

1. Factual Information

1.1 History of Flight

On 23 August 2000, about 1930 Bahrain local time,¹ Gulf Air flight 072, (GF-072) an Airbus A320-212, Sultanate of Oman registration A40-EK, crashed in the Arabian Gulf near Muharraq, Bahrain. GF-072 departed from Cairo International Airport, Cairo, Egypt (CAI), with 2 pilots, 6 cabin crew, and 135 passengers on board, for Bahrain International Airport (BAH), Muharraq, Kingdom of Bahrain. GF-072 was operating as a regularly scheduled international passenger service flight under the Convention on International Civil Aviation and the provisions of Sultanate of Oman Civil Aviation Regulations Part 121 and was on an instrument flight rules (IFR) flight plan. The airplane had been cleared to land on Runway 12 at BAH, but crashed at sea about 3 miles north-east of the airport soon after initiating a go-around following the second landing attempt. The airplane was destroyed by impact forces, and all 143 persons on board were killed. Night, visual meteorological conditions existed at the time of the accident.

According to Gulf Air company records and witness statements, the flight crew arrived at the departure gate at CAI about 25 minutes before the scheduled departure time of 1600 (Cairo local time)² on 23 August 2000 and the flight was airborne at 1652. According to the cockpit voice recorder (CVR), the captain was performing the pilot-flying (PF) duties, and the first officer was performing the pilot-not-flying (PNF) duties.

About 1921:48, as GF-072 was descending through approximately 14,000 feet above mean sea level (amsl) and about 30 nautical miles (nm) north-west of Bahrain Airport, Dammam Approach gave the following instruction to GF-072:

Gulf Air zero seven two, uh, self navigation for runway one two is approved. Three point five (3,500 feet)³ as well approved and Bahrain Approach one two seven eight five (127.85 MHz) approved.

During the readback several seconds later, the captain asked, "Gulf Air zero seven two, confirm we can go for runway one two?" Dammam Approach responded, "Affirmative. Three approves (approvals) you have. Direct for one two (Runway 12). Three point five (3,500 feet) approved. One two seven

¹ Unless otherwise indicated, all times are Bahrain local time (Universal Co-ordinated Time + 3 hours), based on a 24-hour clock.

² Cairo and Bahrain are in the same time zone during the summer.

³ For clarification, additional information is provided to explain some CVR comments and is shown in parentheses. This information was not recorded on the CVR.

eight five (127.85 MHz) approved.” The CVR⁴ then recorded the captain instructing the first officer to contact Bahrain Approach. After the first officer made contact, Bahrain Approach stated, “.....cleared (for) self position and, uh, as you’re cleared by Dhahran. Confirm three thousand five hundred (3,500) feet.” The CVR then recorded the captain telling the first officer, “tell them we are cleared to seven thousand (7,000 feet).” The first officer complied and Bahrain Approach responded again to flight GF-072 to continue descent to 3,500 feet⁵.

After the flightcrew began executing the approach checklist, Bahrain Approach instructed GF-072 at 1923:21 to continue descent to 1,500 feet and report when established on the VOR/DME⁶ for Runway 12. About 1923:36, the CVR recorded the first officer asking, “V bugs?”⁷ and the captain responded, “V bugs, one three six (136 knots), two zero six (206 knots), set.”

About 1924:38, the CVR recorded the captain saying to the first officer, Now you see you have to be ready, for all this, okay? If (it) change on you all of a sudden, you don’t say I’ll go. You have to know DME. If you can make it or not. Okay?

This was followed by another comment by the captain,

Now, I’ve just changed all the flight plan, RAD NAV (Radio Navigation), everything for you, before you even blink. Yeah? Okay ammy?

About 1925:15, with the airplane about 9 nm from Runway 12⁸, 1873 feet above ground level (AGL), and an airspeed (computed airspeed recorded by the FDR) of 313 knots, the captain stated, “final descent is seven DME.” At 1925:37, with the airplane about 7.7 nm from Runway 12, 1715 feet AGL, and an airspeed of 272 knots, the captain instructed the first officer to “call established”. About 1925:45, about 7 nm from the runway, Bahrain Approach cleared GF-072 for the VOR/DME approach to Runway 12 and instructed the flight to contact Bahrain Tower.

About 1926:00, the CVR recorded the captain saying, “final green”, and at 1926:04 the first officer contacted Bahrain Tower and stated that GF-072 was “eight DME, established.” Tower controller then cleared GF-072 to land and reported wind from 090 degrees at eight knots. The first officer

⁴ Appendix B contains the CVR transcript. The transcript expresses the time of CVR comments and sounds in co-ordinated Universal Time (UTC). Bahrain local time/Cairo Summer time is 3 hours ahead of UTC.

⁵ FDR data indicate that speed-brakes were used during the descent (from 19:22:49 to 19:24:33, from 19:25:05 to 19:25:57, and then from 19:26:05 to 19:26:13).

⁶ VOR/DME stands for Very-high frequency Omni-directional Range/Distance Measuring Equipment and is a navigational aid that provides bearing and distance to the radar facility.

⁷ A “V bug” is a movable indicator on the airspeed indicator.

⁸ Stated distances from GF-072 to Runway 12 are to the runway’s displaced threshold. The runway’s displaced threshold is 2.1 nm from VOR/DME facility. Hence, the DME distance is different than the distance to Runway 12.

acknowledged the transmission. About 1926:13, with the airplane about 5.2 nm from the runway, 1678 feet AGL, and an airspeed of 224 knots, the captain called for “flaps one.” Seconds later, the captain called for “gear down”, and FDR data subsequently showed the landing gear moving to the gear-down position.

About 1926:37, the CVR recorded the captain stating, “Okay, visual with airfield.” Seconds later, FDR data showed the autopilot and flight director being disengaged⁹. About 1926:49 and about 2.9 nm from the runway, the airplane descended through 1,000 feet AGL. About 1926:51, with the airplane about 2.8 nm from the runway, 976 feet AGL, and 207 knots, the captain stated, “Have to be established by five hundred feet.” Flaps “two” were then selected. As the flight continued on its approach for Runway 12, the captain stated about 1927:06 and again about 1927:13, “....we’re not going to make it.”

About 1927:23, the captain instructed the first officer to “Tell him to do a three sixty (360 degree) left (orbit).” The first officer complied and the request was approved by Bahrain Tower. The left turn was initiated about 0.9 nm from the runway, 584 feet AGL, and an airspeed of 177 knots. During the airplane’s left turn, FDR data showed the flap configuration going from flaps “two” to flaps “three” and then to flaps full. About 1928:17, the captain called for landing checklist. At 1928:28, with the airplane approximately half-way through the left turn, the first officer stated, “landing checklist completed.” After about three-fourths of the 360° turn, the airplane rolled out to wings level.

FDR data showed that the airplane’s altitude during the left turn ranged from 965 feet to 332 feet AGL, and that the airplane’s bank angle reached a maximum of about 36 degrees. About 1928:57, after being cleared again by Bahrain Tower to land on Runway 12, the captain stated, “...we overshot it.” FDR data then showed the airplane beginning to turn left again, followed by changes consistent with an increase in engine thrust. About 1929:07, the captain stated, “tell him going around” and FDR data indicated an increase to maximum TOGA¹⁰ engine thrust. Bahrain Tower responded with, “I can see that. Zero seven two sir uh....would you like radar vectors....for final again?” The first officer accepted, and Bahrain Tower instructed the crew to, “fly heading three zero zero (300 degrees), climb (to) two thousand five hundred (2,500) feet.” The first officer acknowledged the transmission. During this time, the flaps were moved to position “three” and the gear was selected up. FDR data showed that the gear remained retracted until the end of the recording.

⁹ FDR data indicate that the autothrust remained active throughout the approach, until TOGA was selected.

¹⁰ TOGA stands for Takeoff/Go-Around.

About 1929:41, with the airplane at 1054 feet AGL, at an airspeed of 191 knots, and having just crossed over the runway, the CVR recorded the beginning of a 14-second interval of the aural Master Warning¹¹ (consistent with a flap-overspeed condition), followed by the statement from the first officer, “speed, overspeed limit...” Approximately two seconds after the beginning of the Master Warning, FDR data indicated a forward movement of the captain’s side stick. The captain’s side stick was held forward of the neutral position¹² for approximately 11 seconds, with a maximum forward deflection of about 9.7 degrees¹³ reached. During this time, the airplane’s pitch attitude decreased from about 5 degrees nose-up to about 15.5 degrees nose-down, the recorded vertical acceleration decreased from about +1.0 “G”¹⁴ to about +0.5 G’s, and the airspeed increased from about 193 knots to about 234 knots.

About 1929:51, with the airplane descending through 1004 feet AGL at an airspeed of 221 knots, the CVR recorded a single aural warning of “sink rate” from the Ground Proximity Warning System (GPWS), followed by the repetitive GPWS aural warning “whoop whoop, pull up”, which continued until the end of the recording.

About 1929:52, the captain requested, “flaps up.” About 1929:54, the CVR indicated that the Master Warning ceased for about 1 second, but then began again and lasted about 3 seconds. Approximately 2 seconds after the GPWS warnings began, FDR data indicated movement of the captain’s side stick aft of the neutral position, with a maximum aft deflection of approximately 11.7 degrees reached. However, the FDR data showed that this nose-up command was not maintained and that subsequent movements never exceeded 50% of full-aft availability. FDR data indicated no movement from the first officer’s side stick throughout the approach and accident sequence.

About 1929:59, the captain requests, “flaps all the way” and the first officer responded, “zero.” This was the last comment from the crew recorded on the CVR, which stopped recording at 1930:02. The FDR data showed continuous movement of the flap position toward the zero position after the captain’s “flaps up” command. The last flap position recorded on the FDR was about 2 degrees of extension. The last recorded pitch attitude was about 6 degrees nose-down and last recorded airspeed was about 282 knots. FDR data indicated that TOGA selection and corresponding maximum engine thrust remained until the end of the recording.

FDR data indicated that during the go-around after selection of TOGA thrust, GF-072 was initially at about a 9 degree nose-up pitch attitude.

¹¹ The aural Master Warning is a continuous repetitive chime.

¹² Forward movement of the sidestick will induce a nose-down pitch response.

¹³ Maximum fore and aft sidestick deflection is 16 degrees from the neutral position.

¹⁴ One G is the nominal acceleration of 9.8 m/sec².

However, the pitch attitude gradually decreased to about 5 degrees nose-up over the next 25 seconds, where it remained until the captain's forward sidestick commands resulted in nose-down pitch changes.

Figure 1 shows the Instrument Approach Chart for the Bahrain Runway 12 VOR/DME procedure. The VOR/DME radar facility is located approximately 2.1 miles from the threshold for Runway 12. Figure 2 shows an overhead view of the GF-072 trajectory, with selected FDR information, CVR comments and sounds, and air traffic control (ATC) data for the last 4 minutes of flight. Figure 3 shows the side view (vertical profile) for the last 19 seconds of flight.

**Figure 1. Instrument Approach Chart for Bahrain Runway 12
VOR/DME Procedure**

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

Figure 2. Overhead view of GF-072 trajectory with selected FDR, CVR, and ATC communication excerpts.

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

Figure 3. Side view (vertical profile) of GF-072 trajectory.

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

1.2 Injuries to Persons

Table 1: Injury chart.

	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	2	6	135	0	143
Serious	0	0	0	0	0
Minor	0	0	0	0	0
None	0	0	0	0	0
Total	2	6	135	0	143

1.3 Damage to Airplane

The airplane was destroyed by impact forces. The estimated value of the airplane was about US \$ 36 million.

