight crew's decision to proceed directly to the reported location of the *Discoverer Spirit* required the pilots, at a minimum, to coordinate a change in course and communicate with the dispatcher to receive updated coordinates for the ship, which would have been programmed into the GPS after the course change. It is also possible that the

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[103] Even though an FDR was not required to be installed on the accident helicopter, an FDR would have provided investigators with pertinent information to help determine the sequence of events that led to this accident. The lack of a requirement for FDRs aboard helicopters is discussed in section 2.6.

flight crew initiated a change in control from one pilot to the other or a change in flight control method from automatic (coupling of the autopilot and flight director) to manual flight or vice versa. Such changes require effective crew coordination, including continuous crosschecking and monitoring of instruments to ensure that the intended system inputs have correctly been made.

The accident flight was the first one that paired the captain and the copilot. Coordinating with a new flight crewmember can require more effort than coordinating with a previous crewmember. Also, new crew pairings have been associated with increased errors and less effective communication patterns than crew pairings with crewmembers who have previously flown together.[104] During critical phases of flight, a lack of familiarity can affect a flight crew's ability to coordinate effectively. However, because of the poor quality of the CVR recording, it was not possible for the Safety Board to determine whether crew coordination was a factor in this accident.

2.2.3.3 Use of Automated Systems

The accident helicopter's flight control system allowed the pilot to couple the autopilots and flight director so that the helicopter would automatically carry out pilot-set flightpath commands. The pilots might have intended to use this feature to automatically maintain heading and altitude while they completed some immediate manual tasks related to the change in destination. However, the pilots could have incorrectly programmed the flight director mode selector and either not have detected this situation or have misinterpreted it given the available system feedback (as discussed in section 2.3.2). It is also possible that the pilots were in the process of reprogramming the flight director mode selector. Research on the use of automated flight systems in transport-category aircraft found that the reprogramming of automated flight control systems is prone to human error because reprogramming involves multiple, complex steps.[105]

The accident pilots might not have chosen to use the coupling feature when changing destinations and instead might have chosen to rely on their ability to manually maintain the appropriate flightpath. The helicopter's ATT mode provides stability to the helicopter during manual flight and reduces a pilot's manual control requirements. If the helicopter were descending at a shallow rate, the ATT mode would have maintained this trajectory with minimal, if any, physical cues.

One of the most critical issues associated with flight deck automation is "automation misuse," that is, pilot overreliance on automation, because it can lead to deficiencies in monitoring an aircraft's performance.[106] Pilots may become complacent if

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[104] H.C. Foushee, J.K. Lauber, M.M. Baetge, and D.B. Acomb, *Crew Factors in Flight Operations: III. The Operational Significance of Exposure to Short-Haul Air Transport Operations*, National Aeronautics and Space Administration Technical Memorandum 88322 (August 1986).

[105] R.O. Besco and K. Funk, "Conceptual Design Guidelines to Rediscover Systems Engineering for Automated Flight Decks," *International Journal of Aviation Psychology*, Vol. 9, No. 2 (2000): 189-198.

[106] R. Parasuraman and V. Riley, "Humans and Automation: Use, Misuse, Disuse, Abuse," *Human Factors*, Vol. 39, No. 2 (1997): 230-253.

they are overconfident in automation and may fail to exercise appropriate vigilance.[107] As a result, significant deviations in altitude or flightpath, if controlled by automation, may develop without detection by the flight crew, especially when the flight crew is focused on other tasks. The only reliable way for pilots to detect such deviations is through continuous monitoring of cockpit instrumentation. Although the opportunity for successful monitoring would be increased with two flight crewmembers rather than an individual pilot, research indicated that an overreliance on automation and a failure to monitor were unaffected by the presence of a second pilot in the cockpit.[108]

Evidence was not available for the Safety Board to determine whether the accident pilots were relying on an automated system for altitude and flightpath control. Nevertheless, the Board notes that, because the possibility exists for monitoring errors when using automated systems (and from distractions during times of increased workload), other systems have been developed to provide pilots with warnings of impending conditions that require corrective actions. One such system is TAWS, which alerts flight crews to a potential collision with terrain or water. Helicopters are not currently required to be equipped with TAWS; this issue is discussed and analyzed in section 2.3.1.

2.3 Cockpit Systems

2.3.1 Terrain Awareness and Warning System

TAWS has the ability to look ahead of an aircraft to detect the terrain or other obstructions along a flightpath. However, none of the S-76A helicopters in Era Aviation's fleet were equipped with a TAWS or were required to be so equipped.

At the time of the FAA's March 2000 final rule requiring that a TAWS be installed aboard all turbine-powered airplanes configured with six or more passenger seats, TAWS technology had not been specifically developed for the unique flightpaths of rotorcraft compared with fixed-wing aircraft (that is, lower altitudes and the ability to land at off-airport sites). Thus, the installation of TAWS aboard helicopters at that time would have likely resulted in numerous false warnings; systems with this tendency typically prompt a lack of operator trust and result in the failure to respond to the systems' warnings. However, TAWS technology is now available for helicopters,[109] and this technology can include warnings for terrain, obstacles, landing gear, excessive bank and sink rates, tail low attitudes, and below glideslope (on an instrument approach).

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[107] K. Funk, B. Lyall, J. Wilson, R. Vint, M. Niemczyk, C. Suroteguh, and G. Owen, "Flight Deck Automation Issues," *International Journal of Aviation Psychology*, Vol. 9, No. 2 (2000): 109-123.

[108] L.J. Skitka, K.L. Mosier, M. Burdick, and B. Rosenblatt, "Automation Bias and Errors: Are Crews Better Than Individuals?," *International Journal of Aviation Psychology*, Vol. 10, No. 1 (2000): 85-97.

[109] For example, Honeywell's Mark XXII enhanced GPWS, which was certified in 2001, contains an obstacle database that includes locations of more than 5,000 oil platforms and structures in the Gulf of Mexico. Also, during its visit to PHI, the Safety Board learned that the company equipped its helicopters with TAWS upon customer request.

A simulation by the manufacturer of TAWS for helicopters showed that, if a TAWS had been installed aboard the accident helicopter and the helicopter were descending toward the water at a rate of 150 fpm, the "caution terrain" alert would have occurred 97 seconds before impact at an altitude of about 240 feet, along with a water indication that changed from blue to yellow on the system's forward-looking terrain awareness display. The simulation also showed that the "warning terrain" alert would have occurred 84 seconds before impact at an altitude of about 210 feet, along with a water indication that changed from yellow to red on the forward-looking terrain awareness display. If the helicopter were descending toward the water at a rate of 250 fpm, the caution terrain alert would have occurred 68 seconds before impact at an altitude of about 270 feet, and the warning terrain alert would have occurred 55 seconds before impact at an altitude of about 215 feet (along with the water indication color changes on the forward-looking terrain awareness display).

