3 CONCLUSIONS

3.1 Findings

3.1.1 Flight Crew

1. The flight crew was licensed and qualified for the flight in accordance with applicable regulations.
2. The flight crew held valid medical certificates and was medically fit to operate the flight.
3. Although atherosclerosis was found (minor atherosclerosis for the Captain and extensive atherosclerosis for the First Officer), the Hellenic Air Force Aviation Medical Centre estimated that brain hypoxia was the dominant and determinant cause of incapacitation.
4. The flight crew was adequately rested and their flight and duty times were in compliance with Cyprus DCA and Operator requirements.
5. During the Preflight procedure, the Before Start and the After Takeoff checklists completion, the flight crew did not recognize and correct the incorrect position of the pressurization mode selector (MAN position instead of AUTO).
6. The green light indication that the pressurization mode selector was in MAN (manual) position should have been perceived by the flight crew during preflight, takeoff, and climb.
7. At an aircraft altitude of 12 040 ft and at a cabin pressure that corresponds to an altitude of 10 000 ft, about 5 minutes after takeoff, the Cabin Altitude Warning horn sounded.
8. The initial actions by the flight crew to disconnect the autopilot, to retard and then again advance the throttles, indicated that it interpreted the warning horn as a Takeoff Configuration Warning.
9. The incorrect interpretation of the reason for the warning horn indicated that the flight crew was not aware of the inadequate pressurization of the aircraft.
10. There were numerous remarks in the last five years by training and check pilots on file for the First Officer referring to checklist discipline and procedural (SOP) difficulties.
11. The flight crew contacted the company Operations Centre Dispatcher and referred to a Takeoff Configuration Warning horn and the Equipment Cooling lights.
12. Communications between the flight crew and the company Operations Centre Dispatcher were not recorded; nor was there a regulatory requirement to record such communications.

13. At an aircraft altitude of 17 000 to 18 000 ft, the Master Caution was activated and was not canceled for 53 seconds. The reason for its activation may have been either the inadequate cooling of the Equipment or the deployment of the oxygen masks in the cabin. The above activation for either of the above two reasons does not permit identification of the other reason. Independently of the Master Caution indication, there are separate indications for both malfunctions on the overhead panel.

14. The flight crew possibly identified the reason for the Master Caution to be only the inadequate cooling of the Equipment that was indicated on the overhead panel, and did not identify the second reason for its activation, i.e., passenger oxygen masks deployment, that was later also indicated on the overhead panel. The crew became preoccupied with the Equipment Cooling fan situation and did not detect the problem with the pressurization system.

15. The workload in the cockpit during the climb was already high and was exacerbated by the loud warning horn that the flight crew did not cancel.

16. The remarks and observations by training pilots and check pilots with respect to the First Officer's performance explained the omissions of the flight crew in it's performance of the Preflight procedures, the Before Start and the After Takeoff checklists, as well as the non-identification of the warnings and reasons for the activations of the warnings on the flight deck during the climb to cruise.

17. Before hypoxia began to affect the flight crew's performance, inadequate CRM contributed to the failure to diagnose the pressurization problem.

18. The flight crew probably lost useful consciousness as a result of hypoxia some time after their last radio communication on the company frequency at 06:20:21 h, approximately 13 minutes after takeoff.

19. Histological examinations revealed the presence of recent myocardial ischemia in both pilots, which according to the Hellenic Air Force Aviation Medical Centre (KAI) was likely due to the extended exposure to hypoxia.

20. The toxicology test measured ethanol (34 mg/dl or 0.034 % weight/volume) in the specimen of the First Officer. The toxicological report stated that in view of the conditions, the finding may have resulted from post-mortem ethanol production.

3.1.2 Cabin Crew

1. The cabin crew members were trained and qualified in accordance with existing regulations.

2. The cabin crew members were adequately rested and their duty times were in accordance with existing regulations.

3. After the deployment of the oxygen masks in the cabin, the cabin crew members would have expected initiation of a descent or at least leveling-off of the aircraft.

4. It could not be determined what actions were taken by the cabin crew members after deployment of the oxygen masks in the cabin, nor whether any of the cabin crew members attempted to contact the flight crew or enter the flight deck after passenger oxygen masks deployment.

5. Shortly before flameout of the left engine, a member of the cabin crew was observed by an F-16 pilot to enter the flight deck, to sit at the captain's seat, and to attempt to gain control of the aircraft.

6. The above cabin crew member held a Commercial Pilot License.

3.1.3 Aircraft

1. The aircraft held a valid Certificate of Airworthiness.

2. The mass and centre of gravity of the aircraft were within prescribed limits.

3. The aircraft had been supplied with the required amount of fuel. Fuel was not a factor in this accident.

4. No deferred maintenance defects had been recorded.

5. Data retrieved from the non-volatile memory (NVM) of the No. 2 cabin pressurization controller for at least the last 42 flights revealed a pressurization leak or insufficient inflow of air for reasons that could not be determined.