1.4 Other Damage

No other damage to property was sustained.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 37, was hired by Gulf Air on 27 December 1979 and employed as an Engineer Cadet. Company records indicated the following additional information:

Promoted to Trainee Engineer:	19 Dec 1983
Promoted to Trainee Flight Engineer, Lockheed L1011:	14 Feb 1988
Promoted to Flight Engineer, Lockheed L1011:	14 Jan 1989
Promoted to Senior Flight Engineer, Lockheed L1011:	14 Jan 1992
Promoted to First Officer, Lockheed L1011:	23 Jan 1994
Transferred to First Officer, Boeing 767:	26 Sep 1994
Promoted to Supervisory First Officer, Boeing 767:	17 Feb 1996
Transferred to Supervisory First Officer, Airbus A320:	25 Feb 1998
Transferred to Supervisory First Officer Boeing 767	6 Jun 1999
Transferred to Supervisory First Officer, Airbus A320:	6 Jan 2000
Promoted to Captain, Airbus A320:	17 Jun 2000

The captain held an Airline Transport Pilot (ATP) certificate (number TA-1178) issued by the Sultanate of Oman, valid until 31 March 2001, with type ratings on the Airbus A320 as Pilot-in-Command (endorsed on 26 April 2000), 767 as Co-pilot, L1011 as Co-pilot. The captain held a First Class Airman Medical certificate issued by the Sultanate of Oman on 3 July 2000, without limitations.

The captain's flight experience according to Gulf Air records was as follows:

Table 2: Flying and Duty Time - Captain

FLYING TIME	HOURS
Total Pilot Time	4,416
Total Pilot in Training sponsored by Gulf Air	186
Total Pilot with Gulf Air	4,230
Total Gulf Air A-320 PIC ¹⁵	86
Total Gulf Air A-320 SIC ¹⁶	997
Total Gulf Air B-767 SIC	2,346
Total Gulf Air L1011 SIC	800
Total Gulf Air Flight Engineer	
	2,402

The captain's flight and duty time according to Gulf Air records was as follows:

	DUTY TIME (Hrs:Mins)	FLIGHT TIME (Hrs:Mins)
Previous 24 hours	00:00	00:00
Previous 7 days	24:35	17:05
August 2000	61:40	25:35
Since 1 Jan 2000	1,073:17	475:35

The captain's initial (and most recent) proficiency check on the A320 occurred on 26 April 2000 and was valid until 1 November 2000. The captain's initial (and most recent) line check occurred on 16 June 2000 and was valid until 1 July 2001. Prior to 19 August 2000, the two pilots had not flown together as captain and first officer.

Prior to the trip that began on 19 August 2000, the captain last flew on 30 July 2000. He had days off on 31 July and 1 August 2000 and took vacation leave between 2 August and 18 August 2000.

Gulf Air indicated that GPWS training is conducted during Controlled Flight Into Terrain (CFIT) training in recurrent and command training

¹⁵ Pilot-in-Command (Captain)

¹⁶ Second-in-Command (First Officer or Co-pilot)

programs (see paragraph 1.17.1.2.2). The captain's most recent Training and Proficiency record indicated that he underwent CFIT training during recurrent/upgrade training on 23 April 2000.

Gulf Air records and interviews by investigators revealed the following.

From the captain's most recent line check that was completed on 16 June 2000, it was indicated that all competency check elements were completed to a satisfactory standard and the designated examiner noted, "well flown test, good SOP operation."

The captain's initial upgrade checkride that was completed on 26 April 2000 indicated overall "Pass" rating, however, "D" ratings on two emergency manoeuvres, i.e. a rejected take-off and an engine failure after V1. He was not required to "re-sit" on these items. (According to DGCAM's Designated Examiner Procedures, a "D" rating is the lowest acceptable standard for a sequence, and if more than three unrelated sequences are graded "D", the overall checkride should be rated as "Fail").

Gulf Air pilots that had flown with the captain were interviewed and used the following words to describe his personality: responsible, knowledgeable, open to suggestions, happy, very helpful, professional, and sharp. Pilots' interviewed varied in terms of their description of the captain's confidence in his abilities. One interviewee noted that the captain was confident but not dominant or overconfident. Another interviewee stated that the captain was slightly overconfident but not overpowering or dominant, while another interviewee indicated that the captain was a little loud and confident to the extent that he may have bordered on overconfidence and was somewhat boastful of his knowledge of aircraft systems.

One first officer interviewed recalled an incident involving the captain's use of the airplane's engine anti-ice. The captain left the engine anti-ice on after they had flown clear of icing conditions. The first officer challenged the captain on this during flight, but the captain refused to accept the first officer's explanation and chose to leave the anti-ice on. After landing the first officer showed the captain the reference in the airplane's manual regarding use of anti-ice; however, the captain refused to accept this interpretation and maintained that his use of engine anti-ice was appropriate. The first officer indicated that during this incident the captain was not happy with his questioning, but never became angry. The same first officer also recalled an incident in which the captain was "strict" with the engineers (maintenance personnel) because an airplane log was not properly signed off regarding one of the Acceptable Deferred Defects (ADDs). The captain would not accept the flight due to this; however, the issue was eventually resolved.

1.5.2 The First Officer

The first officer, age 25, was hired by Gulf Air on 4 July 1999 as a training cadet after attending Gulf Air's Ab-Initio training program.¹⁷ He held a Commercial Pilot (CP) certificate (number CA-558) issued by Sultanate of Oman, valid until 30 November 2004, with type rating on Airbus A320 as co-pilot. The first officer held a First Class Airman Medical certificate issued by Sultanate of Oman on 26 July 2000 without limitations. He was promoted to A320 first officer on 20 April 2000.

The first officer's flight experience according to Gulf Air records was as follows:

Table 3: Flying and Duty Time – First Officer

FLYING TIME	HOURS
Total Pilot Time	608
Total Pilot in Training sponsored by Gulf Air	200
Total Pilot with Gulf Air	408
Total Gulf Air A-320 PIC	0
Total Gulf Air A-320 SIC	408
Total Gulf Air Flight Engineer	0

The first officer's flight and duty time according to Gulf Air records was as follows:

	DUTY TIME (Hrs:Mins)	FLIGHT TIME (Hrs:Mins)
Previous 24 hours	00:00	00:00
Previous 7 days	24:35	17:05
August 2000	123:30	72:03
Since 1 Jan 2000	1,170:43	408:33

The first officer's initial A320 SIC type rating endorsement and SIC proficiency check occurred on 5 November 1999. His most recent A320 proficiency check occurred on 11 June 2000 was valid until 1 January 2001. The first officer's most recent A320 line check occurred on 19 April 2000 and was valid until 1 May 2001.

The first officer's most recent Training and Proficiency record, indicated that he underwent CFIT training during recurrent training on 10 June 2000.

¹⁷ The Ab-Initio training program provides training for cadets (who already hold a commercial pilot license or a frozen airline transport license) to company standards for a line first officer.

Gulf Air records and interviews by investigators reveal the following:

The first officer was sponsored by Gulf Air during his initial training at the Qatari Aeronautical College located in Doha, Qatar. Upon completion of this training, the first officer obtained his Commercial Pilot/Instrument Rated (CPL/IR) license issued by the Sultanate of Oman and was hired by Gulf Air as a training cadet in the Gulf Air Ab-Initio pilot training program.

The first officer failed his initial proficiency check in the A-320 on October 29, 1999. He received marks of "D" on the following: LOC/DME approach, VOR/DME approach, normal landing, crosswind landing, landings from non-precision approach, automation and technology and engine failure procedures¹⁸. The first officer received additional proficiency training and passed his initial A-320 SIC type rating and proficiency check on November 5, 1999.

After completion of his simulator proficiency check in November 1999, the first officer began his line training on the A-320. The first officer was recommended for his initial flight line competency check on April 17, 2000. On April 19, 2000, the first officer passed his initial line competency check.

One captain that had flown with the first officer, stated that the first officer had difficulty with the approach and departure procedures at Sanaa, Yemen, during a flight on May 11, 2000. This captain indicated that the first officer was able to keep up with the aircraft and perform well at all airports with normal procedures and operations, but had difficulty at Sanaa because he was not familiar with the procedures. The captain felt that the first officer had not been exposed to information specific to Sanaa and did not ask questions regarding the non-standard procedures. The captain noted that neither Gulf Air nor the DGCAM require a special check out for Sanaa airport.

Several Gulf Air captains that had flown with the first officer were interviewed and used the following words to describe the personality of the first officer: timid, meek, mild, polite, disciplined, shy and reserved in social situations, and keen to learn (i.e., inquisitive). While most of the captains interviewed stated that they did not think that the first officer's reserved nature would hinder him from speaking up during flight operations, others felt that he might have been too reserved to speak up or challenge a captain. One designated examiner/simulator training captain recalled that during a training session, he intentionally exceeded the 30 knot taxi speed limit specified in Gulf Air standard operating procedures (SOPs) and the first officer failed to challenge him regarding this.

¹⁸ According to the DGCAM Designated Examiner Procedures, sequences on proficiency checks are graded on a scale from "A" through "E" where "E" is failing, and if more than three unrelated sequences are graded "D", the overall checkride should be rated as "Fail".

1.5.3 Flightcrew 72-Hour History

The captain and first officer were conducting a four-day trip that began at Bahrain on 19 August 2000. The captain and first officer arrived in Cairo, Egypt, at 1350 local time (1050 UTC) on 22 August 2000.

Interviews and records established the following. On the evening of the 22 August, the captain, an air steward (from another set of crew), and a stewardess went to the hotel restaurant about 2030, and remained there until about 2230. The first officer was also at the hotel restaurant about this time, sitting at another table with two stewardesses. The movement of the first officer thereafter could not be accurately determined due to lack of eyewitness accounts and no documentary evidence. The captain went to the hotel casino about 2300. After midnight, the captain, steward, and stewardess took a taxi to Khan Al-Khalil, where they purchased some gifts and had some coffee, before returning to the hotel about 0215. They then went to the crew room for a while and then to the steward's room. About 0315 the captain left them to go to sleep.

The Gulf Air Operations Manual - Vol. 6, Sec 7.2.25, specifies that all A-320 crewmembers away from base are to report for duty one hour before scheduled departure time. Hotel records indicate the following timings (local time) in respect of the GF-072 crew:

1.	Call (wake-up) Time	13:40
2.	Pick-up Time	14:40
3.	Leaving Time	14:40

The driving time from the hotel to the airport is about ten minutes. The flight from Cairo to Bahrain on 23 August 2000 was scheduled to depart Cairo at 1600 local time (1300 UTC). According to the captain who flew A40-EK into Cairo on flight GF-071, the GF-072 flight crew arrived at the gate about 25 minutes before the scheduled departure to take over the airplane. The flightcrew of GF-071 indicated that the captain of GF-072 seemed upset because ground staff had directed them to the wrong gate.

1.5.4 The Air Traffic Controllers

1.5.4.1 Bahrain Approach Control

The air traffic control specialist who was working Bahrain Approach Control during the time of the accident was a trainee who was working under the supervision of an acting air traffic control Watch Supervisor. He had been a trainee in this position since 21 May 2000. Prior to this, he had worked in the Bahrain Air Traffic Control Tower. He began working in the Control Tower in 1991.

The ATC Watch Supervisor has been validated at Bahrain Airport since October 1994. He completed his last Annual Certificate of Competency on 27 March 2000.