The Safety Board concludes that, if a TAWS had been installed aboard the accident helicopter, the system's aural and visual warnings should have provided the flight crew with ample time to recognize that the helicopter was descending toward the water, initiate the necessary corrective actions, and recover from the descent. Therefore, the Safety Board believes that the FAA should require all existing and new U.S.-registered turbine-powered rotorcraft certificated for six or more passenger seats to be equipped with a TAWS.

As part of its special investigation report on EMS aircraft accidents, the Safety Board issued Safety Recommendation A-06-15, which asked the FAA to require EMS operators to install TAWS on their aircraft. It is important to provide the same level of safety for other helicopter operations, including the transportation of oil service personnel to and from offshore platforms.

2.3.2 Dual Digital Automatic Flight Control System

The accident helicopter was equipped with an SPZ-7000 DDAFCS. Although the Safety Board found no evidence to indicate that the SPZ-7000 contributed to this accident, the Board noted three characteristics about this flight control system that have safety-of-flight implications if pilots are not familiar with the system.

First, the SPZ-7000 does not provide an indication on the ADIs showing which flight director (FD1 or FD2) has been engaged. The SPZ-7000 has two independent flight control computers; one computer provides commands to the autopilot and flight director at the pilot's station, and the other computer provides commands to the autopilot and flight director at the copilot's station (referred to as a split cockpit). Thus, it is possible for the pilot and copilot ADIs to simultaneously present a different set of pitch and roll command cues.[110] This situation can be beneficial if the nonflying pilot

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[110] In contrast, many of the flight control systems currently in use in transport-category fixed-wing aircraft have dual but dependent flight control computers. In such systems, only one set of commands guides flight director command cues, which are presented simultaneously for both pilot stations.

wants to program the flight director in advance of the subsequent phase of flight. However, only one pilot station can be coupled at a time, and a lack of pilot awareness regarding which set of command cues is coupled to the autopilot can lead to automation mode confusion.[111]

Two indications in the cockpit provide the pilot with direct feedback regarding the flight director status: the FD1/2 button on the autopilot controller on the center pedestal (see figure 2), which shows the flight director that has been engaged, and the CPLT FD light (see number 9 in figure 1), which illuminates on the caution/advisory panel on the center of the front instrument panel when FD1 is selected. No similar light illuminates when FD2 is selected, and the only indication in front of the pilots that FD2 is selected is the absence of illumination of the CPLT FD light. Neither the FD1/2 button nor the CPLT FD light is located near either pilot's ADI or the flight director mode selector, where other indications regarding flight director mode selections are presented.

Second, the SPZ-7000 does not annunciate the coupling status on the front instrument panel and does not provide an aural alert when the autopilot and flight director have become decoupled. As a result, the only direct indication of the coupling status is the illumination, or absence of illumination, of the CPL light on the autopilot controller on the center pedestal (see figure 2).

Although indirect indications of the flight director source and coupling status can be determined through monitoring cockpit instrumentation, the possibility of automation mode confusion increases when pilots are required to search multiple locations for information pertaining to the same system.[112] Displays for many newer flight control systems, including those used on the Sikorsky S-92 and Agusta AB-139 helicopters, annunciate the flight director source and the coupling status directly on the ADIs.

Third, when only one flight director mode (either pitch or roll) is selected, both pitch and roll command cues appear simultaneously on the SPZ-7000, but no annunciation appears on the ADIs regarding the source of guidance for the unselected command cue. Because the SPZ-7000 allows for independent engagement of flight director mode selections (referred to as split-axis engagement), the system can be coupled to the longitudinal (pitch), lateral (roll), and vertical axes individually, two at a time, or all three simultaneously. The ability to engage only one or two axes, instead of all three, can be beneficial in certain circumstances, such as search and rescue, when a pilot may engage a roll function on the flight director mode selector (such as heading) but need to make pitch control inputs to maintain a certain height above varying terrain. However, the simultaneous presentation of command cues for both selected and unselected axes allows for the possibility of pilot misinterpretation of the command cue for the unselected axis. Specifically, a pilot may be unaware that a flight director mode has not been selected for

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[111] Automation mode confusion is a lack of awareness of the current mode of an automated system. It can result from inadequate feedback about the automated system's actions and intentions.

[112] R. Parasuraman and V. Riley, "Humans and Automation: Use, Misuse, Disuse, Abuse," *Human Factors*, Vol. 39, No. 2 (1997): 230-253.

both axes (because of the presence of two command cues)[113] and thus not realize that the command cue for the unselected axis is not synchronized to a selected pitch or roll function.

Even if a pilot were aware that a flight director mode had not been selected for both axes, the lack of an annunciation on the ADIs regarding the source of guidance for the unselected axis might also result in pilot misinterpretation of the command cue. The source of guidance for an unselected command cue varies between flight control system models and may or may not be synchronized to the helicopter's attitude. For the SPZ-7000, the command cue for an unselected axis is synchronized to the helicopter's attitude. As a result, the command cue for the unselected axis will indicate a deviation from attitude rather than a deviation from altitude (when a flight director roll function is selected) and heading (when a flight director pitch function is selected).

Some of the FAA's observations of the SPZ-7000 DDFACS (see section 1.18.5.1) were consistent with those made by the Safety Board. Specifically, the FAA found that (1) no aural or visual annunciations occurred for a pilot-induced decouple, (2) the only cues that the flight director was not coupled on the selected side were the lack of flight director mode selections and the lack of flight director mode annunciations on the ADIs, (3) both pitch and roll command cues were displayed when only one axis was selected, and (4) the decoupling indications were not particularly compelling.

Although the SPZ-7000 is no longer in production, it is still in use on numerous helicopters.[114] The SPZ-7000's successor is the SPZ-7600, which is installed in S-76C helicopters.[115] Although the SPZ-7600 has many of the same components and operations as the SPZ-7000, the SPZ-7600 has key differences regarding coupling status annunciation, which promotes pilot mode awareness. For example, although the SPZ-7000 and the SPZ-7600 both have a DCPL warning indicator on the DAFCS caution panels (which are in direct view of the pilots and are next to the ADIs) to indicate when the autopilot and flight director have become decoupled, the SPZ-7000 DCPL warning indicators illuminate only during abnormal operations, whereas the SPZ-7600's DCPL warning indicators illuminate during both normal and abnormal operations. Also, although both the SPZ-7000 and the SPZ-7600 are not manufactured with an aural alert to indicate system decoupling, operators of helicopters that are equipped with the SPZ-7600 can install an after-market product that provides this alert to the pilots' headsets, the cabin, or both.

The SPZ-7600 also has a key difference regarding command cue guidance for the dual-cue format. With the SPZ-7000, both command cues appear simultaneously when only one axis is engaged. However, with the SPZ-7600 dual-cue format, the command cue for only the selected axis will appear on the pilots' ADIs. Specifically, if a flight director

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[113] For the dual-cue format, pitch attitude is represented by a horizontal command bar, and roll attitude is represented by a vertical command bar (see figure 7). For the single-cue format, pitch and roll guidance is integrated into angular bars in the shape of a chevron (see figure 8).