6. There were nine write-ups related to the Equipment Cooling system in the Aircraft Technical Log from 9 June to 13 August 2005.

7. The maintenance actions performed in the early morning hours of the day of the accident comprised:

   - A visual inspection of the rear right door (R2), no defects were found;
   - A pressurization test, no leakage was found.

8. The record of the maintenance actions in the Aircraft Technical Log was incomplete.

9. After the pressurization test, the pressurization mode selector was not selected to AUTO. Although not a formal omission, it would have been prudent to position the pressurization mode selector back to AUTO.

10. The first recorded data of the accident flight on the non-volatile memory (NVM) chip in the cabin pressurization controller was at 10 000 ft cabin altitude (12 040 ft aircraft altitude). The data showed that the pressurization system was operating in the manual mode.

11. The aircraft departed the holding pattern and started descending from FL340 when the left engine flamed out from fuel depletion. The right engine also flamed out from fuel depletion shortly before impact.

12. The aircraft was structurally intact before impact.

13. The aircraft was destroyed by the impact.

3.1.4 Manufacturer

1. The description in the Boeing AMM for the procedure for the pressurization check (under the heading ***"Put the Airplane Back to its Initial Condition"***) was vague. It did not specify an action item that the pressurization mode selector be returned to the AUTO position after the pressurization check.

2. The manufacturer's Preflight procedure and checklists (Before Start and After Takeoff) for checking and verifying the position of controls on the pressurization panel were not consistent with good Human Factors principles and were insufficient to guard against omissions by flight crews.

3. The manufacturer's procedures should have contained enough redundancy to ensure that the pressurization system was properly configured for flight. Because the position of the pressurization mode selector was critical for pressurization, the specific action should have been explicitly listed in the checklists referring to the pressurization system (Before Start and After Takeoff).

4. The use of the same aural warning to signify two different situations (Takeoff Configuration and Cabin Altitude) was not consistent with good Human Factors principles.

5. Over the past several years, numerous incidents had been reported involving confusion between the Takeoff Configuration Warning and Cabin Altitude Warning on the Boeing 737 and NASA's ASRS office had alerted the manufacturer and the aviation industry..

6. Numerous incidents had been reported world-wide involving cabin pressurization problems on the Boeing 737. A number of remedial actions had been taken by the manufacturer since 2000, but the measures taken had been inadequate and ineffective in preventing further similar incidents and accidents.

3.1.5 ATC

1. The air traffic controllers in Nicosia and Athens, who handled flight HCY 522 were properly licensed and properly qualified.
2. The ATC facilities in Nicosia and Athens were appropriately staffed and the communication equipment operated per regulations. There were no communications or navigational aid abnormalities.
3. Nicosia ACC informed by telephone Athinai ACC that flight HCY 522 was not responding to its radio calls while approaching EVENO, but did not use the formal ICAO procedure (Doc 4444) for the two-way Radio Communication Failure (RCF).
4. One minute before the flight entered the Athinai FIR, the Athinai ACC controller "accepted" the flight, but did not seek communication with it when it entered the FIR and failed to contact Athinai ACC as prescribed.
5. The above mentioned actions by Nicosia and Athinai ACCs did not contribute to the formation of events of the accident.

3.1.6 EASA, JAA and ICAO

1. Despite several EASA, JAA and ICAO audit and follow up audit findings performed on Cyprus DCA, there was no enforcement of implementation of action plans in order to meet its international obligations in the shortest possible time.

3.1.7 Flight HCY522

1. When the flight HCY522 was intercepted by the F-16s, the F-16 lead pilot reported that there was no visible damage to the Boeing 737 aircraft, that the Captain's seat was vacant, the person in the First Officer's seat was not wearing an oxygen mask and was slumped over the controls, and some seated passengers in the cabin were observed wearing oxygen masks.
2. Shortly before the aircraft started descending, the F-16 pilot reported that a man wearing clothing of a specific color entered the cockpit and sat down in the Captain's vacant seat. He did not appear to be wearing an oxygen mask. He seemed to make efforts to gain control of the aircraft. It was determined that this man was a cabin attendant who held a Commercial Pilot License.
3. When the left engine flamed out due to fuel depletion, the aircraft exited the holding pattern and started a left descending turn, and followed an uneven flight path of fluctuating speeds and altitudes. Shortly before impact, the right engine also flamed out from fuel depletion.
4. The cabin crew member in the cockpit attempted to transmit a MAYDAY message, which was recorded on the CVR. However, the MAYDAY calls

were not transmitted over the VHF radio because the microphone key, as shown by the FDR, was not pressed. The performance of the cabin crew member was very likely impaired by the hypoxic and stressful conditions.

5. Three of the four portable oxygen cylinders on board the aircraft had most likely been used.

6. The cabin altitude was calculated to have been about 24 000 ft, while the aircraft was at a cruise level of 34 000 ft (FL340).