The trainee was monitoring GF-072 and approved the flight's request for a 360° left turn on the initial approach. The trainee stated that airplane's estimated altitude during the orbit was between 500 and 800 feet and that it seemed unusual and tight to him. He indicated that he has seen other 360° turns, but that they are usually not done so tight or so close to the runway threshold.

The supervisor stated that he observed the radar track of the GF-072 during the approach and that he thought the 360° turn was very quick and tight. He stated that he had seen other Gulf Air airplanes do 360° turns during final approach, although it is not common.

1.5.4.2 Air Traffic Control Tower

The Aerodrome Controller has been validated at Bahrain since December 1994 and completed his last Annual Certificate of Competency on 8 March 2000. In addition to being a qualified Local Controller, he was also qualified as a Ground Controller and an Approach Controller.

The Ground Movement Controller has been validated at Bahrain since 1 January 1986 and completed his last Annual Certificate of Competency on 4 June 2000.

The tower controller stated that when GF-072 was handed off to him, he issued a normal landing clearance along with the wind direction and speed. He noticed that GF-072's 360° turn was very tight. He stated that as the airplane was coming around in the turn, it crossed the final approach course with the nose down and moving very fast. He stated that he had never seen that kind of approach before, and he asked his tower colleague to "look at this." About this time, GF-072 reported that they were going to go around.

1.6 Airplane Information

The accident airplane was an Airbus A320-212, A40-EK, Serial Number 481, owned by the Gulf Air Company (Gulf Air). The airplane was registered and issued an Airworthiness Certificate on September 29, 1994. The aircraft had accumulated 17,370 hours TSN¹⁹ and 13,990 landings at the time of the accident.

¹⁹ TSN = Time Since New

The Gulf Aircraft Maintenance Company (GAMCO) performed all airplane maintenance for Gulf Air. The last maintenance performed on A40-EK was a special maintenance input conducted on 17-18 August 2000. An engine vibration survey and fan trim balance on both engines was performed and no anomalies were noted. There were no Minimum Equipment List (MEL) deferred defects and no significant outstanding Acceptable Deferred Defect or Base Deferred Defects. Certificate of release to return to service was issued on 18 August 2000.

A40-EK was equipped with two CFM International (CFMI)²⁰ CFM56-5A3 turbofan engines. The number 1 engine (serial number 731-794) was installed on A40-EK on 20 September 1999, and had accumulated 17,901 hours and 14,384 cycles since new. The last shop visit for this engine was a minor repair performed by General Electric (GE) Engine Services at Cardiff, Wales, United Kingdom, in September 1999.

The number 2 engine (serial number 731-795) was installed on A40-EK on 11 May 1998, and had accumulated 18,274 hours and 14,638 cycles since new. The last shop visit for this engine was an overhaul performed by GE Engine Services in April 1998.

The maintenance logs from A40-EK were reviewed for the period from 1 June 2000 to 23 August 2000; two repetitive defects were noted. One involved false engine fire loop indications, and the other writeup noted a brief exhaust gas temperature overheat of the engines after takeoff. Both writeups had been resolved and cleared before the accident flight.

The first officer who flew A40-EK before the accident flight indicated that there was a repetitive AIR PACK 1 OVHT caution during cruise on their flight to Cairo. The flightcrew cleared the fault by switching off the pack. Later in the flight, an AIR PACK 1 REGUL FAULT appeared. The first officer stated that the remainder of the flight was normal and that at no time did there appear to be any problem with the flight controls.

1.6.1 A320 Flight Control Design

The A320 employs a fly-by-wire flight control system. With this design, all flight control surfaces are electrically controlled and hydraulically activated. The horizontal stabiliser and the rudder can also be controlled mechanically. Each pilot uses a sidestick to command pitch and roll changes (instead of a control wheel). These sidestick commands are interpreted by flight control computers, which then send the signals for the appropriate movement of the flight controls.

²⁰ CFMI is jointly owned by General Electric Aircraft Engines (GEAE) of the United States and Société Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA) of France.

The sidesticks are located on each pilot's lateral console; each is spring-loaded to the neutral position. A take-over pushbutton is located on the top of each sidestick. To become the controlling pilot/sidestick, the pushbutton for that sidestick must be pressed and held down. Holding the pushbutton down for over 40 seconds latches the priority on that sidestick and allows that pilot to release his pushbutton without losing priority. The other pilot can deactivate the other pilot's sidestick and assume controlling priority by pressing and holding his take-over pushbutton. The last pushbutton to be engaged determines the controlling sidestick. When only one pilot operates the sidestick, the signals from only his sidestick provide the flight control commands. If the other pilot also operates his sidestick (whether in the same or opposite direction), the signals from both sidesticks are added. When the autopilot is engaged, the first action by depressing the takeover pushbutton is disengagement of the autopilot.

Each side-stick incorporates a spring force to resist movement from its neutral position (i.e., resistance increases as sidestick deflection increases). As shown in Figure 4, resistance increases to 100 Newtons (about 22 pounds) at the sidestick pitch deflection limits of ± 16 degrees.

The A320's flight control design (under "normal law")²¹ is a load-factor-demand mode with automatic trim throughout the flight envelope. In this mode, flight envelope protections are enabled (see section 1.6.4). In normal law, deflection of the sidestick causes movement of the elevators and/or horizontal stabiliser to maintain load factor proportional to stick deflection and independent of speed. With the sidestick at neutral and wings level, the system maintains +1.0G in pitch (corrected for pitch attitude); there is no need for the pilot to trim when changing speed or configuration. Pitch trim is automatic both in manual mode and when the autopilot is engaged. In turns up to 33° of bank, no pitch corrections are necessary to hold altitude once the turn is established.

At bank attitudes up to 33 degrees, the system holds the commanded bank attitude constant when the sidestick is at neutral. If the sidestick is released at a bank angle greater than 33 degrees, the bank angle automatically reduces to 33 degrees. Sidestick command must be maintained to achieve bank angles above 33 degrees.

²¹ The A320 typically operates under normal mode, but can be operated under alternate and direct modes under certain situations, which offer less automatic protections and may provide different responses to flight control inputs. Recorded FDR data indicate that GF-072 was operating under normal mode.

Figure 4: Side-stick spring force vs. deflection)

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

1.6.2 AutoThrust

Engine thrust on the A320 can be controlled either manually by the flightcrew or automatically by the autothrust (A/THR) system.

When armed, the A/THR system automatically activates if the thrust levers are moved into the “active” range, which is between idle thrust and maximum climb thrust (for 2 engines operative). Outside of this range, thrust levers control thrust directly.

When active, the A/THR system is designed to maintain a target thrust (THRUST mode) or a target airspeed (SPEED/MACH mode).²² The A/THR system can operate independently or with the autopilot/flight director (AP/FD). When performing independently, A/THR controls the airspeed. If the A/THR system is working with the AP/FD, the A/THR mode and AP/FD pitch modes are linked together.

1.6.3 A320 Cockpit Instrumentation

Figures 5 and 5a: Cockpit Instrumentation

Figure 6: Primary Flight Display (PFD)

The layout of the A320 cockpit includes six display units, control panels, and indication lights to present data to the pilots (see figure 5). The display units are comprised of a primary flight display (PFD) and a navigation display for each pilot, as well as an engine/warning display and a system display located between the pilots’ navigation displays. The PFDs provide data such as airspeed, altitude, pitch attitude, bank angle, heading, and flight modes (see figure 6). Display of airspeed is on the speed scale on the left side of PFD and includes the following:

- airspeed: represented by a yellow pointer and reference line
- speed trend: a vertical arrow that starts at the airspeed reference line. The tip of the arrow shows the speed the airplane will reach in 10 seconds if its acceleration remains constant.
- V_{MAX} : the lower end of a red and black strip along the speed scale defines this speed. It is the lowest of the following
 - V_{MO} or the speed corresponding to M_{MO}
 - V_{LE} maximum speed with landing gear extended.
 - V_{FE} maximum speed with flaps extended.

²² The A/THR system also provides maximum thrust when the airplane’s angle of attack exceeds a specific threshold.

Figure 5: A320 Cockpit Instrumentation (Schematic Arrangement)

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

Figure 5a: A320 Cockpit Instrumentation (Actual Instruments)

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

Figure 6: Primary Flight Display

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

Figure 7: Slats/Flaps Configurations

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

1.6.4 A320 Flight Envelope Protections

The A320's flight control design logic provides protection throughout the airplane's flight envelope. These include protections for high speed, pitch attitude, bank attitude, load factor, and high angle-of-attack.

High speed protection is activated at or above V_{MO}/M_{MO} , regardless of autopilot status. As the speed increases above V_{MO}/M_{MO} , the sidestick's nose-down authority is progressively reduced, and a nose-up order is applied to aid recovery. There is no automatic aircraft protection or automatic aircraft response for flap-overspeed.

The nose-down limit under the pitch attitude protection is 15 degrees. This limit is maintained even if further nose-down positions are commanded by the sidestick.

The airplane's load factor is automatically limited to +2.5 G's and -1.0 G when in a clean configuration. For other configurations, the load factor is limited to +2.0 G's to 0 G. Regardless of the pitch commands from the sidestick, the airplane will not exceed these limits.

Stall protection maintains the airplane below its maximum angle-of-attack (α_{max})²³, even if the sidestick is pulled full aft.

1.6.5 A320 Flap Control System

The cockpit flap lever controls the positions of the wing's trailing edge flaps and leading edge slats. The five positions of the flap lever are "0", "1", "2", "3", and "Full" (see Figure 7).

To change the flap setting, the lever must be pulled out of the detent for each position. Gates at positions "1" and "3" prevent the pilot from selecting excessive flap/slat travel with a single action. Flap positions and retraction times between the different configurations are provided in Table 4.

²³Exceeding the airplane's maximum angle of attack can result in a stall, which is characterised by a loss of lift and loss of altitude.

Table 4: Flap Retraction Time

CONFIGURATION	FLAP POSITION (DEGREES)	FLAP RETRACTION TIME (SEC.)
full to 3	35 to 17 ²⁴	4.6
3 to 2	17 to 15	2.4
3 to 1+F	17 to 10	3.9
2 to 1+F	15 to 10	2.5
1+F to 0	10 to 0	7.4
full to 0	35 to 0	13.2

Take Off & Go-Around Flap Scenario

Flap lever position “1” corresponds to a flap configuration identified as either “1” or “1+F”, depending on airspeed. With airspeed greater than 210 knots, the configuration is identified by “1” and corresponds to a slat/flap extension of 18°/0°.) With airspeed less than or equal to 210 knots, the configuration is identified by “1+F” and corresponds to a slat/flap extension of 18°/10°. When in configuration “1+F”, if the airspeed increases above 210 knots the flaps will automatically retract to 0°.

1.6.6 Flap Overspeed Situation

In addition to the red and black strip on the airspeed indicator above the flap limit speed, cockpit indications of a flap over-speed situation include a single repetitive chime, illumination of the Master Warning lights, and an ECAM message indicating a flap over-speed situation.

These indications will activate if the airplane exceeds a V_{FE} ²⁵ as follows:

<u>Flap Configuration</u>	<u>V_{FE} (knots)</u>
Full	177
3	185
2	200
1 + F	215
1	230

For the flap configuration that existed at the time the overspeed warning first activated on GF-072, the following ECAM²⁶ message would have appeared:

²⁴ Although flaps “3” correlates to a nominal flap position of 20°, the actual flap extension for this flap setting is 17°.

²⁵ V_{FE} is the maximum speed for trailing edge flaps extended.