[114] According to a Honeywell official, more than 300 SPZ-7000s were manufactured.

[115] A Honeywell official stated that more than 850 SPZ-7600s have been manufactured to date.

roll function, such as heading, is selected and no flight director pitch function is engaged, only the vertical command bar (roll attitude) will appear. Likewise, if a flight director pitch function, such as altitude, is selected and no flight director roll function is engaged, only the horizontal command bar (pitch attitude) will appear. Thus, with the SPZ-7600 dual-cue format, pilots cannot misinterpret command cue guidance for the unselected axis, which also promotes pilot mode awareness.

Despite the improvements present in the SPZ-7600 (compared with the SPZ-7000), two issues exist with the single-cue format for that system. One issue is that the guidance for the unselected axis is still presented without annunciation. As a result, pilots could still misinterpret the status of the command cue for the unselected axis when using the SPZ-7600 single-cue format. The other issue is that the command cue for the unselected axis for the SPZ-7600 is not synchronized to attitude (as with the SPZ-7000); instead, the single-cue format symbol maintains a centered or neutral position regardless of pilot input. Thus, pilots may mistake a centered (pitch attitude) or neutral (roll attitude) command cue as feedback that the aircraft is either on a commanded flightpath or is synchronized to attitude (as with the SPZ-7000).[116]

Pilot mode awareness is a critical aspect associated with reducing errors from the use of automated flight control systems.[117] During postaccident interviews, Era Aviation pilots (including the chief pilot and director of training) were not able to fully explain the flight director and coupling status annunciations and command cue presentations associated with the SPZ-7000 and SPZ-7600. Additional training on these systems could help improve pilot understanding of the systems' capabilities, which is especially critical for pilots who operate both the SPZ-7000 and SPZ-7600. The Safety Board concludes that additional pilot training on the SPZ-7000 and SPZ-7600 DDAFCSs would promote automation mode awareness for pilots operating helicopters equipped with these systems. Therefore, the Safety Board believes that the FAA should ensure that all operators of helicopters equipped with either the SPZ-7000 or SPZ-7600 DDAFCSs provide training that includes information on flight director and coupling status annunciations; the command cue presentations when only the pitch or the roll mode is engaged; and, if applicable, the differences between the SPZ-7000 and the SPZ-7600.

2.4 Tracking of Gulf of Mexico Helicopter Flights

The FAA cannot currently provide flight-tracking services for low-flying aircraft in the Gulf of Mexico beyond the capabilities of existing FAA land-based radar sites. For example, during the accident flight, radar data were available until the helicopter was about 58 nm southeast of the Houston ASR-9 radar site, which provides maximum radar coverage of about 60 nm. The helicopter flew for another 18 minutes, traveling an additional 35 nm to the southeast, but no radar data were available for that portion of the

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[116] Displays for some newer flight control systems annunciate the source of guidance for the unselected axis (for example, "ROLL" or "PTCH") when the unselected axis is synchronized to attitude.

[117] U.S. Department of Transportation, Federal Aviation Administration, *Report on the Interfaces Between Flightcrews and Modern Flight Deck Systems* (Washington, DC: FAA, 1996).

flight. In addition to the lack of radar data for low-flying aircraft in the Gulf of Mexico, only helicopter dispatchers are aware of the status of their respective company's flights because there is no direct communication between pilots of such aircraft and air traffic controllers.[118]

The FAA's Safe Flight 21 Gulf of Mexico initiative (see section 1.18.3) was developed to determine whether ADS-B technology would be effective in providing pilots with navigation, air traffic, terrain, and weather information in the cockpit and enabling air traffic controllers and operators to provide surveillance (including position and altitude) of low-flying aircraft in those areas with limited or no radar coverage. The ADS-B infrastructure included ground-based transceivers, weather sensors, and communications outlets that would be used along with ADS-B monitors installed by operators on aircraft that fly in the Gulf of Mexico.

ADS-B technology had already been successfully deployed in Alaska as part of the Safe Flight 21 Capstone program. The FAA's Capstone Web site indicated that, according to a 2004 safety study by the University of Alaska, the accident rate for aircraft under the Capstone program had decreased by 47 percent from 2000 to 2004. Also, according to a 2003 safety study contracted by the Capstone program,[119] the ADS-B technology used in the Capstone program would have been effective in preventing about 80 percent of the en route CFIT accidents that occurred in southwest Alaska (the Phase I Capstone area) between 1990 and 1999.[120]

The Capstone program and the Safe Flight 21 Gulf of Mexico initiative were both intended to benefit pilots of low-flying aircraft in areas of limited radar coverage. The final phase of the Capstone program is currently being developed with funding for site surveys (but not for construction of the sites). However, in November 2005, the FAA indicated that implementation of the Safe Flight 21 Gulf of Mexico initiative would not begin until fiscal year 2013. As a result, helicopter pilots transporting oil service personnel to and from offshore platforms would not be afforded the same level of safety as general aviation pilots operating in Alaska.

ADS-B technology has many potential benefits for flight operations in the Gulf of Mexico. For example, if the ADS-B infrastructure had been operational in the Gulf of Mexico at the time of the accident, (1) the Era Aviation dispatcher would have had better flight-tracking and communication capabilities and thus could have monitored the accident helicopter's flightpath and provided an alert to the flight crew about the descent

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[118] For some helicopter operators, the status of their company's flights is transmitted only intermittently (as with Era Aviation, whose pilots provide dispatchers with position reports every 15 minutes.) As a result, no continuous flight tracking is provided for such flights.

[119] University of Alaska Anchorage, *Capstone Phase I Interim Safety Study, 2002* (Anchorage, Alaska: University of Alaska, 2003).

[120] According to the study, the ADS-B technology should prevent en route CFIT accidents by providing the pilot with information about the aircraft's proximity to high ground. Specifically, the technology compares information about nearby terrain (stored in an on-board database) with the aircraft's altitude and GPS location and then presents the information on a cockpit display. Terrain that is 500 feet or less below the aircraft is shown in yellow, and terrain that is level with or higher than the aircraft is shown in red.

and (2) the pilots would have received a warning in the cockpit about the descent. Also, ADS-B technology has many potential benefits for search and rescue operations in the Gulf of Mexico. For example, in September 2005, a Houston Helicopters S-76A helicopter was ditched in the Gulf of Mexico after an in-flight fire.[121] The 2 pilots and 10 passengers escaped from the helicopter but remained in the water for about 7 hours until they were located by U.S. Coast Guard personnel using night vision goggles.[122] ADS-B technology would have facilitated the search and expedited the rescue of the helicopter occupants. In addition, ADS-B technology would benefit accident investigations because information on an aircraft's airspeed, altitude, and position (that is, whether the aircraft was turning, climbing, or descending) would be available to investigators.

