AIRCRAFT ACCIDENT REPORT 1/2006

ACCIDENT INVESTIGATION DIVISION

Civil Aviation Department
Hong Kong

**Report on the accident to Eurocopter EC155B1 helicopter,
B-HRX, operated by the Government Flying Service of Hong Kong
near Hong Kong International Airport
on 26 August 2003**

Hong Kong

In accordance with Annex 13 to the ICAO Convention on International Civil Aviation and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations, the sole objective of this investigation is the prevention of aircraft accidents. It is not the purpose of this activity to apportion blame or liability.

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March 2006

The Honourable Donald Tsang, GBM
The Chief Executive
Chief Executive's Office
Government House
Hong Kong

Dear Sir,

In accordance with regulation 10(6) of the Hong Kong Civil Aviation (Investigation of Accidents) Regulations I have the honour to submit the report by Mr. Y. P. Tsang, an Inspector of Accidents, on the circumstances of the accident to Eurocopter EC155B1 helicopter, B-HRX near Hong Kong International Airport on 26 August 2003.

Yours faithfully,

(Norman S. M. LO)
Director-General of Civil Aviation

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AAIB	Air Accidents Investigation Branch (of the United Kingdom)
ADELT	Automatically Deployable Emergency Locator Transmitter
AGL	Above Ground Level
AIP	Aeronautical Information Publication
ALT Mode	Altitude Mode
ALT A Mode	Altitude Acquisition and Hold Mode
Altitude	The vertical distance of an aircraft above mean sea level
AMSL	Above Mean Sea Level
AN(HK)O	Air Navigation (Hong Kong) Order 1995
AP	Autopilot
APS	Aircraft Prepared for Service
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATZ	Aerodrome Traffic Zone
AVAD	Automatic Voice Alert Device
BEA	Bureau d’Enquetes et d’Analyses pour la Securite de l’Aviation Civile
^{o}C	Degrees Celsius
CAD	Civil Aviation Department
CAS	Civil Aid Services
Casevac	Casualty Evacuation
CFIT	Controlled Flight into Terrain
Cloud base	That lowest zone above the surface in which the type of obscuration perceptibly changes from that corresponding to clear air or haze to that corresponding to water droplets or ice crystals
C of G	Centre of Gravity
CRM	Crew Resource Management
CTR	Control Zone
CVR	Cockpit Voice Recorder
DC	Direct Current
DGAC	Direction Generale de l’Aviation Civile
EASA	European Aviation Safety Agency

EC	Eurocopter
ELT	Emergency Locator Transmitter
EMS	Emergency Medical Services
ENG 1	Left hand (number one) engine
ESS 1	Essential bus number one
EUROCAE	European Organisation for Civil Aviation Electronics
FADEC	Full Authority Digital Engine Control
FAR	Federal Aviation Regulations
FDR	Flight Data Recorder
FSCC	Fire Services Co-ordination Centre
FTL	Flight Times Limitations
g	Acceleration due to gravity (9.8 m/s^2)
Gx axis	Acceleration in the forward/backward (horizontal) plane
Gz axis	Acceleration in the upward/downward (vertical) plane
GFS	Government Flying Service
GPS	Global Positioning System
HDG Mode	Heading Mode
HKAN	Hong Kong Airworthiness Notice
HKIA	Hong Kong International Airport
HMU	Hydromechanical unit
hPa	Hectopascals (unit measurement for atmospheric pressure)
hrs	Hours
HUMS	Health and Utilisation Monitoring System
IAS	Indicated Airspeed
IAS Mode	Indicated Airspeed Mode
ICAO	International Civil Aviation Organisation
IF	Instrument Flying
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
kg	kilograms
km	kilometres

kt	knots
LOFT	Line Oriented Flight Training
LUT	Local User Terminal
ºM	Degrees Magnetic
MCC	Mission Control Center
M'ARMS	Modular Aircraft Recording Monitoring System
MARPOL	Marine Police
MARPOLOC	Marine Police Operational Chart
MCT	Minimum Continuation Training
METAR	Meteorological Aerodrome Report
MFDAU	Miscellaneous Flight Data Acquisition Unit
MHz	Megahertz
MRB	Main Rotor Blades
MRCC	Maritime Rescue Co-ordination Centre
MTOW	Maximum Authorised Take Off Weight
NAS	National Aircraft Standard
ND	Navigation Display
N2	Engine free turbine speed
nm	nautical miles
NOTAM	Notice to Airmen
NPA	Notice of proposed amendment
PB2	Primary bus number two
PFD	Primary Flight Display
PIC	Pilot-in-Command
PLB	Personal Locator Beacon
QFE	The atmospheric pressure corrected to the official airfield elevation
QNH	Corrected mean sea level atmospheric pressure
RCC	Rescue Coordination Center
RFM	Rotorcraft Flight Manual
R/T	Radiotelephony
rpm	Revolutions per minute
RTOW	Regulated Take Off Weight
SPOC	Search and Rescue Point of Contact