²⁶ ECAM = Electronic Centralised Aircraft Monitor.

OVERSPEED

-VFE.....185

The V_{FE} corresponding to the next flap lever position (from the current position and airspeed) is also indicated by an amber “=” along the left side of the PFDs adjacent to the particular airspeed.

1.6.7 Ground Proximity Warning System

The accident airplane was equipped with an Allied Signal Mark V GPWS Warning Computer. The GPWS is designed to generate aural warnings when one of several unsafe modes occurs. The cockpit loudspeakers broadcast the aural warning messages associated with each mode. The CVR from GF-072 recorded the aural warnings associated with Mode 1 (Excessive Rate of Descent), during the last 11 seconds of the recording.²⁷

Mode 1 has two thresholds, which are dependent on an airplane’s radio altitude and vertical descent rate. Penetration of the first threshold generates the repetitive warning “SINK RATE”. Penetration of the second boundary generates the repetitive warning “WHOOOP WHOOOP PULL UP”. Mode 1 warnings are enabled from radio altitudes 2,450 feet to 10 feet.

1.6.8 Weight and Balance

The following information was obtained from the Gulf Air load manifest for GF-072 as well as A320 operating limitations:

Table 5: Weight and Balance

TAKEOFF WEIGHTS		
	POUNDS	KILOGRAMS
Basic Operating Weight	97,623	44,281
Ramp Fuel Weight	23,589	10,700
Passenger Weight	18,554	8,416 (61 male, 37 female, 29 children, and 8 infants for a total of 135 passengers)
Baggage Weight	11,325	5,137
Taxi Gross Weight	151,091	68,534
Maximum Taxi Weight	170,635	77,400
Takeoff Fuel Weight	23,149	10,500
Takeoff Gross Weight	150,651	68,334
Maximum Takeoff Gross Weight	169,754	77,000

²⁷ The Mode 1 alert has priority over other GPWS modes.

TAKEOFF CENTRE-OF-GRAVITY AND SPEEDS	
Takeoff Centre of Gravity (CG)	32.7% mean aerodynamic chord (MAC)
Takeoff CG Limits	15% to 37% MAC
Takeoff Stabiliser Trim Setting	0.9 units airplane nose down (ND)
Takeoff Flap Setting	1 + F
Takeoff Speeds	$V_1=154$ knots, $V_R=161$ knots, $V_2=161$ knots

Based upon the FDR data about the aircraft weights at the time of take-off and landing (impact), the fuel consumed during the flight was about 8,183 kilograms (18,003 pounds). Based on this fuel burn, the cg at the time of the approach would have been approximately 35.9% MAC, which is within the cg limits for the airplane.

ESTIMATED LANDING WEIGHTS		
	POUNDS	KILOGRAMS
Fuel Burn	18,003	8,183
Landing Gross Weight	132,524	60,238
Maximum Landing Gross Weight	142,198	64,500
Landing Speed	$V_{APP}=136$ knots	

1.7 Meteorological Information

1.7.1 Weather Conditions at Bahrain International Airport

According to the Bahrain Meteorological Office, the reported weather at 1630 UTC (1930 local time) was:

Surface wind direction:	090 degrees True
Surface wind velocity:	08 knots
Visibility/Weather:	CAVOK ²⁸
Air temperature:	34 degrees Celsius
Dew point:	29 degrees Celsius
QNH:	1001.2 hP (29.57 inches)

Bahrain International Airport ATIS²⁹ information TANGO on 23 August 2000, at 16:19:30 UTC, was reported as following: "Bahrain information TANGO at 1600. Runway in use 12. Wind 090 degrees 7 knots. CAVOK. Temperature 35. Dew point 29. Q.N.H. 1001. NOSIG. Report information TANGO at first contact." According to ATC transcripts, GF-072 acknowledged having received information TANGO.

The moonrise was 2345 local time and there was no sun or moon in the sky at the time of the accident. Sunset was 1806 local time.

²⁸ CAVOK stands for "Ceiling and Visibility OK" and indicates visibility of 10 kilometres or more, no clouds exist below the greater of 1500 meters or the highest minimum sector altitude, and no weather of significance to aviation.

²⁹ ATIS stands for automatic terminal information service.

1.8 Aids to Navigation

1.8.1 Precision Approach Path Indicator (PAPI)

. Runway 12 is equipped with a Precision Approach Path Indicator (PAPI) system (left of runway) calibrated for a 3° visual glide path angle.

The most recent check of the PAPI system for Runway 12 before the accident was conducted by the Bahrain Civil Aviation Affairs on 22 and 23 August 2000, as part of a regularly-scheduled check. The system was found to be serviceable. The PAPI was again checked following the accident on 26 August 2000 and was found to be functioning properly and within prescribed tolerances. There were no adverse reports on the PAPI from any flights on the days before or after the accident.

1.8.2 Radio Navigation and Landing Aids

Table 6: Radio Navigation and Landing Aids

Type of aid CAT of ILS/MLS/VAR	ID	Frequency	Hours of operation	Site of transmitting antenna coordinates	Elevation of DME transmitting antenna	Remarks
1	2	3	4	5	6	7
VOR/DME (2°E/1996)	BAH	115.300 MHZ	H24	261532.12N 0503915.39E	24FT	121°MAG 0.25 NM MAINT every TUE 0500 – 0800
L ³⁰	LB	395 MHZ	H24	261530.25N 0503918.62E		121° MAG 0.47NM FM THR RWY 30
LLZ RWY 30 ILS CAT 1	IBI	110.300 MHZ	H24	261656.34N 0503649.44E		301°MAG 2.18NM FM THR RWY 30 MAINT every MON, 0530 – 0800
GP ³¹ 30	Dots/ Dashes	335.000 MHZ	H24	261555.88N 0503845.47E		3.00°, RDH 55FT
ILS DME		1001 MHZ	H24	261555.88N 0503845.47E	42 FT	Co-located with GP Dist. Zero TDZ RWY 30
MM 30 ³²	Dot/ Dash	75 KHZ	H24	261529.77N 0503919.45E		121°MAG 0.48 NM FM THR RWY 30

³⁰ L = Locator non-directional beacon (NDB)

³¹ GP = Glide Path

³² MM = Middle Marker

1.9 Communications

No communications problems were reported between the crew of GF-072 and any of the ATC facilities. No emergency was declared by GF-072.

1.10 Airport Information

1.10.1 Bahrain International Airport

The Bahrain International Airport is located about 3.3 nm North East of Manama on Muharraq Island at an elevation of 6 feet amsl. The airport is under the control of Bahrain Civil Aviation Affairs. The associated navigational facilities are owned by Bahrain International Airport. The airport has one runway oriented northwest/southeast: Runway 12/30, which is 3956 meters long and 60 meters wide.

The landing threshold of Runway 12 is displaced from the beginning of the runway by 306 meters. That makes the landing distance available (LDA) 3,650 meters for Runway 12. Runway 12 is equipped with high intensity approach lighting system (Category 1), threshold lighting colour wing-bar: green, a high intensity runway lighting system (including runway centre-line lighting with spacing colour white and red, runway edge lighting with spacing colour, and runway end lighting red colour wing-bars). The threshold elevation of Runway 12 is 6 feet amsl and the slope of runway is 0.0 percent. The following figures contain the Airport Charts for Bahrain International Airport:

- (a) Figure 8: Aerodrome Ground Movement Chart AD 2-11
- (b) Figure 9: Aerodrome Lighting Chart AD 2-13.

Bahrain International Airport was certified as Category 9 aircraft rescue and fire fighting (ARFF) facility. In accordance with this category, the airport is required to maintain a minimum of three ARFF vehicles capable of carrying a total quantity of at least 24,300 Ltrs. of water. The rescue equipment also includes four rescue boats capable of carrying 20 person each, owned by the Coastguard.

Figure 8: Aerodrome Ground Movement Chart AD 2-11

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

Figure 9: Aerodrome Lighting Chart AD 2-13.

To view the above figure, please click its corresponding link under "Figures" on the Home Page.

1.10.2 VOR/DME Runway 12 Approach Procedure at Bahrain International Airport

The Gulf Air instrument approach procedure for VOR/DME Runway 12 at Bahrain International Airport is the same as that specified by the Aeronautical Information Publication (AIP), Bahrain.

The Instrument Approach Chart 13-2 VOR/DME Runway 12 effective 14 November 1997, which is shown in Figure 1, had the following items:

Plan View³³

Facilities	:	VOR/DME	115.3 (MHz VOR/DME frequency) BAH (Identifier)
		NDB	395 (KHz NDB frequency) LB (identifier)
Outbound	:		322° (magnetic course for Category C & D aircraft) 313° (magnetic course for Category A & B aircraft) D9.0 (outbound fixes)
Inbound	:		121° (magnetic course) D9.0 (Intermediate Fix) D7.0 D5.0 } DME fixes D3.0 }

Profile View

2,500' (amsl altitude over VOR/DME facility Initial Approach Fix)
 322° (outbound magnetic course for Category C & D aircraft)
 313° (outbound magnetic course for Category A & B aircraft)
 1500' (amsl at 9.0 DME/2½ min until end of base turn)
 121° (inbound magnetic course)
 1,500' (amsl at the Final Approach Fix at 7.0 DME)
 870' (amsl at 5.0 DME)
 420' (Minimum Descent Altitude for VOR/DME)

Missed Approach: Climb on heading 121° to 2,500' (2,494'), then turn right to rejoin holding, or as directed.

The Instrument Approach Chart also shows location names, crossing altitudes, missed approach procedure, minimum descent altitude(s), etc.

³³ The plan view is the approach viewed from above; the profile view is the approach viewed from the side.

1.11 Flight Recorders

The flight data recorder and cockpit voice recorder were recovered on 24 August 2000 in the forenoon. The underwater locator beacons installed on each recorder had separated during the impact sequence.

The recorders were transported by a Bahraini Civil Aviation Affairs (CAA) official to the NTSB's laboratory in Washington, DC, USA for initial readouts, and thereafter to BEA's laboratory in Paris, France for further readout analysis.

1.11.1 Flight Data Recorder

The accident airplane was equipped with a Sundstrand FDR, part number 980-4100-AXUN and serial number 10854, which was configured to record over 400 parameters. The FDR had a recording duration of 25 hours before the oldest data were overwritten. Examination of the data indicated that the FDR had operated normally. Certain parameters from the FDR data were included in the CVR transcript (see Appendix "B"). Some parameters of the FDR readout for the last five minutes are attached as Appendix "C".

1.11.2 Cockpit Voice Recorder

The accident airplane was equipped with a Sundstrand (solid-state) 30-minute CVR, part number 980-6020-001 and serial number 0513. The recording consisted of 4 channels that included data from the captain, first officer, and cockpit area microphones. The fourth channel also recorded the interphone and the public address system.

The audio portion began about 15:59:41 UTC and continued uninterrupted until 16:30:02 UTC. The end of the recording was consistent with power interruption at impact. The CVR group, consisting of accredited representatives and technical advisers, collectively reviewed the recording. A transcript of the last 8 minutes and 27 seconds of the recording (from 16:21:35 UTC to 16:30:02 UTC) is attached as Appendix B.

1.11.3 Digital AIDS Recorder

The accident airplane was equipped with another data recording device called a Digital AIDS³⁴ Recorder (DAR). The DAR provides easy access for downloading data for condition monitoring and trend analysis.

³⁴ AIDS stands for Aircraft Integrated Data System.