In January 2006, the FAA announced that the Safe Flight 21 program was being transitioned to the National ADS-B Program. At that time, the FAA proposed fiscal year 2007 for the start date for implementation of the program and fiscal year 2010 as the target date for completion of the first segment of ADS-B infrastructure deployment. On March 1, 2006, the FAA verbally informed the Safety Board that the Gulf of Mexico would be among those areas in the first segment of ADS-B infrastructure deployment; however, this information has not been confirmed.

It is critical that the milestones for the National ADS-B Program in the Gulf of Mexico are achieved on or ahead of time and that the fiscal year 2010 completion date for ADS-B deployment in the Gulf of Mexico not slip. This matter is especially important given the number of passengers and flights in the region (in 2004, more than 2.3 million passengers were transported aboard 1.3 million flights) and the inherent risks of offshore helicopter operations, as indicated by the FAA's Aeronautical Information Manual, section 10-2-1, "Offshore Helicopter Operations," which states the following:

> The offshore environment offers unique applications and challenges for helicopter pilots. The mission demands, the nature of oil and gas exploration and production facilities, and the flight environment (weather, terrain, obstacles, traffic), demand special practices, techniques and procedures not found in other flight operations.

Because of the limited radar services in the Gulf of Mexico, some helicopter operators, including Era Aviation, PHI, and Air Logistics, have purchased flight-tracking systems from commercial vendors. These commercial systems allow dispatchers to track aircraft in flight and the weather along the flightpath and to relay text messages to company pilots (and vice versa). Thus, as with ADS-B technology, a commercial

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[121] For more information about this accident, see DFW05MA230 at the Safety Board's Web site.

[122] The pilot of the helicopter declared "MAYDAY" but did not provide position information. Pilots of several aircraft in the area overheard the emergency distress call and immediately notified various FAA facilities of the situation. A ground search for the helicopter was then conducted based on the reported locations of the aircraft pilots who had overheard the emergency distress call. After the helicopter was overdue at its destination by more than 2 hours, the company coordinated with the FAA and the Coast Guard to determine the helicopter's likely location, and the Coast Guard then began its search for the helicopter. Because of damage to the communication infrastructure from Hurricane Katrina, company and FAA communications were not available for the flight.

flight-tracking system could have provided the Era Aviation dispatcher with information about the accident helicopter's descending altitude, which she could have communicated to the flight crew. However, the ADS-B technology would offer an additional level of safety for pilots flying at low altitudes in the Gulf of Mexico by providing them with navigation, air traffic, terrain, and weather information in the cockpit.

The Safety Board concludes that the National ADS-B Program technology would help Gulf of Mexico aircraft operators mitigate the inherent risks associated with offshore operations by providing pilots with terrain, weather, and other flight information in the cockpit and dispatchers with current location information. Therefore, the Safety Board believes that the FAA should ensure that the infrastructure for the National ADS-B Program in the Gulf of Mexico is operational by fiscal year 2010. The Safety Board further believes that, until the infrastructure for the National ADS-B Program in the Gulf of Mexico is fully operational, the FAA should require POIs of Gulf of Mexico aircraft operators to inform the operators about the benefits of commercial flight-tracking systems and encourage the operators to acquire such systems.

2.5 Lack of Adequate Cockpit Voice Recorder Information for This Investigation

The accident helicopter was equipped with a CVR that had been improperly installed. Specifically, the helicopter's CVR installation required that white notched switches (within the internal communications system units for the pilot and copilot stations) be set to the bottom position, but the switches were found set to the top position. The failure to set the switches to the correct position resulted in a lack of audio input to those CVR channels. The functional check of the CVR after installation did not detect the faulty installation.

The CAM was the only source of audio information recorded for the accident flight. However, because of the high noise level within the helicopter cockpit, the flight crew's conversation was mostly unintelligible. The lack of audio information significantly hindered the investigation of this accident.

On August 29, 2002, the Safety Board issued Safety Recommendation A-02-25, which asked that the FAA require operators to implement daily CVR test procedures to prevent the lack of CVR data after aviation accidents and incidents (see section 1.18.6.1). On March 5, 2004, the Safety Board reiterated Safety Recommendation A-02-25 as a result of its investigation of the January 2003 Air Midwest Beech 1900D accident in Charlotte. The Board's investigation of that accident found that the captain's and the copilot's audio information captured from the airplane's VHF radio systems was fair to poor quality.

In its response to Safety Recommendation A-02-25, the FAA stated that it issued Notice N8000.292, "Clarification of Recommendations for Cockpit Voice Recorder Testing," for operators of those airplanes equipped with CVRs that could be tested before the first flight of the day. The FAA indicated that the intent of the notice was to persuade the operators to configure the CVRs during future major maintenance cycles so that flight crews would be able to test them. The FAA also stated that it made a change to chapter 143, "Monitor Cockpit Voice Recorders," of FAA Order 8300.10. According to the FAA, the change tasked airworthiness aviation safety inspectors to evaluate maintenance programs that require maintenance technicians to perform a thorough test of the CVR at appropriate intervals. The Safety Board classified Safety Recommendation A-02-25 "Open—Acceptable Response" pending a permanent change to the FAA's operational requirements to ensure that a CVR functional test would be performed before the first flight of each day.

Although daily preflight testing of the CVR should catch most problems encountered with poor-quality audio recordings, a review of the actual audio recorded by the CVR would ensure that the entire CVR system (including the microphones, audio/communications panels, wiring, and CVR itself) was working properly. Such a review would reveal any problems with audio quality, CVR malfunction, or lack of audio signals to the CVR. The Safety Board recognizes that a review of downloaded audio data would not be feasible on a daily preflight basis, but this review could easily be accomplished periodically during a routine maintenance check of an aircraft.

A periodic maintenance check of a CVR could be similar to the periodic maintenance check that is performed on an FDR, during which the FDR is downloaded and the data are analyzed to ensure that the required parameters are being recorded correctly. The FDR maintenance check is currently being accomplished with minimal impact on the amount of time that the recorder is removed from the aircraft. With the advent of solid-state recorders, the download can be accomplished without the operator having to perform any maintenance to the recorder to comply with the download requirement.

The Safety Board concludes that preflight testing and maintenance checks of an aircraft's CVR are both necessary to ensure that audio data from CVR recordings are adequate. Therefore, the Safety Board believes that the FAA should require all operators of aircraft equipped with a CVR to (1) test the functionality of the CVR before the first flight of each day as part of an approved aircraft checklist and (2) perform a periodic maintenance check of the CVR as part of an approved maintenance check of the aircraft. The CVR preflight test should be performed according to procedures provided by the CVR manufacturer and should include listening to the recorded signals on each channel to verify that the audio is being recorded properly, is intelligible, and is free from electrical noise or other interference. The periodic maintenance check of the CVR should include an audio test followed by a download and review of each channel of recorded audio. The downloaded recording should be checked for overall audio quality, CVR functionality, and intelligibility.