SSCVFDR	Solid State Cockpit Voice and Flight Data Recorder
SSR	Secondary Surveillance Radar
SVFR	Special Visual Flight Rules
TAF	Terminal Aerodrome Forecast
TCDS	Type Certificate Data Sheet
TRTO	Type Rating Training Organisation
TSO	Technical Standard Order
UTC	Co-ordinated Universal Time
VEMD	Vehicle and Engine Management Display
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VS Mode	Vertical Speed Mode

ACCIDENT INVESTIGATION DIVISION

CIVIL AVIATION DEPARTMENT

Aircraft Accident Report 1/2006

Registered Owner:	The Government of the Hong Kong Special Administrative Region
Operator:	Government Flying Service (GFS)
Aircraft Type:	Eurocopter EC155B1 (see Appendix A)
Nationality / Registration:	B-HRX
Place of Accident:	Tung Chung Gap, near Hong Kong International Airport (HKIA) Latitude: 22º 14.9' N Longitude: 113º 56.5' E
Date and Time:	26 August 2003 at 1432 hrs UTC (2232 hrs Hong Kong local time) All times in this Report are in UTC with Hong Kong local time in parenthesis

NB throughout this report the terms 'Tung Chung Gap' and 'Tung Chung Pass' have the following meanings (see Appendix B):

Tung Chung Gap (known locally as 'Pak Kung Au')	The highest point of Tung Chung Road which lay in the valley linking the town of Tung Chung with the South coast of Lantau, at an elevation of 1,097 feet Above Mean Sea Level (AMSL).
Tung Chung Pass	An Air Traffic Control (ATC) designator describing an Aerodrome Traffic Zone (ATZ) entry/exit point that was located on the boundary between the HKIA ATZ and Lantau Control Zone (CTR). When exiting the ATZ, helicopters were required to cross Tung Chung Pass not above 1,500 feet AMSL.

SYNOPSIS

The accident was notified to the Accidents Investigation Division of the Hong Kong Civil Aviation Department (CAD) by the duty Air Traffic Control supervisor at Hong Kong International Airport (HKIA) at 1640 hrs on 26 August 2003 (0040 hrs on 27 August 2003). The investigation by a team of CAD Inspectors of Accidents commenced on the morning of 27 August 2003. Two days later, an investigator from the Bureau d'Enquetes et d'Analyses pour la Securite de l'Aviation Civile (BEA) of France and an accident investigator from the aircraft manufacturer, Eurocopter (EC), arrived in Hong Kong to provide assistance and advice to the CAD team together with a representative of the aircraft engine manufacturer, Turbomeca.

A crew comprising one pilot and an aircrewman had been tasked to perform a night casualty evacuation (casevac) mission. The helicopter departed from HKIA, destined initially for Cheung Chau (one of the Hong Kong outlying islands) for patient pick-up (see Appendix B). The route selected by the pilot took the helicopter across the high ground of Lantau Island via Tung Chung Gap. The weather at HKIA was within the GFS' operating minima for flight over low-lying terrain or over the sea but the weather conditions in Tung Chung Gap were below the operating minima.

Approximately three minutes after take off, in an essentially straight and level flight configuration and at an indicated airspeed of 139 kt, the helicopter impacted with terrain on the western side of the Gap at an altitude of 1,245 feet Above Mean Sea Level (AMSL) and was destroyed. No distress call was made by the crew. Neither crew member survived.

The investigation revealed no evidence of a defect or malfunction of any aircraft system that could have caused or contributed to the accident. The Report concludes that the accident should be classified as an example of Controlled Flight Into Terrain (CFIT).

Nine safety recommendations have been made.

1. FACTUAL INFORMATION

1.1. History of the Flight

On 26 August 2003, the pilot and the aircrewman of the accident flight reported to the headquarters and main operating base of the Hong Kong Government Flying Service (GFS) at 1347 hrs (2147 hrs) and 1323 hrs (2123 hrs) respectively, for a night ('C') shift that was due to commence at 1359 hrs (2159 hrs). It was customary for aircrew to change into their flying suits as soon as they arrived at the GFS: the first time that the pilot was seen in flying clothing was in the pilot's office at 1405 hrs (2205 hrs).

At 1420 hrs (2220 hrs) the duty GFS operations officer received a request for a Type 'A', non life-threatening casevac mission from the Police Headquarters Command and Control Centre (see paragraph 1.17.2.). The crew were alerted for the mission by the sounding of the emergency alarm. The aircrewman passed through the operations room on his way to the helicopter and he was advised by the operations officer that the task involved patient pick-up at a landing site (designated CC04 in the Hong Kong Helicopter Landing Site Directory) on the island of Cheung Chau (which is located just off the South coast of Lantau) and subsequent patient transfer to Central Heliport on Hong Kong Island (see Appendix B). The aircrewman continued to make his way to the helicopter. Moments later, when the pilot passed by the operations room, the operations officer was engaged in a telephone conversation and so the pilot did not collect any details about the task.