Although the DAR is not “crash-protected” like FDRs and CVRs, the unit from GF-072 was recovered in relatively good condition with only impact marks to the case. However, subsequent examination revealed that no data had been recorded on the tape, and that the tape was found at the beginning of the track.

1.12 Wreckage and Impact Information

The debris field was centered approximately 4 kilometers northeast and on a 030 degree radial from Bahrain International Airport. The wreckage was located in the Arabian Gulf in about 3 meters of water. Estimated surface temperature at sea at the time of the accident was about +33°C. The beginning of the debris field was located near 26°17'51" North/50°38'49" East. The debris field was oriented on a heading of about 030 degrees and was about 700 meters in length. The end of the debris field included portions of the cockpit and lower avionics bay. The width of the debris field varied but was approximately 800 meters at the widest point. The majority of the right and left hand structural pieces were found on their respective sides of the debris field. A broad search of the accident area and the approach to Runway 12 revealed no additional wreckage.

The majority of the airplane was recovered along with all significant airplane structural and flight control surfaces and both engines. No evidence of pre-crash failure and no evidence of fire damage were observed on any of the recovered parts. All examined fracture surfaces were consistent with overload failure.

Damage to circuit breaker panels precluded proper documentation of pre-impact circuit breaker positions or conditions.

The fuselage had fragmented into numerous sections. The wings were sheared from the centre box structure near the same location on both sides. Both engines had separated from the pylons and were heavily fragmented. A large section of the empennage was found in one piece.

Portions of the nose gear and both main landing gear (MLG) assemblies had separated. The right hand MLG retraction actuator was found in the extended position, which corresponds to a "gear retracted" position; the retraction actuator for the left hand MLG was not located.

Most of the horizontal stabiliser was recovered separate from the empennage and was substantially fragmented. The horizontal stabiliser actuator screw was broken with the lowest part remaining connected to the ballnut. The length of the screw from the ballnut corresponded to an estimated 2 degrees nose down attitude. The left side pitch trim control wheel was recovered in good condition; the right side was found fractured and jammed. The pitch trim index showed approximately 1.5 degrees nose down.

Slat position measurements on all the slats showed a 12 degree slat extension. Flap position measurements indicated that the flaps were within 2 degrees of the flap fully retracted position. The flaps/slats control box was recovered with the command handle jammed in position "2" but pulled out of the lock gate. The spoilers control box was recovered in good external condition with the handle found in the retract position and the auto ground spoilers not armed.

Both engines sustained damage consistent with impact and water immersion. Most of the fan blades were found broken just above the root or between the root and mid-span. The remaining portions of the fan blades were bent opposite to the direction of rotation. The engines were found split open in various locations. Examination of the rotating parts within each engine revealed evidence of rotational smearing, rubbing, and blade fractures that were consistent with the engines producing power at the time of impact. Neither engine exhibited any evidence of uncontained failures, case ruptures, or in-flight fires. All of the thrust reverser actuators that were found indicated that the thrust reversers on both engines were in the stowed position.

1.13 Medical and Pathological Information

The remains of the deceased occupants of the aeroplane were examined by the Forensic Science Laboratory (FSL) and Forensic Medicine of the General Directorate of Criminal Investigation, Ministry of the Interior, Bahrain to determine the cause of death. The total number of accident fatalities were (143), and the total number of remains sets examined were (144). One additional remains set was that of a fetus that appeared to have been delivered during the impact. Autopsy examinations and toxicological analysis determined that all the aeroplane occupants died of blunt force trauma. There was no evidence of any thermal injuries or carbon monoxide inhalation. However, traumatic injuries described would have precluded survival after the impact sequence.

Tissue and fluid samples for both pilots were transported to the FAA's Civil Aeromedical Institute (CAMI) for toxicology analysis. The CAMI laboratory performed its routine analysis for major drugs of abuse and prescription and over-the-counter medication, and the results were negative. The levels of Amphetamine and Methamphetamine were below threshold normally used to state the presence of the drugs, and were therefore reported as negative. The analysis indicated presence of Phenethylamine and Tyramine in the blood and tissue samples of both pilots, however the report noted that these are putrefaction products. Ethanol was detected in the tissue samples taken from the captain and the blood samples taken from the first officer (the CAMI laboratory noted that the ethanol found in these samples may be the result of post-mortem ethanol formation and not from the ingestion of ethanol). No ethanol was detected in the tissue samples taken from the first officer.

The captain indicated that no medication was presently being prescribed to him on his most recent medical examination record on file dated 3 July 2000. The First Officer indicated that no medication was presently being prescribed to him on his most recent medical examination record on file dated 26 July 2000.

1.14 Fire

Examination of the wreckage revealed no evidence of fire damage.

1.15 Survival Aspects

The accident was not survivable.

1.16 Tests and Research

1.16.1 Recovery Study

Although data were obtained during simulation and flight test activities, an additional study of GF-072's final trajectory was performed to determine the effect of certain variables on altitude loss during GPWS recovery. The variables that were examined were 1) the amount of the pilot's pitch-up command; 2) the time between GPWS warning and the pilot's reaction; and 3) the length of time of the pitch command input.

To determine the altitude lost during the recovery, the following scenarios were evaluated assuming the same conditions that existed with GF-072 when the GPWS warning began (altitude, pitch attitude, airspeed, descent rate, etc.). Calculations for the study indicated that the first GPWS alert were consistent with the altitude at which GPWS alerts started on the GF-072 FDR.

Table 7: Responses vs Altitudes Loss

Pitch-up Command	Response Time	Reaction Time	Altitude Loss
full-back stick ³⁵	1 second	0.25 seconds	300 feet
half-back stick	1 second	0.5 seconds	540 feet
half-back stick	2 seconds	1 second	670 feet

³⁵ Gulf Air procedures for response to a GPWS warning of "WHOOOP WHOOP PULL UP" stipulate that full back stick is to be employed and maintained and that during night conditions, the response should be immediate.

1.16.2 GF-072 Simulation

A series of simulations were organised on 26th and 27th September, 2000 at Airbus Industrie's facilities in Toulouse. An A320 fixed base engineering simulator was used in an attempt to simulate the approach, orbit, and go-around of GF-072 at BAH. The investigation committee was assisted by an Airbus chief test pilot and an Airbus flight test engineer. The simulator sessions also allowed investigative team members to fly the approach to Runway 12 and observe cockpit warnings during the overspeed and GPWS warnings. Several scenarios were flown.

During one of the simulator sessions, the 360° turn and go-around manoeuvres were performed to approximate the flight path and sequence and timing of events recorded on the FDR recovered from A40-EK. However, in these scenarios, the pilots were instructed to recover with full aft stick movement at the onset of the ground proximity warning system (GPWS) "whoop, whoop, pull up" alert. In this scenario, the simulator recovered with about 300 feet of altitude loss.

In the following scenario, a half-back stick command was applied instead of a full back stick command. The delay between the GPWS warning and the stick command was approximately 4 seconds. In this scenario, the simulator recovered with about 650 feet of altitude loss.

In another scenario a recovery was performed by the co-pilot after he verified that the captain took no action to recover from the GPWS "whoop, whoop, pull up" alert. The co-pilot depressed the priority button on his sidestick, announced his control override, and applied full aft side stick input. In this scenario, the simulator recovered with about 400 feet of altitude loss.

In another scenario the 360 degree turn was performed as described above. However, upon selection of TOGA power, the pilots were instructed to make no further control inputs. In this scenario, the simulator trimmed nose down in order to counter the nose up effect due to the thrust increase and to maintain +1.0G, which is the target when the stick is in the neutral position in normal law. The pitch remained positive and the aircraft climbed slowly. This is because the pitch was positive at the beginning of the manoeuvre. In normal law, +1.0G is maintained even in a pitch up attitude if the speed (and thus the vertical speed) is constant.

In the final scenario demonstrated, the 360 degree turn was initiated to match the flight path and sequence and timing of events recorded on the FDR recovered from A40-EK. However, instead of rolling the wings to level upon reaching a heading of about 211 degrees magnetic, the turn was continued at a moderate bank angle at the pilots discretion to align with Runway 12 and the approach and landing were continued. In these demonstrations the pilots were able to successfully land on runway 12 from the 360 degree turn. However, the pilot's noted that the approach was not stabilised and a short

amount of time was available to successfully complete the final approach and landing.

While in the simulator, the group examined the reach distance from the left seat to the emergency cancel pushbutton which is located on the ECAM control panel on the central pedestal. The group concurred that the reach distance to the emergency cancel pushbutton was not very far and reaching for it from the left seat was not likely to cause an inadvertent forward side stick deflection.

1.16.3 Flight Tests

On September 27, 2000 a flight demonstration was conducted to observe various conditions similar to the flight profile flown by GF-072 on August 23, 2000. The flight demonstration was conducted during daytime in visual meteorological conditions. The flight test was conducted in an Airbus A320 test aircraft.

The Airbus chief test pilot was the pilot-in-command of the test flight, which was coordinated by an Airbus test flight engineer. Other participants and observers were members from the Technical Investigation Committee including CAA Bahrain, NTSB, BEA representatives as well as Gulf Air, Airbus and FAA technical advisors. The co-pilot was alternatively the chairman of the Technical Investigation Committee and a Gulf Air A320 chief pilot.

Starting from level flight in a clean configuration, manoeuvres were performed to achieve a +0.5G nose down attitude which was held for about 10 seconds. All occupants on the test airplane noted that the +0.5G condition was highly noticeable.

A second test was performed to assess the sensation during the acceleration in climb with a constant 5 degrees nose-up pitch attitude at TOGA power. Non-flying occupants were instructed to close their eyes during the manoeuvre to simulate the absence of visual references. None of the occupants on the airplane reported to have perceived a significant increase of pitch.

Additional tests were performed to simulate the 360 degree orbit of the accident flight, yet continuing to turn at the end of the orbit (instead of rolling out). Several scenarios were flown, with a similar flaps sequence as in GF-072 or with full flaps being selected at the pilot's discretion. The pilots were able to align the airplane with the runway and perform low approaches down to 50 feet where a go-around was performed.

1.16.4 Over-water Light Visibility Study

To determine the surface lighting and overwater visibility conditions that might have existed at the time of the accident, investigation group members observed the area of the crash site several hours after sunset on 2 September 2000. The area was viewed from three different locations: the control tower located on the airport, a point along the shoreline southwest of the approach end of Runway 12, and a jetty southwest of the crash site. As on the night of the accident, there was no visible moon and ceiling and visibility were CAVOK at the times of the observations.

On the day of the study, the observers noted that no lights were visible along the horizon over the water looking to the north or northeast toward the crash site. The observers noted that a few scattered stars were visible in haze from the shoreline and jetty locations. No lights from ships, boats, or buoys were observed on the water from the locations.

1.16.5 Flap Lever Examination

FDR data and flap actuator measurements indicated a flap position of approximately 2 degrees at impact. However, examination of the flap lever after recovery of the wreckage revealed that the flap lever was in position "2" (which would be consistent with a flap position of 15 degrees). The flap lever and the power control unit, including both flap position pick-off units (which provides the FDR flap position data), were sent to the vendor for examination under control of the CAA. Electrical and mechanical tests of the position pick-off units revealed a flap position between one and two degrees.

1.16.6 Final Flight Path Study

A study of the final four minutes of the flight path of GF-072 was conducted to determine what would have been the external visual environment, as viewed from the cockpit, during this part of the accident flight. The co-ordinates of the accident flight path profile derived by the BEA laboratory from the aircraft's FDR-recordings were used in the study. The study also utilised information from the CVR, and was carried out in two parts:

Part 1: Tests using the Gulf Air A320 flight simulator of at Doha, Qatar. These took place on 17-18 May, 2001.