In addition, the FAA's actions in response to Safety Recommendation A-02-25—the issuance of Notice N8000.292 and the change to FAA Order 8300.10—are not adequate to ensure that a CVR, once installed, will operate as required because the CVR test detailed in the notice and the order might not contain sufficient instructions to detect all faulty recordings. For example, although the preflight test recommended in Safety Recommendation A-02-25 might have been sufficient to discover the problem with the CVR installed on the Air Midwest accident airplane, the preflight test would not have discovered the faulty CVR installed on the Era Aviation accident helicopter. Therefore, the Safety Board classifies Safety Recommendation A-02-25 "Closed—Superseded" as a result of the issuance of Safety Recommendation A-06-23.

2.6 Lack of Flight Data Recorder Information for Helicopter Operations

The accident helicopter was not equipped with an FDR. In August 2003, the S-76A and several other helicopter models became permanently exempt from 14 CFR 135.152, which required that multiengine, turbine-powered aircraft with 10 to 19 passenger seats (excluding required crewmember seats) be equipped with an FDR.

In June 2001, Era Aviation requested a temporary exemption from the requirements of 14 CFR 135.152 for two of its S-76A helicopters (one of which was the accident helicopter) while the FAA was in the process of changing the regulation. In its letter, Era Aviation stated that operations without FDRs "do not degrade safety." The letter also stated that the Safety Board's accident data for rotorcraft operated under Part 135 with seating of 10 to 19 passengers do not indicate "that the cause of accidents is in question or that the investigative process would have been improved by the requirement for a DFDR."

In its August 2001 letter to Era Aviation that granted the exemption, the FAA cited Grant of Exemption No. 6785, which stated that the FAA had found that operators had demonstrated "valid reasons" for exempting several helicopter models (including the S-76A) from the FDR requirements, but the letter did not state what these valid reasons were. The FAA's letter also stated, "exempting certain helicopters from the FDR requirements would be in the public interest and would not adversely affect safety."

The Safety Board does not agree with the FAA's position that the lack of an FDR aboard helicopters is in the public interest and does not adversely affect safety. An FDR is an important investigative tool that is used to determine an aircraft's performance. Because the information that investigators learn from FDR data can help prevent accidents and incidents from recurring, the lack of FDRs aboard helicopters undoubtedly affects safety.

The Safety Board also disagrees with Era Aviation's position that, according to helicopter accident data, the investigative process would not be improved by the requirement for an FDR. The lack of FDR information hindered the Board's investigation of this accident, especially because of the poor quality of the CVR recording and the limited radar data. If an FDR had been installed on the accident helicopter, pertinent information would have been available to investigators, including the helicopter's flightpath, engine operation, autopilot operation, and flight control inputs.

The investigation of the August 2005 accident involving an S-76C that crashed in the Baltic Sea shortly after takeoff from Tallinn, Estonia, demonstrated that recorded flight data for helicopter operations are critical for effective accident and incident investigations. The S-76C had an FDR installed, and FDR data showed that the helicopter's pitch and roll movements were severe during the accident sequence and were not consistent with the recorded cyclic inputs. It is likely that the helicopter's movement and the cyclic's movement would not have been known without the FDR data. As a result, investigators identified airworthiness concerns about S-76 actuators because the FDR data were consistent with a loss of control of the forward actuator.

The Estonian accident was the first one involving a large helicopter for which FDR data were available. The FDR data have been extremely valuable during the investigation of that accident, which clearly demonstrates the possibility that FDR data for previous accidents would have been equally valuable if these data had been available.

The Safety Board concludes that, because the FAA exempted the S-76A helicopter from the FDR requirements in 14 CFR 135.152, recorded flight data were not available to help reconstruct the events that led to this accident, which significantly hampered the investigation. To prevent a similar situation from recurring, the Board urges the FAA to act on Safety Recommendations A-06-17 and -18 (see section 1.18.6.2) in a timely manner.

3. Conclusions

3.1 Findings

1. The captain and the copilot were properly certificated and qualified under Federal regulations. No evidence indicated any medical or behavioral conditions that might have adversely affected their performance during the accident flight. Flight crew fatigue was not a factor in this accident.

2. The accident helicopter was properly certified, equipped, and maintained in accordance with Federal regulations. The recovered components, with the exception of the cockpit voice recorder, showed no evidence of any structural, engine, or system failures.

3. Weather was not a factor in this accident. The dispatcher who handled the accident flight provided appropriate flight-tracking services. The search and rescue effort for this accident was timely. The accident was not survivable for the helicopter occupants because they were subjected to impact forces that exceeded the limits of human tolerance.

4. Even though visual meteorological conditions prevailed at the time of the accident, few, if any, references outside of the helicopter would have been available to the flight crew.

5. The helicopter crashed into the water at a high airspeed, a shallow descent angle, and a near-level roll attitude.

6. The pilots were not attempting an emergency landing on the water.

7. After the helicopter crashed into the water, the fuselage pitched nose down, and the tailboom broke off in a downward direction.

8. The flight crew was not adequately monitoring the helicopter’s altitude and missed numerous cues to indicate that the helicopter was inadvertently descending toward the water.

9. If a terrain awareness and warning system had been installed aboard the accident helicopter, the system’s aural and visual warnings should have provided the flight crew with ample time to recognize that the helicopter was descending toward the water, initiate the necessary corrective actions, and recover from the descent.

10. Additional pilot training on the SPZ-7000 and SPZ-7600 dual digital automatic flight control systems would promote automation mode awareness for pilots operating helicopters equipped with these systems.

11. The National Automatic Dependent Surveillance–Broadcast Program technology would help Gulf of Mexico aircraft operators mitigate the inherent risks associated with offshore operations by providing pilots with terrain, weather, and other flight information in the cockpit and dispatchers with current location information.

12. Preflight testing and maintenance checks of an aircraft's cockpit voice recorder (CVR) are both necessary to ensure that audio data from CVR recordings are adequate.

13. Because the Federal Aviation Administration exempted the S-76A helicopter from the flight data recorder requirements in 14 *Code of Federal Regulations* 135.152, recorded flight data were not available to help reconstruct the events that led to this accident, which significantly hampered the investigation.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the flight crew's failure to identify and arrest the helicopter's descent for undetermined reasons, which resulted in controlled flight into terrain.