7. The duration (30 minutes) of the CVR installed on the aircraft was insufficient to provide key information that would have clarified the chain of events during the climb phase of the flight. The CVR stopped recording when the engines flamed out.

3.1.8 Operator

1. The After Takeoff checklist section referring to the pressurization system in the Operator's QRH had not been updated according to the latest Boeing revision.

2. The manuals, procedures, and training of the Operator, and to a large extent of the international aviation industry, did not address the actions required of cabin crew members when the passenger oxygen masks have deployed in the cabin and, during climb to cruise, the aircraft has not start descending or at least leveled off, and no relevant announcement has been made from the flight deck.

3. The absence of applied hypoxia training at the Operator, and to a large extent at other airlines, for airline transport pilots increased the risk of accidents because of the insidious nature of incapacitation during climb to cruising altitude as a result of pressurization anomalies or gradual loss of pressurization.

4. There were organizational safety deficiencies within the Operator's management structure and safety culture as evidenced by diachronic findings in the audits prior to the accident, including:

   a) Inadequate Quality System;

   b) Inadequate Operational Management control;

   c) Inadequate Quality and Operations Manual:

   d) Cases of non-attendance of management personnel at quarterly management quality review meeting, as required;

   e) Organization, management, and associated operational supervision not properly matched to the scale and scope of operations;

   f) Inadequate monitoring of pilot certificates and training;

g) Insufficient involvement of management pilots in managerial duties, due to lack of time;

h) Incompletely updated training and duty records;

i) Lack of updating of some manuals and in part not fully in compliance with regulations;

j) Key management personnel at time performing the work of two positions;

k) Periods of vacant key management positions;

l) Inadequate remedial actions on audit findings, including level one findings, which could cause suspension of the AOC.

3.1.9 Cyprus DCA

1. Organizational safety related deficiencies existed within the Cyprus DCA from at least 1999 and continued to the time of the accident, although some corrective actions were exercised since 2003. These deficiencies prevented the DCA from carrying out its safety oversight obligations within Cyprus, as evidenced by findings in previous audits, including:

   a) Lack of resources and qualified personnel, and inability to adequately perform the safety oversight activities as required by ICAO;

   b) Over-reliance on the UK CAA;

   c) Inadequate on-the-job training for Cypriot inspectors to assume the duties for the DCA;

   d) Lack of DCA internal expertise to assess the effectiveness or the technical aspects of the UK CAA inspections and the work performed;

   e) Ineffectiveness of the DCA in bringing the Cyprus Civil Aviation legislation and regulations into compliance with the international requirements (ICAO Standards and Recommended Practices);

   f) Inadequacy of the structure of the DCA to support safety oversight on current and future operations under the present circumstances;

   g) No risk management process;

   h) Non-exploitation by the DCA of the full scope of contracted services from the UK CAA, related to on-the-job training of Cyprus Flight Inspectors for reasons beyond the control of the UK CAA;

   i) Non-assumption of responsibility of the DCA in directing the UK CAA regarding the accomplishment of its contractual duties;

   j) Lack of effective implementation of the corrective action plans from previous audits (ICAO - 46.57 % non-implementation, when an excess of 15% non-implementation generally indicated significant problems in terms of State oversight capability).

3.2 Causes

3.2.1 Direct Causes

1. Non-recognition that the cabin pressurization mode selector was in the MAN (manual) position during the performance of the:
   a) Preflight procedure;
   b) Before Start checklist; and
   c) After Takeoff checklist.
2. Non-identification of the warnings and the reasons for the activation of the warnings (cabin altitude warning horn, passenger oxygen masks deployment indication, Master Caution), and continuation of the climb.
3. Incapacitation of the flight crew due to hypoxia, resulting in continuation of the flight via the flight management computer and the autopilot, depletion of the fuel and engine flameout, and impact of the aircraft with the ground.

3.2.2 Latent causes

1. The Operator's deficiencies in organization, quality management and safety culture, documented diachronically as findings in numerous audits.
2. The Regulatory Authority's diachronic inadequate execution of its oversight responsibilities to ensure the safety of operations of the airlines under its supervision and its inadequate responses to findings of deficiencies documented in numerous audits.
3. Inadequate application of Crew Resource Management (CRM) principles by the flight crew.
4. Ineffectiveness and inadequacy of measures taken by the manufacturer in response to previous pressurization incidents in the particular type of aircraft, both with regard to modifications to aircraft systems as well as to guidance to the crews.

3.2.3 Contributing Factors to the Accident

1. Omission of returning the pressurization mode selector to AUTO after un-scheduled maintenance on the aircraft.
2. Lack of specific procedures (on an international basis) for cabin crew procedures to address the situation of loss of pressurization, passenger oxygen masks deployment, and continuation of the aircraft ascent (climb).
3. Ineffectiveness of international aviation authorities to enforce implementation of corrective action plans after relevant audits.