Two accredited representatives from the Technical Investigation Committee, and the Gulf Air A320 chief pilot, participated in the tests. The co-ordinates of the flight path of GF-072 were programmed into the flight management computer of the simulator. A number of runs simulating the final four minutes of the accident flight were carried out, using both day and night visual displays.

Part 2: Tests at Bahrain International Airport, using a helicopter made available by the Ministry of Interior of Bahrain. These flights took place between 10 and 20 May 2001

The helicopter was flown by an experienced training captain. An accredited representative, and the Chairman of the Recorders Group from the Technical Investigation Committee, participated in the tests. The test flights utilised the coordinates of the flight path of GF-072 to specify precisely the flight profiles flown by the helicopter. The purpose of the helicopter flights was solely to determine, as accurately as possible, the nature of the external visual information that would have been available to the flight crew of GF-072 on the last part of the accident flight.

Video recordings were made during the helicopter flights to facilitate subsequent analysis. The video cameras were positioned at the eye level of pilots. Although the field of view from a helicopter cockpit is greater than that of the A320, the field of view data derived by the BEA laboratory was used to assess the simulated A320 cockpit field of view. The exercises were carried out under dark night conditions, in which the light, visibility, and other environmental conditions were similar to those prevailing at the time of accident. The accident flight profile was also flown in daylight. To enable direct comparison for the purpose of analysis, a composite video presentation was prepared, which simultaneously showed the visual environment from the same aircraft positions in both daylight and night conditions.

The study focused on four segments of the flight path. These segments, and the consolidated observations from the simulator and helicopter flight reconstructions for each one, are outlined below:

Segment 1: A part of the first approach, from 1926:36 to 1927:25:

Observation: The lights of the runway flare path and the 'strobe lights' at the touchdown area on either side of the runway 12 would have been clearly visible from the A320 cockpit, and readily identifiable.

Segment 2: A portion of the 'orbit', from about 1927:45 to 1928:40:

Observation: There would have been very few external visual reference cues, until the lights of the coast came back into view at about 1928:40.

Segment 3: The last part of the 'orbit', where the first officer said to the captain, "Runway in sight ... three hundred" at 1928:47:

Observations:

- (i) The lights of the runway 12 flare path, and the 'strobe lights', would have been visible at about the 10 o'clock position, and would have been clearly identifiable from the cockpit positions of both pilots of

- GF-072.
- (ii) There was no other feature that would have appeared visually similar to runway 12.
 - (iii) A comparison of the pattern of lights and visual appearance of runway 12 and the causeway (Shaikh Isa bridge) was done. Given that the causeway is curved, with the presence of moving lights of road traffic and the colouration of such lights, it would have been very difficult to mistake the lights of the causeway for runway 12.

Segment 4: During the go-around, after overflying the runway at the commencement of the 'Master Warning' (1929:41), at which time the aircraft was heading towards the open sea:

Observation: The surface lights on the land mass would have disappeared from view, except for a few very distant lights to the right of the aircraft. At this point, there were no external visual cues ahead of the aircraft, which was heading into 'dark night' conditions of total blackness.

1.17 Organisational and Management Information

1.17.1 Gulf Air

Gulf Air started as the Gulf Aviation Company and was registered as a private shareholding company in Bahrain on 24 March 1950. In 1951, British Overseas Aircraft Corporation (BOAC) became a major shareholder and technical partner in Gulf Aviation. In 1973, the governments of Abu Dhabi, Bahrain, Oman, and Qatar purchased BOAC's shares and bought out the private founder-shareholders. In 1974, the Gulf Aviation Company became Gulf Air, the national carrier of the four states.

The position of president and chief executive (PCE) of Gulf Air is rotated every five years among the four owner countries. From 1 Jan 1996 to 31 Dec 2000, the position of PCE was filled by a nominee from Abu Dhabi. Beginning 1 Jan 2001, the position was filled by a nominee from Bahrain.

At the time of the GF-072 accident, Gulf Air had a fleet of 32 airplanes: 9 Boeing 767-300s, 5 Airbus A-340-300s, 12 Airbus A-320-200s, and 6 Airbus A-330-200s. At the time of the accident, Gulf Air's total number of employees was 5,067. This included 485 pilots: 264 captains and 221 first officers.

Gulf Air Flight Operations is overseen by the President and Chief Executive, who oversees the Vice President Operations. The approved organisational chart indicates that the Vice President Operations is responsible for the Senior Manager Flight Operations, Senior Manager Flight Training, Manager Flight Operations Quality, Senior Manager Flight Operations Support, and Manager Flight Safety.

The DGCAM Principal Operations Inspector (POI) for Gulf Air at the time of the accident indicated that there were numerous management changes involving Gulf Air operations since 1997 (not including fleet training managers or supervisors). The POI indicated that some of the management changes were requested by DGCAM because of its concern about the managers' ability to perform their duties or because of regulatory violations.

1.17.1.1 Gulf Air Flight Safety

Gulf Air pilots can report safety-related incidents to the Flight Safety Department by submitting an Air Safety Report (ASR). A report concerning a "go-around" would be an ASR. Gulf Air indicated that safety concerns may also be reported to the Fleet office by means of a Commander's Voyage Report, which is then forwarded to the Flight Safety Manager. Gulf Air indicated that ASRs received on the A320 fleet vary from 6 to 15 per month. The Flight Safety Manager reviews the reports and may then forward them for further investigation. The investigation report is later forwarded to the appropriate Fleet Office and could be published in the Flight Safety Bulletin. This Bulletin is issued three to four times a year. The Flight Safety Manager indicated that he was in the process of implementing a confidential reporting system for crewmembers at the time of the accident.

The Manager of Flight Safety has been in the Flight Safety Department since 1995. Between 1995 and 1998 he had some assistance, and thereafter, he has been the only person in the Flight Safety Department.

According to several DGCAM memos, Gulf Air did not have the required Accident Prevention and Flight Safety Program at the time of the accident. However, some aspects were in the process of being established. (see 1.17.8)

1.17.2 Gulf Air A320 Flight Crew Training

Gulf Air's flight crew training is conducted in Bahrain and Doha. The training facilities at Bahrain include the Safety and Survival School, and Technical Training Centre. The training facilities at Doha include one A-320 full flight simulator and CBT³⁶ Centre.

Gulf Air utilised an Ab-Initio pilot training program as a means of training cadet pilots who already held a commercial pilot license (CPL) to the standard required for first officer. There are two means of entry into the Gulf Air Ab-Initio pilot training program: (1) Gulf Air cadets who are graduates of the Gulf Air National Pilot Training Scheme holding a basic commercial pilot's licence with an instrument rating (CPL/IR), or (2) self-sponsored CPL/IR holders with varying levels of experience. According to Gulf Air records, the

³⁶ CBT = Computer Based Training

last intake of pilot trainees under the Gulf Air National Pilot Training Scheme was Class 96-02, which entered in early 1996. The last trainee who completed the program graduated in April 1998.

A cadet pilot is referred to as a second officer or trainee. Gulf Air's A320 Training Manual stated that the second officers were required to complete multiple simulator exercises and comprehensive line training. The training manual indicated that supervisory first officers are utilised during the early stages of a second officer's training by monitoring the operation and assisting in the training; however, the flight instructor is responsible for the second officer's progress at all times.

1.17.2.1 Recurrent Training and Proficiency Checks

According to the Gulf Air A320 Training Manual, pilots are required to undergo recurrent and proficiency checks in accordance with DGCAM's rules and regulations. The manual indicates that the training is normally accomplished every six months and requires two days. The recurrent training includes a four-hour simulator session designed to refresh the pilot's knowledge and handling abilities, and also includes TCAS and CFIT training.³⁷

1.17.2.2 Controlled Flight Into Terrain (CFIT) Training Programme

According to the Gulf Air Operations Training Manual, the CFIT training programme consists of the following:

- "Distribution of CFIT Operators Guide to each pilot; the reference material presented in this covers the history of CFIT, the causal factors involved in CFIT, and recommended procedures for pilots to reduce their risk of being involved in a CFIT accident or incident.
- A video produced by the CFIT Task Force will be required viewing for all pilots during recurrent SEP training at the Safety and Survival School (see Section 1.17.2.5); additionally, the video will be available for viewing in the HQ building, via the Fleet Office.
- All pilots will undergo specific CFIT training in the simulator, as part of their regular recurrent training. This will consist of a once-only CFIT Briefing presented by the Designated Examiner or simulator Instructor, followed by a CFIT Questionnaire to be completed by each pilot. Appropriate recurrent training exercises will be conducted in the simulator".

³⁷ TCAS stands for Traffic Collision and Avoidance System and CFIT stands for Controlled Flight Into Terrain.

The CFIT Operator's Guide (referred in the beginning of this section) describes the subject in detail, e.g.: Section 3 defines a CFIT accident as "an event where a mechanically normally functioning airplane is inadvertently flown into the ground, water or obstacle". It further highlights the value of the Ground Proximity Warning System (GPWS) in preventing CFIT accidents, and states, "The GPWS warning is normally the flight crew's last opportunity to avoid CFIT. Incidents and accidents have occurred because flight crews have failed to make timely and correct responses to the GPWS warnings". Section 4D describes GPWS warning escape manoeuvres in general and as applicable to each type of aircraft.

Gulf Air Manager Flight Training A-320 provided clarification on CFIT training:

- Once only CFIT briefing is conducted at the time of conversion training.
- Once only CFIT Questionnaire is completed by each pilot during the simulator part of initial CFIT training.
- CFIT simulator exercises are conducted during recurrent training.
- A320 simulator computes ground proximity and rate of descent parameters at all simulated airports. The terrain around Muscat airport provides the most suitable situation for ground proximity simulation.
- A memo dated 20 April 2000 issued to Designated Examiners/Simulator Instructors on Base Check reminder states, "each pilot should complete TCAS, CFIT and Windshear exercises...".
- The content of the CFIT simulator training is left to the discretion of the instructor; CFIT is a box to be ticked on the training records in case of recurrent training; there was no detailed syllabus for CFIT training.

The Airbus Industrie's A320 Normal Course Syllabus for pilots Part 142 includes "GPWS Pull-up Demonstration". Gulf Air Manager Flight Training A320 indicated that there was no similar syllabus for Gulf Air, and no requirement to execute such a demonstration for the A320 fleet.

1.17.2.3 Flap Over-speed Situations

Gulf Air indicated that it has no training for flap overspeed situations. Information on configuration changes is provided in the Gulf Air A320 Flight Crew Operating Manual (FCOM). (See Section 1.17.3.6).

1.17.2.4 Go-around

Gulf Air indicated that training for single-engine go-around procedures is conducted during initial, up-grade and recurrent training. Training for two-

engine go-around procedures is conducted during initial and up-grade training.

1.17.2.5 Safety Equipment Procedures (SEP) Training

Gulf Air conducts the SEP training at its Safety and Survival School in Bahrain. Gulf Air Operations Manual Training describes the scope of emergency training for each aircraft type, model and configuration in which the crewmembers are to fly, as appropriate to that crewmember's station.

1.17.3 Gulf Air A320 Procedures

1.17.3.1 Speed Restrictions during Descent

There is no specific speed restriction below 10,000 feet within the airspace (applicable to the flight path of the accident aircraft) under the control of Dammam, Saudi Arabia or Bahrain.