4. Recommendations

4.1 New Recommendations

As a result of the investigation of this accident, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Require all existing and new U.S.-registered turbine-powered rotorcraft certificated for six or more passenger seats to be equipped with a terrain awareness and warning system. (A-06-19)
>
> Ensure that all operators of helicopters equipped with either the SPZ-7000 or SPZ-7600 dual digital automatic flight control systems provide training that includes information on flight director and coupling status annunciations; the command cue presentations when only the pitch or the roll mode is engaged; and, if applicable, the differences between the SPZ-7000 and the SPZ-7600. (A-06-20)
>
> Ensure that the infrastructure for the National Automatic Dependent Surveillance–Broadcast Program in the Gulf of Mexico is operational by fiscal year 2010. (A-06-21)
>
> Until the infrastructure for the National Automatic Dependent Surveillance–Broadcast Program in the Gulf of Mexico is fully operational, require principal operations inspectors of Gulf of Mexico aircraft operators to inform the operators about the benefits of commercial flight-tracking systems and encourage the operators to acquire such systems. (A-06-22)
>
> Require all operators of aircraft equipped with a cockpit voice recorder (CVR) to (1) test the functionality of the CVR before the first flight of each day as part of an approved aircraft checklist and (2) perform a periodic maintenance check of the CVR as part of an approved maintenance check of the aircraft. The CVR preflight test should be performed according to procedures provided by the CVR manufacturer and should include listening to the recorded signals on each channel to verify that the audio is being recorded properly, is intelligible, and is free from electrical noise or other interference. The periodic maintenance check of the CVR should include an audio test followed by a download and review of each channel of recorded audio. The downloaded recording should be checked for overall audio quality, CVR functionality, and intelligibility. (A-06-23)

4.2 Additional Recommendations Resulting From This Accident Investigation

As a result of the investigation of this accident (and the August 2005 accident involving the S-76C helicopter that crashed in the Baltic Sea shortly after takeoff),[123] the Safety Board issued the following recommendations to the FAA on March 7, 2006:

> Require all rotorcraft operating under 14 *Code of Federal Regulations* Parts 91 and 135 with a transport-category certification to be equipped with a cockpit voice recorder (CVR) and a flight data recorder (FDR). For those transport-category rotorcraft manufactured before October 11, 1991, require a CVR and an FDR or an onboard cockpit image recorder with the capability of recording cockpit audio, crew communications, and aircraft parametric data. (A-06-17)
>
> Do not permit exemptions or exceptions to the flight recorder regulations that allow transport-category rotorcraft to operate without flight recorders, and withdraw the current exemptions and exceptions that allow transport-category rotorcraft to operate without flight recorders. (A-06-18)

4.3 Previously Issued Recommendation Classified in This Report

Safety Recommendation A-02-25 (previously classified “Open—Acceptable Response”) is classified “Closed—Superseded” as a result of the issuance of Safety Recommendation A-06-23.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

ELLEN ENGLEMAN CONNERS
Member

DEBORAH A. P. HERSMAN
Member

KATHRYN O. HIGGINS
Member

Adopted: March 7, 2006

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[123] See sections 1.16.2 and 2.6 for more information about this accident.

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5. Appendixes

Appendix A

Investigation and Public Hearing

Investigation

The National Transportation Safety Board's South Central Regional Office in Arlington, Texas, was initially notified of this accident. Investigators from Safety Board headquarters in Washington, D.C., arrived at LCH on March 25, 2004. A Board investigator participated in recovery operations in the Gulf of Mexico. Wreckage identification and documentation occurred at LCH. Investigators remained on scene until April 3, 2004.

Four investigative teams were formed: operations, airworthiness, human performance, and cockpit voice recorder. Specialists in the areas of air traffic control, survival factors, and meteorology assisted in the investigation.

Parties to the investigation were the FAA; Era Aviation, LLC; Union Oil Company of California; Sikorsky Aircraft Corporation; and Honeywell. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the Safety Board's counterpart agency in France, the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) participated in the investigation as the representative of the State of Design and Manufacture (Powerplants). Turbomeca participated in the investigation as a technical advisor to the BEA, as provided in Annex 13.

Public Hearing

No public hearing was held for this accident.

Appendix B
Cockpit Voice Recorder

The following is the transcript of the L-3 Communications FA2100 cockpit voice recorder, serial number 118739, installed on an Era Aviation Sikorsky S-76A++, N579EH, which crashed into the Gulf of Mexico during controlled flight on March 23, 2004.

LEGEND

PILOT	Voice identified as the Pilot
CO-PILOT	Voice identified as the Co-Pilot
*****	Unintelligible word
*******	Unintelligible words or phrase(s)
( )	Questionable insertion
[ ]	Editorial insertion
...	Pause or interruption

Note 1: Times are expressed in central standard time (CST).

Note 2: Voice events transcribed from the CVR cockpit area microphone (CAM) channel only. Sources of other audio events transcribed, as noted.

Note 3: Audio events are not specifically defined or identified as air-to-ground communication or intra-cockpit communication events within the transcript.

Time (CST)
VOICE ID **CONTENT OR COMMENT**

1847:42
START OF RECORDING
START OF TRANSCRIPT

[Conversational-tone voices audible and intermittent throughout the recording from 1847:42 through 1918:13, but unintelligible – except where transcribed.]

1848:18
CO-PILOT * Lake Charles **

1848:46
CO-PILOT * Lake Charles five seven nine ***

1849:40
CO-PILOT *** five seven nine. there you are. we're off at ah four five High Island * five five seven… ***

1850:20
CO-PILOT * Lake Charles *** … ok ** four five High Island five five seven ***

1851:05
CO-PILOT *** give High Island five five seven a call and ***

1912:54
PILOT I dunno we have enough **… 'bout another hour of (flight)/(flying) to do ***

1914:00
CO-PILOT Lake Charles this is five seven nine … * five seven nine * we (have) enough to ah fly to ah spirit …*** … ** seven three eight. * five… * four five and ten... and one point ah six.

Time (CST) **VOICE ID**	**CONTENT OR COMMENT**
1918:13	[unintelligible conversational tone voices not discernable at this point through the end of the recording]
1918:25	[sound of decreasing background noise]
1918:33.3	[sound of tone, 640 Hz frequency for 0.4 seconds duration, recorded on CVR audio channel 1]
1918:33.4	[sound of electronic static clicks, recorded on CVR audio channels 1 and 4 (CAM channel)]
1918:33.5	[sound of electronic static click, recorded on CVR audio channels 2 and 3]
1918:33.8	**END OF TRANSCRIPT** **END OF RECORDING**

Appendix C
Flight Simulation Scenarios

The Safety Board examined numerous possible scenarios in which the flight crew's actions could have inadvertently led to a controlled descent into water. The Board used FlightSafety's S-76A simulator for these tests. All of the scenarios were based on a flight that occurred at night and over water with limited visual references (sparse lighting from platforms) and a cloud ceiling of 2,000 feet agl. For each of the scenarios, the starting altitude was 1,100 feet msl, the airspeed was 130 knots, the autopilots were engaged in the ATT mode, the initial rate of descent was 200 fpm, and the decision height was 200 feet. All of the scenarios involved a change in heading of 10º to the right (to reflect the flight crew's decision not to refuel at High Island A-557 and to proceed directly to the *Discoverer Spirit*) and a resulting increase in rate of descent from 200 fpm to 250 to 300 fpm, which was maintained after the helicopter rolled to a level altitude.

The four scenarios that were deemed to be the most likely to have occurred during the accident flight (assuming that the flight crew had engaged the DDAFCS) were (1) pilot 2 maintained control but did not select altitude hold mode, (2) pilot 1 coupled the flight director but did not select altitude hold mode, (3) pilot 1 selected the altitude mode but did not couple the flight director, and (4) pilot 1 selected the altitude preselect mode but did not couple the flight director. A detailed description of each of these scenarios follows.[124]

Pilot 2 Maintained Control but Did Not Select Altitude Mode

The first scenario began with FD2 engaged and coupled and with NAV and VS selected on the flight director mode selector. Pilot 2 (in the right seat) then pressed SBY on the flight director mode selector, which canceled the NAV and VS modes and decoupled FD2. With the HSI heading bug,[125] pilot 2 changed the helicopter's heading 10º to the right to reflect the flight crew's decision not to refuel at High Island A-557 and to proceed directly to the *Discoverer Spirit*. Pilot 2 then pressed HDG on the flight director mode selector, coupling FD2 once again, but did not press ALT. Because the helicopter's power setting was not changed and ALT was not selected on pilot 2's flight director mode selector, the process of making the 10º turn to the right led to a 250- to 300-fpm descent that was maintained after rollout.

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[124] The abbreviations discussed in these four scenarios are defined in section 1.6.3.2.

[125] The heading bug is a blue notch that is positioned around a rotating compass card to indicate the direction in which the helicopter is to be flown.

The following is a description of what was seen on pilot 2's instrumentation during this scenario:

- A green HDG indication appeared at the top left of the ADI after the pilot pressed the HDG button on the flight director mode selector.
- No command bars appeared initially on the ADI because FD2 was automatically set to SBY before HDG was selected. Once the selection was made, the command bars appeared. The pitch command bar was centered, and the roll command bar was in the neutral position.
- The radar altitude appeared in blue at the bottom right of the ADI followed by an RA indication in white.
- The decision height was displayed in blue at the bottom left of the ADI followed by a DH indication in white. A white square box appeared above the radar altitude (at the bottom right of the ADI) when the helicopter was 100 feet above the decision height (based on the radar altimeter). When the decision height was reached, an amber DH indication appeared inside the box and remained there as the helicopter continued to descend.
- A yellow rising runway symbol appeared at the bottom center of the ADI at 180 feet (based on the radar altimeter). As the helicopter's altitude decreased, this symbol ascended until it met the aircraft symbol at 0 feet.
- The flight director mode selector's SBY button was initially illuminated in green. Once the HDG button was selected, it illuminated in green, and the SBY button was no longer illuminated.
- The VSI showed a rate of descent of 250 to 300 fpm, which placed the needle below the centerline.
- The barometric altimeter showed decreasing altitude by a counterclockwise rotation of the needle.

Pilot 1 Coupled the Flight Director but Did Not Select Altitude Mode

The second scenario began with FD2 engaged and coupled and with NAV and VS selected on the flight director mode selector. Pilot 2 (in the right seat) transferred control of the helicopter to pilot 1 (in the left seat). Pilot 1 then selected FD1, and the flight director mode selector was automatically set to SBY. With the HSI heading bug, pilot 1 changed the helicopter's heading 10º to the right. Pilot 1 then pressed HDG on the flight director mode selector, coupling FD1, but did not press the ALT button. Because the power setting was not changed and ALT was not selected on pilot 1's flight director selector mode, the process of making the 10º turn to the right led to a 250- to 300-fpm descent that was maintained after rollout.

The following is a description of what was seen on pilot 1's instrumentation during this scenario:

- A green CPLT FD indication appeared at the top left of the caution/advisory panel.
- A green HDG indication appeared at the top left of the ADI after the HDG button on the flight director mode selector was pressed.
- The command bars disappeared from the ADI when FD1 was selected. When HDG was selected, the command bars reappeared. The pitch command bar was centered, and the roll command bar was in the neutral position.
- The radar altitude appeared in blue at the bottom right of the ADI followed by an RA indication in white.
- The decision height was displayed in blue at the bottom left of the ADI followed by a DH indication in white. A white square box appeared above the radar altitude (at the bottom right of the ADI) when the helicopter was 100 feet above the decision height (based on the radar altimeter). When the decision height was reached, an amber DH indication appeared inside the box and remained there as the helicopter continued to descend.
- A yellow rising runway symbol appeared at the bottom center of the ADI at 180 feet (based on the radar altimeter). As the helicopter's altitude decreased, this symbol ascended until it met the aircraft symbol at 0 feet.
- The flight director mode selector's SBY button was initially illuminated in green. Once the HDG button was selected, it illuminated in green, and the SBY button was no longer illuminated.
- The VSI showed a rate of descent of 250 to 300 fpm, which placed the needle below the centerline.
- The barometric altimeter showed decreasing altitude by a counterclockwise rotation of the needle.

Pilot 1 Selected Altitude Mode but Did Not Couple the Flight Director

The third scenario began with FD2 engaged and coupled and with NAV and VS selected on the flight director mode selector. Pilot 2 (in the right seat) transferred control of the helicopter to pilot 1 (in the left seat). Pilot 1 selected FD1 and then selected CPL on the autopilot controller, which decoupled FD1. With the HSI heading bug, pilot 1 changed the helicopter's heading 10° to the right. Pilot 1 also pressed HDG and then ALT on the flight director mode selector. Because the power setting was not altered and FD1 was not coupled, the heading change led to a 250- to 300-fpm descent that was maintained after rollout.

The following is a description of what was seen on pilot 1's instrumentation during this scenario:

- A green CPLT FD indication appeared at the top left of the caution/advisory panel, even after FD1 was decoupled.
- After the HDG and ALT buttons on the flight director mode selector were pressed, green HDG and ALT indications appeared at the top left and top right, respectively, of the ADI.
- The command bars disappeared from the ADI when FD1 was selected. When HDG was selected, the command bars reappeared. The pitch command bar appeared above the center position, and the roll command bar was in the neutral position.
- The radar altitude appeared in blue at the bottom right of the ADI followed by an RA indication in white.
- The decision height was displayed in blue at the bottom left of the ADI followed by a DH indication in white. A white square box appeared above the radar altitude (at the bottom right of the ADI) when the helicopter was 100 feet above the decision height (based on the radar altimeter). When the decision height was reached, an amber DH indication appeared inside the box and remained there as the helicopter continued to descend.
- A yellow rising runway symbol appeared at the bottom center of the ADI at 180 feet (based on the radar altimeter). As the helicopter's altitude decreased, this symbol ascended until it met the aircraft symbol at 0 feet.
- The flight director mode selector's SBY button was initially illuminated in green. Once the HDG and ALT buttons were selected, they illuminated in green, and the SBY button was no longer illuminated.
- The VSI showed a rate of descent of 250 to 300 fpm, which placed the needle below the centerline.
- The barometric altimeter showed decreasing altitude by a counterclockwise rotation of the needle.