Gulf Air procedures for descent and approach specify: "A speed limit of 250 knots below 10,000 feet is the defaulted speed, in the managed speed descent profile. The flight crew may delete or modify it if necessary...". The aircraft are expected to check with the ATC if there are any speed restrictions before selecting speeds higher than 250 knots when below 10,000 feet.

According to Gulf Air SOPs the instrument approaches are to be made on the "managed speed modes".

1.17.3.2 Stabilised Approach

The A320 FCOM describes the requirements of stabilised approach as follows:

(a) Non-precision approach (Approach Speed Technique):

"The standard speed technique is to make a stabilised approach using AP/FD and A/THR. The aircraft intercepts the final descent path in the landing configuration and at VAPP. For this purpose, the flight crew should insert VAPP as a speed constraint at the FAF. In all cases, the crew should use managed speed. At 1000 feet above runway elevation it should be stabilised on the final descent path in the landing configuration with thrust above idle."

(b) Visual Approach:

"Perform the approach on a nominal 3 degree glide slope using visual references. Approach to be stabilised by 500 feet AGL on the correct approach path, in the landing configuration at VAPP."

- (c) If the aircraft is not stabilised:

“Flight crew should consider making a go-around if the aircraft is not stabilised on the approach path in landing configuration at 1000 feet (in instrument conditions) or at 500 feet (in visual conditions), (or as restricted by airline policy/regulations).”

Gulf Air Operations Information Bulletin No. 05/2000 issued on 28 March 2000 states:

“All approaches shall be stabilised by 1000 feet Height Above Touchdown (HAT) in Instrument Meteorological Conditions (IMC) and by 500 feet HAT in Visual Meteorological Conditions (VMC).”

1.17.3.3 Circling

Gulf Air procedures for a circling approach state that the minimum circling height is the greater of:

- the minimum specified under “Circle-to-land” on the Jeppesen approach chart; or
- the Company circling minimum of : 1000 ft. AAL³⁸

The minimum circling height according to the Jeppesen approach chart was 600 feet.

1.17.3.4 Go-Around

The Standard Operating Procedures section of the Gulf Air A320 FCOM contains go-around procedures for both with and without flight director guidance.

For a go-around without flight director, the procedure calls for the following actions (with the first three actions to be applied simultaneously):

THRUST LEVERS.....TOGA
 ANNOUNCE.....“GO AROUND – FLAPS”
 ROTATION.....15° OF PITCH
Rotate to 12.5° if one engine is out.
 FLAPS.....RETRACT ONE STEP
Announce “FLAPS” when indicated.
 ANNOUNCE.....“POSITIVE CLIMB”
 ORDER.....“GEAR UP”

³⁸ AAL = Above Aerodrome Level

L/G UP.....SELECT
 CONFIRM/ANNOUNCE.....“GEAR UP – FLAPS”

For a go-around *with* flight director, the same procedures as listed above are stipulated, except for the following procedure for pitch:

ROTATION.....PERFORM

- Rotate the aircraft to get a positive rate of climb and establish the required pitch attitude as directed by the SRS³⁹ pitch command bar.
- Check and announce the FMA: TOGA (or MAN TOGA), SRS, GA TRK
- Go-around without Flight Director – continued procedure.

- At GA thrust reduction altitude:
Disregard CLB or LRV CLB flashing on FMA⁴⁰.
- At go around acceleration attitude:
(The acceleration altitude at Bahrain is 1,500 feet AAL)
For go around with no FD, thrust reduction and acceleration altitude should be the same.
 - Select speed target to green dot.
 - Adjust aircraft attitude to 10/12 degrees.
 - Select thrust levers to CL detent and activate the A/THR.
 - Set FD to ON. (Basic mode HDG V/S or TRK FPA engages).
 - Select appropriate mode.
 - Check FMA.
 - Retract the flaps at appropriate speeds (see Flap Retraction Schedule).
 - Monitor go around routing and first cleared altitude.

Note: If thrust levers are set to CL detent at thrust altitude, a thrust reduction may occur if the current speed is above the speed target.

1.17.3.5 Flap Retraction Schedule

The flap retraction schedule (F⁴¹, S⁴² and Green Dot Speeds) are computed by the FMGC based on current aircraft weight. During the go-around procedure, the selection of TOGA power automatically transfers this data to the captain and First Officer’s speed tape on their PFD. This is

³⁹ SRS = Speed Reference System

⁴⁰ Disregard climb or lever climb flashing on Flight Mode Annunciator.

⁴¹ F = Minimum speed at which the flaps may be retracted at takeoff/go-around.

⁴² S = Minimum speed at which the slats may be retracted at takeoff/go-around

displayed as 'F', 'S' and Green Dot (o)⁴³ on the speed tape. This data is also displayed on the 'PERF'⁴⁴ page of the MCDU⁴⁵.

When flaps/slats are in configuration 3 or 2, the minimum flap retraction speed (as described above) is displayed in green along the speed scale on the captain's and first officer's PFD.

1.17.3.6 Over-speed Situations

The Abnormal and Emergency section of the Gulf Air A320 Flight Crew Operating Manual (FCOM) provides V_{MO} and V_{FE} airspeeds. The Supplementary Techniques section of the FCOM provides pilot procedures and airplane response as airspeeds approach or exceed V_{MO} . No procedures are included in the Gulf Air or Airbus A320 FCOMs for flap overspeed situations (see Section 1.17.2.3).

1.17.3.7 GPWS Alert

The Abnormal and Emergency section of the Gulf Air A320 FCOM contains procedures for response to GPWS alerts. For night or instrument meteorological conditions, the procedure states that flight crews are to "apply the procedure immediately; do not delay reaction for diagnosis." When WHOOP WHOOP PULL UP OR TERRAIN WHOOP WHOOP PULL UP sounds, the procedure calls for simultaneously doing the following:

AUTOPILOT.....OFF
 PITCHPULL UP (*Pull up to full back stick and maintain*)
 THRUST LEVERS.....TOGA

The FCOM states that GPWS response procedures are "memory items" that are to be applied without referring to manuals or checklists.

1.17.4 Flight Crew Decision-making and Task Sharing

The "Abnormal and Emergency" section of Gulf Air's A320 FCOM specifies task sharing between the two pilots that applies to all procedures. The pilot flying (PF) is to remain flying throughout the procedure, and is responsible for

- thrust levers,
- control of flight path and airspeed,
- aircraft configuration (request configuration change),

⁴³ Green Dot (o) = Engine out operation speed in clean configuration – best lift to drag ratio speed, corresponds to the final take-off speed.

⁴⁴ PERF = Performance

⁴⁵ MCDU = Multi Control Display Unit

- navigation, and
- communication⁴⁶

The pilot not-flying is responsible for

- reading aloud the ECAM and checklists and
- executing required actions or actions requested by the PF

1.17.4.1 Standard Calls

The A320 FCOM describes the standard calls in respect of the Flight Parameters as follows:

“PNF will make call-outs for the following conditions during final approach. Attitude callouts also to be made through to landing.

- “SPEED” when speed becomes less than $V_{app} - 5$ or more than speed target +10.
- “SINK RATE” when V/S is greater than 1000 ft/min.
- “BANK” when bank angle becomes greater than 7 degrees.
- “PITCH” when pitch attitude becomes lower than -2.5 degrees or higher than +10 degrees.
- “LOC” or “GLIDE” when either localiser or glide slope deviation is one dot.
- “COURSE” when greater than 1/2 dot (VOR) or 5 degrees (ADF).
- “___ FT HIGH (LOW)” at altitude check points.”

1.17.4.2 Crew Resource Management Program

Under the Sultanate of Oman Civil Aviation Regulations (CARs), Gulf Air has had a requirement for a crew resource management (CRM) program since June 1999.

The Acting Manager for Human Factors for Gulf Air assumed his duties in December 1999. Included in his duties is establishment and management of a CRM program for Gulf Air. He described the CRM training initiative at that time as “non-existent”. He stated that Gulf Air had an informal CRM program from about 1992 until late 1996 or early 1997 that was developed in-house. It was not used thereafter. He suggested that the previous Manager

⁴⁶ Under the “Normal” section of the FCOM, the PNF is responsible for communication.

of Human Factors resigned because of continued frustration trying to get the CRM program organised and authorised.

According to the Acting Manager for Human Factors, a company was selected in January 2000 to develop a CRM program. Original plans were to initiate facilitator training in February and March 2000 and line pilot initial training in May 2000. However, contract negotiations have delayed the effort. According to Gulf Air, initial CRM courses for its pilots commenced on 1 November 2000. The manager indicated that cultural aspects of the region would be addressed in the CRM training.

1.17.5 Crew Pairing

Flight crew who have recently converted to the aircraft type, or have recently been upgraded to Commander, will be restricted to which crew members they may operate with and their roster will be marked with a blue line. The blue line period extended from the initial line check until a minimum of 40 sectors have been completed in the respective crew category, on Gulf Air operations. This was changed to “20 Sectors (for newly promoted Commanders) and 10 Sectors (for pilots transferring from another fleet)” from 15 August 1999. Gulf Air indicated that this was in accordance with the minimum requirements specified in the regulations.

1.17.6 Gulf Air Accident and Incident History

On 23rd September 1983, a Gulf Air Boeing 737 was destroyed as the result of an in-flight detonation of an explosive or incendiary device near the airplane’s forward cargo door. Fire and Smoke produced from the explosion entered the control cabin and passenger compartment and resulted in the incapacitation of the flight crew to the extent that control of the airplane became impossible. The aeroplane was destroyed on impact and all of the 112 persons on board were killed.

In March 1997, a Gulf Air A320 was involved in an accident in which the airplane deviated off the right side of Runway 31 at Abu Dhabi during takeoff. Although there were no fatalities, 3 of the 107 passengers and 1 of the 8 crewmembers sustained serious injuries and the airplane suffered major damage. Gulf Air did not provide details of the accident investigation findings to its A320 pilots.

On 18 August 1999, a Gulf Air A320 (A40-EN) was involved in a hail-storm incident. After departure from Dubai, during climb to the cleared altitude of FL190, the aircraft encountered hail storm and both windscreens shattered. The aircraft diverted to Abu Dhabi and executed an autoland. Both crew confirmed weather returns from the radar were green on their track, and no significant weather was ever reported to the crew. Despite a request from DGCAM early on the morning of 19 August 1999, the CVR was not secured, and the recording information was subsequently lost.

On 27 January 2000, Gulf Air flight A320 (A40-EI), on a flight GF-973 from Abu Dhabi to Amman, experienced a depressurisation incident. The first officer from GF-072 was then the second officer on flight GF-973 (receiving line training in the right hand seat) and was being evaluated by a supervisory first officer, who was seated in the observer's seat. The aircraft apparently struck debris during takeoff from Abu Dhabi and received damage that prevented proper pressurisation on climb-out. A Gulf Air board of inquiry into the incident cited the crew's "poor airmanship and awareness" as a factor contributing to the incident. The board was critical of the crew, particularly the captain and the first officer (of GF-973). However, as a result of the incident, the then second officer of GF-973 (i.e. the first officer of GF-072) was ordered to complete two days of CBT systems training, and four hours of simulator training to "help improve cockpit awareness, task sharing, ECAM handling and decision making."

GPWS incidents on 3 January 2000 and 22 January 2000 were on A340 aircraft. Initial GPWS activation incident was related to pilot's deviation from approach profile, pilot misunderstanding of briefing material, and false warning.