Pilot 1 Selected Altitude Preselect but Did Not Couple the Flight Director

The fourth scenario began with FD2 engaged and coupled and with NAV and VS selected on the flight director mode selector. Pilot 2 (in the right seat) transferred control of the helicopter to pilot 1 (in the left seat). Pilot 1 selected FD1 and then CPL on the autopilot controller, which decoupled FD1. With the heading bug, pilot 1 changed the helicopter's heading 10º to the right. Pilot 1 pressed HDG and ALT PRE on the flight director mode selector and entered the desired altitude (900 feet) into the AL-300. Pilot 1 also pressed VS on the flight director mode selector and entered the desired rate of descent (200 fpm) with the collective. The helicopter descended at that rate until reaching the selected altitude. However, because the power setting was not altered and FD1 was not coupled, the heading change led to a 250- to 300-fpm descent that was maintained after rollout.

The following is a description of what was seen on pilot 1's instrumentation during this scenario:

- A green CPLT FD indication appeared at the top left of the caution/advisory panel, even after FD1 was decoupled.
- After the HDG and ALT PRE buttons on the flight director mode selector were selected, a green HDG indication appeared at the top left of the ADI, and a white ALTP (altitude preselect) indication surrounded by a white box appeared at the top right of the ADI. The white ALTP indication changed to a green ALT indication after the selected altitude was reached.
- After the VS button on the flight director mode selector was selected, a green VS indication appeared on the left side of the ADI. The green VS indication disappeared after the selected altitude was reached.
- The command bars disappeared from the ADI when FD1 was selected. When HDG was selected, the command bars reappeared. The pitch command bar was centered, and the roll command bar was in the neutral position.
- The radar altitude appeared in blue at the bottom right of the ADI followed by an RA indication in white.
- The decision height was displayed in blue at the bottom left of the ADI followed by a DH indication in white. A white square box appeared above the radar altitude information when the helicopter was 100 feet above the decision height (based on the radar altimeter). When the decision height was reached, an amber DH indication appeared inside the box and remained there as the helicopter continued to descend.
- A yellow rising runway symbol appeared at the bottom center of the ADI at 180 feet (based on the radar altimeter). As the altitude decreased, this symbol ascended until it met the aircraft symbol at 0 feet.
- The flight director mode selector's SBY button was initially illuminated in green. Once the HDG button was selected, it illuminated in green, and the SBY button was no longer illuminated. Also, the flight director mode selector's VS button illuminated in green and the ALT PRE button's ARM light illuminated in amber to indicate that the helicopter was descending toward the preselected altitude. When the helicopter was near the preselected altitude, the ALT PRE button's ARM light extinguished, and the CAP (captured) light illuminated in green. Once the helicopter reached the selected altitude, the CAP light extinguished, and the green ALT button illuminated.
- The VSI showed a rate of descent of 250 to 300 fpm, which placed the needle below the centerline.
- The barometric altimeter showed decreasing altitude by a counterclockwise rotation of the needle.

- At an altitude of 600 feet (300 feet below the preselected altitude), an amber light at the top left of the barometric altimeter illuminated, and an aural tone sounded over the pilots' headsets for 1 second. The light remained illuminated throughout the rest of the flight.

Appendix D

Gulf of Mexico Helicopter Accident Data March 2000 Through February 2006

The following is a list of Gulf of Mexico helicopter accidents from 2000 to February 2006:

Date	Operator	Model	Number of injuries			
			Fatal	Serious	Minor	None
Part 135 operations						
3-20-00	Horizon Helicopters	Bell 206			3	
5-24-00	Tex-Air Helicopters	Eurocopter AS-350			2	
5-31-00	Panther Helicopters	Bell 206		1		
12-26-00	Tarlton Helicopters	Bell 206	1			
3-20-01	Air Logistics	Sikorsky S-76A	1			8
5-4-01	Air Logistics	Bell 407				2
8-5-01	Air Logistics	Bell 206		3		
8-24-01	Air Logistics	Bell 206		2		
9-26-01	Air Logistics	Bell 206				3
10-18-01	Air Logistics	Bell 206		3	2	
7-25-02	Air Logistics	Bell 206			2	
8-1-02	Go Helitrans	Bell 206				4
1-9-03	Tex-Air Helicopters	Aerospatiale AS-350			4	1
1-16-03	Air Logistics	Bell 206	1	3		
1-21-03	Air Logistics	Bell 206				5
2-16-03	Houston Helicopters	Bell 407	2	3		
2-22-03	Petroleum Helicopters	Bell 407	1			1
3-24-03	Petroleum Helicopters	Bell 407				2
5-11-03	Petroleum Helicopters	Bell 407				4
5-29-03	Tarlton Helicopters	Robinson R44	1			
7-7-03	Tex-Air Helicopters	Aerospatiale AS-350				2
8-13-03	Petroleum Helicopters	Bell 206	3	1	1	
9-12-03	Go Helitrans	Bell 206			1	3
10-10-03	Petroleum Helicopters	Bell 206	3			
12-1-03	Petroleum Helicopters	Bell 407	1			
1-28-04	Rotocraft Leasing Company	Bell 206				6
3-6-04	Petroleum Helicopters	Bell 206			1	2
3-23-04	Era Aviation	Sikorsky S-76A	10			
6-24-04	American Helicopters	Bell 206	3			
7-21-04	Omni Energy Services	Bell 206			1	2
9-29-04	Panther Helicopters	Bell 206				3
11-5-04	Rotocraft Leasing Company	Bell 206		1	1	1
12-17-04	Omni Energy Services	Bell 407	1	1	2	
2-18-05	Rotocraft Leasing Company	Bell 206				3

Date	**Operator**	**Model**	**Number of injuries**			
			Fatal	**Serious**	**Minor**	**None**
		Part 91 operations				
6-8-05	American Helicopters	Bell 206				4
7-11-05	Chevron/Texaco USA	Bell 430				3
9-6-05	Houston Helicopters	Sikorsky S-76A		4	6	
10-6-05	Industrial Helicopters	Bell 206	3			
4-29-00	Chevron USA	Bell 206				2
9-7-00	Horizon Helicopters	Bell 206		1		
10-28-00	Tex-Air Helicopters	Aerospatiale AS-350	1			
12-1-00	American Helicopters	Bell 206				1
12-29-00	Petroleum Helicopters	Bell 407	1			
7-10-01	Air Logistics	Sikorsky S-76A				1
11-10-01	Industrial Helicopters	Bell 407				1
1-8-02	Air Logistics	Bell 206				1
3-23-02	Petroleum Helicopters	Bell 206	1			
6-29-02	Evergreen Helicopters	Bell 206				1
12-31-02	Air Logistics	Bell 206				1
3-6-03	Taylor Energy Company	Eurocopter AS-350				5
7-8-03	Tex-Air Helicopters	Eurocopter EC120				3
7-17-04	Rotocraft Leasing Company	Bell 206	1			
12-9-04	Evergreen Helicopters	Bell 206				1
3-13-05	Rotorcraft Leasing Company	Bell 206		1		
8-17-05	Air Logistics	Bell 206				1
8-18-05	Air Logistics	Bell 206	2			
2-19-06	Central Helicopters	Bell 222				2