1.17.7 Gulf Air Violations/Sanctions/Misc

A review of about three years preceding the accident indicates that there have been a number of violations/cases of non-compliance with the DGCAM regulations in areas such as:

- Flight operations
- Cabin safety
- Flight and duty time and rest period limitations
- Minimum Equipment List(s)
- Emergency equipment
- Flight training
- Record keeping
- Unapproved changes to various programmes

Examples of sanctions

- Revocation of ETOPs time.
- Revocation of three-engine ferry flight.
- Crew licence suspensions

1.17.8 Oversight of Gulf Air

The regulatory oversight of Gulf Air is the responsibility of the Directorate General of Civil Aviation and Meteorology (DGCAM). The DGCAM is organised under the Ministry of Communications for the Sultanate of Oman. The DGCAM is also responsible for analysing accidents and incidents involving Gulf Air.

The DGCAM Principal Operations Inspector (POI) for Gulf Air at the time of the accident worked as an inspector and manager for Transport Canada for 19 years before coming to Bahrain in 1997. He has been rated on the A310, A320, A330, and A340. When the POI initially began his assignment, he monitored the pilot training programs as a part of planned surveillance. He stated that he also participated in airworthiness issues involving Gulf Air. In October 2000, he resigned his assignment and has since returned to Canada.

The DGCAM had approved a 3-year implementation program for Gulf Air to adopt CAR 121 requirements with a target date of December 2000. The grace period was designed to allow Gulf Air sufficient time to develop new procedures and amend existing manuals. Some of the issues on this subject are still being addressed.

ICAO has scheduled a Safety Oversight Audit at Oman in April 2001 under the Universal Safety Oversight Programme.

1.17.8.1 DGCAM Oman Safety Oversight

A review of correspondence between DGCAM and Gulf Air revealed numerous letters citing lack of compliance with CARs. The records in respect of some letters requiring/requesting action indicate the following:

- (a) the company could not locate response(s) having been returned to the DGCAM, nor were there records of these requested actions having been addressed by the company;
- (b) letters were actioned internally by the company in some way, but no reply to the DGCAM could be located;
- (c) action was taken on certain issues, however, it was deemed unacceptable corrective action by DGCAM and to be re-addressed by the company; some such items involved lengthy time frames in correspondence;

The POI at that time, stated that Gulf Air did not meet nor have a number of regulatory required programmes; such as:

- CRM
- quality management
- safety awareness
- surface contamination complete with required crew training,
- crew records for flight duty and rest time limitation.

A number of issues raised by the POI are still in the process of resolution.

The records indicate the following:

- the DGCAM raised a number of regulatory and operational concerns to the Board of Directors of Gulf Air;
- the Board appointed a technical committee comprising of the DGCAs of owner States to advise on the remedial actions in September 1999; and
- the Board agreed on the technical committee recommendations that stipulated a “total co-operation between the DGCAM and Gulf Air management to achieve/maintain a high level of safety” in December 1999.

1.17.9 ICAO Special Evaluation

In response to a request by the DGCAM, a consultant from the International Civil Aviation Organisation (ICAO) conducted a special evaluation to review the level of Gulf Air’s compliance with Civil Aviation Regulations. The special evaluation was done from 17 October through 21 October 1998. During this period, DGCAM personnel and Gulf Air Flight Operations managers were interviewed and an A320 cockpit enroute check was conducted. Numerous correspondence documents as well as circumstances of recent incidents regarding non-compliance of regulatory requirements were reviewed. The following are two of the conclusions from the above review:

- delayed or non-compliance with regulatory requirements,
- Gulf Air’s opposition to CAR 121.

Based on this review the ICAO letter to DGCAM dated 25 October 1998 stated that, except for isolated incidents, most infractions could be traced to inadequate supervisory oversight rather than deliberate disregard for the regulations. However, the regulatory compliance level by Gulf Air Flight Operations was assessed as satisfactory.

1.17.10 Lufthansa Consulting Group's Assistance

The Board of Directors for Gulf Air decided on 7 December 1999 to employ the services of a consultant to assist in upgrading the Gulf Air operating guidance and documentation. After reviewing several proposals, the Board agreed to appoint Lufthansa Consulting Group for this purpose. The Lufthansa Consulting Group was appointed in June 2000.

1.17.11 Gulf Air Post-accident Safety Initiatives

1.17.11.1 Go-Around Procedures

On 7 November 2000, Gulf Air's Acting Manager Fleet Training A320 has issued a memo to all A320 training captains regarding go-around procedures. The memo directed that all pilots are to practice two-engine go-around procedures during Simulator Continuation Training and under the following conditions:

1. Flight Directors 'ON'
2. Flight Directors 'OFF'
3. Track/FPA⁴⁷ selected
4. Go-around ATC clearances other than standard published go-around procedures.

Note : Ab-initio and Upgrade Training syllabi include single and two-engine go-around training. However, the Continuation Training Syllabus included single engine go-around training, but not two-engine go-around training. This memo was issued to enhance the Continuation Training Programme.

1.17.11.2 Ab-Initio Training

Following the accident, Gulf Air suspended additional hires of ab-initio pilots until further notice. Gulf Air also suspended its Ab-Initio Simulator Training program, pending a full review, in order to assess it against industry standards and recent changes to regulatory requirements. Gulf Air indicated that these actions were prompted by issues arising from the GF-072 accident and by a recent DGCAM Oman Operational Directive specifying new requirements for simulator training. According to Gulf Air, the intent of the directive is to increase the proportion of simulator training that is conducted with a normal crew complement (i.e., a captain in the left seat and a first officer in the right seat), rather than pilot trainees being paired with another trainee of the same level. Gulf Air indicated that the directive is also intended to ensure that a trainee undergoes a greater share of training in his proper seat and a more realistic operating crew environment.

⁴⁷ When selected, Track/Flight Path Angle mode provides a display of the airplane's track and its flight path vector on the primary flight display.

1.17.11.3 Cockpit Crew Resource Management (CRM) Training

Gulf Air indicated that the initial CRM Training course was already under development at the time of the GF-072 accident. Initial CRM courses for Gulf Air pilots commenced on 1 November 2000. Gulf Air's intention is to complete the Initial CRM training for all Gulf Air pilots no later than June 2001.

1.17.11.4 Command Upgrade Training

Gulf Air modified its Command Line Training program to include an additional final phase of 20 sectors (minimum) with a "normal" crew complement consisting of the upgrade trainee in the left seat, an instructor or examiner in the jump seat, and a line first officer in the right seat. Gulf Air indicated that this training process is intended to allow an assessment of the trainee commander's ability to operate satisfactorily with a first officer during actual line operations, with the benefit of the guidance and support available from the instructor. DGCAM Oman has approved these modifications to the training program.

1.17.11.5 Gulf Air A320 Fleet Instructions

Gulf Air has issued A320 Fleet Instructions on the following subjects (attached as Appendix D):

- (a) **Standard Operating Procedures (SOP)**, A320 Fleet Instruction No. 14/2000 (Re-issue No. 1) dated 4 October 2000:
- (1) Speed Control Below FL100 or 10,000ft. amsl.
 - (2) Stabilised Approach Criteria
 - (3) Visual Manoeuvring in the Vicinity of an Airport

The Fleet Instruction assures the pilots as follows:

"All pilots are further assured that no disciplinary action whatsoever will be taken against any crew that elects to carry out a go-around for safety-related reasons, including inability, for whatever reason, to stabilise an approach by the applicable minimum height."

- (b) **Flight Director Usage During Non-precision Approach**, A320 Fleet Instruction No. 18/2000 dated 4 February 2001.

1.17.11.6 Recurrent Training and Checking

Gulf Air is implementing enhanced training on go-around procedures for all A320 pilots during their recurrent training sessions. Gulf Air indicated that the training is intended to: 1) cover new company requirements involving speed control, stabilised approaches, and visual manoeuvring that were published in the Fleet Instructions Numbers 14/2000 and 18/2000 (refer to Section 1.17.11.5 and Appendix D); and 2) practice go-around procedures with both engines operating under the following circumstances:

- Flight directors on and off;
- Track/FPA (Flight Path Angle) selected;
- Go-arounds conducted in accordance with ATC clearances that differ from published procedures.

1.17.11.7 Instructor Selection and Training

Gulf Air suspended all instructor appointments on 28 September 2000 in order to allow a review and enhance the instructor selection criteria and procedures in order to comply with the DGCAM operations directive⁴⁸.

1.17.11.8 Pilot Selection

All first officers eligible for upgrade will be required to undergo screening tests to assess their suitability for command, including screening tests conducted by an accredited aviation psychology organisation. All ab-initio second officers and direct-entry pilots undergo screening tests conducted by an accredited aviation psychology organisation.

1.17.11.9 Modification to A320 Automatic Flight System (AFS) Automatic Return of Flight Director (FD) Bars at Go-Around Initiation

Gulf Air is in the process of implementing an Airbus Industrie modification to the A320 Automatic Flight System. This modification will automatically re-instate the FD bars at go-around initiation. The FD bars will automatically display SRS instructions, and level wings on the track at the time of initiating "Go-Around", and will return in 'HDG/v/s' mode.

1.18 Additional Information

1.18.1 Spatial Disorientation Study

The above study was undertaken at the US Naval Aerospace Medical Research Laboratory, Pensacola, Florida, USA. The scope of the study addressed the lateral and vertical acceleration and estimated perceived pitch aspects. The perceived pitch experienced by occupants of the airplane was estimated from a computation based on the net gravitational force.

⁴⁸ The draft Operations Directive was initiated to all operators on 5 June 2000 for consultation purposes. The final Operations Directive was issued on 18 September 2000.

1.18.2 Flight Safety Foundation Study of Controlled Flight Into Terrain (CFIT) Accidents

In the early 1990s, the Flight Safety Foundation (FSF) created a CFIT Awareness Task Force to promote general CFIT awareness, which evolved into an international Approach and Landing Accident (ALA) Reduction Task Force.

Several factors that frequently appeared in CFIT accident reports included night and limited visibility conditions, terrain not observed until just before impact, loss of horizontal or vertical situational awareness, unfamiliarity with terrain and obstructions, flight crew uncertainty about altitudes and distance from the airport, navigational equipment improperly set or misinterpreted by the flight crew, and an unstabilised approach.

The FSF, using statistics from the UK CAA global database, found that 287 of the 621 fatal CFIT accidents world-wide between 1980 and 1986 occurred during the approach and landing phase of flight. A study commissioned by UK CAA for FSF⁴⁹ determined the 5 most frequently identified primary causal factors as follows:

1. Omission of action/inappropriate action - generally referred to the crew continuing descent below the specified minimum without visual reference or when visual cues were lost .
2. Lack of positional awareness in the air - generally involved a lack of appreciation of the aircraft's proximity to high ground.
3. Flight handling.
4. "Press-on-itis,". It is referred to a flight crew's "determination to get a destination or persistence in a situation when that action is unwise."
5. Poor professional judgement/airmanship.

The study also determined that all five primary causal factors involved crewmembers. On the basis of the results of this study, the FSF Approach and Landing Accident (ALA) Reduction Task Force issued nine conclusions and recommended several initiatives to support each conclusion⁵⁰.

⁴⁹ "A Study of Fatal Approach-and-Landing Accidents Worldwide, 1980-1996," Flight Safety Digest, February-March 1998. This study was also included as part of a special FSF report, "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-Landing and Controlled-Flight-Into-Terrain Accidents," Flight Safety Digest, November-December 1998 and January-February 1999.

⁵⁰ These conclusions and recommendations were presented at the FSF's Corporate Aviation Safety Seminar, held from 5 to 7 May 1998.