There were two principal routes for GFS helicopters to cross Lantau Island (the elevation of the highest point of which was 3,066 feet AMSL). Silvermine Pass had a somewhat diffuse plateau-like structure at an elevation of around 800 feet AMSL and could be navigated with relative ease at night due to a certain amount of background cultural illumination. If the cloud base was sufficiently high, a routeing via Tung Chung Pass and Gap was also available: the high point of this route was a very distinct 'V' shaped col at Tung Chung Gap at an elevation of 1,097 feet AMSL. Although the flight path from HKIA to CC04 via Tung Chung Pass and Gap was marginally more direct than that via Silvermine Pass, the majority of GFS pilots preferred to use the latter and so the operations officer assumed that the crew would wish to follow this route and filed a flight plan for the crew accordingly (see Appendix B).

It was a requirement of the GFS Operations Manual that the aircraft commander carry out a crew briefing before flight, although it was recognized that the duration and depth of the brief would necessarily be dictated by the nature and urgency of the sortie. There was evidence to suggest that the pilot carried out a pre-flight self-briefing in the GFS flight planning room, but there was no evidence of any communication at that time or subsequently between the pilot and aircrewman that addressed the manner in which the flight was to be conducted. Both crewmembers proceeded independently to the helicopter and it was clear from the cockpit voice recorder (CVR) that, at the time of manning the aircraft at 1422 hrs (2222 hrs), the pilot was unaware of the casevac destination. One of the ground crew members noted that the aircrewman was wearing his helmet and that the pilot was wearing a headset (subsequently confirmed as belonging to him). Both crewmembers were wearing their crew lifejackets.

As soon as the crew intercom was functioning, the pilot asked the aircrewman for the destination of the mission, who advised that the routeing would be to "Cheung Chau, Central" (a regular operational destination). The pilot's response indicated that he had already guessed the routeing correctly.

The weather forecast and Meteorological Aerodrome Report (METAR) at HKIA (see paragraph 1.7.) were within GFS limits for single pilot flight at night over low-lying terrain and the sea (see paragraph 1.6.6.2.), but there was no precise information available concerning the weather conditions over Tung Chung Gap. The aircraft commander of a commercial Sikorsky S76 helicopter, who was operating to the South of Lantau at approximately 1412 hrs (2212 hrs) and again at 1440 hrs (2240 hrs), subsequently stated that, when viewed from the South, the Gap was obscured by low cloud.

The first engine was started at 14:24:35 hrs (22:24:35 hrs) and rotors were engaged. The second engine was then started. During the post-start checks the pilot engaged the Autopilot (AP) and selected a target altitude of 1,500 feet on the Altitude Acquisition and Hold Mode (ALT A Mode) [1] of the AP in preparation for departure. The crew continued in the normal way to the pre-taxi and pre take-off checks, which included arming of the

[1] The ALT A Mode was designed to acquire and maintain a preset pressure altitude. Adjustment of the reference value was achieved by use of a rotary knob on the mode selector box on the inter-seat console or via the 'beep trim' control on the collective lever. This Mode had errors of ±30 feet.

Automatically Deployable Emergency Locator Transmitter (ADELT). During the ground taxi to the take off point, a number of pre take off checks were completed. Overlapping with the items of these checks and R/T exchanges between other parties recorded by the CVR, the pilot mentioned "Tung Chung Pass" very briefly and probably to himself. It is possible that the aircrewman heard and understood this comment but, if he did, he made no response.

At the take off point at 14:28:35 hrs (22:28:35 hrs) and with the callsign of 'Casevac five zero', the pilot requested ATC clearance to taxi and line up on Taxiway Kilo for a departure to the East and routeing to Cheung Chau via Tung Chung Pass. This was different to the flight plan that had been filed by the operations officer. It was the first time that the intention of the pilot to route via Tung Chung Pass was made known to ATC and the GFS operations officer who was monitoring the radio transmissions. Moreover, if the aircrewman had missed the pilot's comment during taxi, it was the first time that his intention to route via Tung Chung Pass was made known to the aircrewman. The helicopter was given clearance to lift. Although the QNH was not passed to the pilot as it should have been, as required by the Manual of Air Traffic Control, the pilot had already set the correct QNH (1011 hPa) on the pilot's Primary Flight Display (PFD).

The helicopter lifted into the hover at 14:29:24 hrs (22:29:24 hrs) and was air taxied towards Taxiway Kilo. One of the aircraft's landing lights was selected to 'on' for departure, as witnessed by ATC. Once lined up over the taxiway, departure was initiated at 14:29:30 hrs (22:29:30 hrs) using an initial track that paralleled Runway 07R and an initial accelerative attitude of 11 degrees below the horizon. Shortly thereafter, when established in the climb passing 100 feet, the aircraft entered a climbing turn to the right towards Tung Chung Pass. The flight path from this point described a very gentle curve to the right and, after 3 km or so, followed closely the general direction of the road that led to the Gap (see Appendix C). At no time during the flight was the Heading Mode (HDG Mode) [2] of the AP engaged by the pilot, so all heading changes were necessarily accomplished through manual inputs to the cyclic control. After the initial turn towards Tung Chung Pass, which used up to 17 degrees of bank, roll inputs were relatively minor and mainly to the right.

Immediately after take off the pilot said: "See whether Tung Chung Pass is OK". Passing an altitude of approximately 300 feet the pilot engaged the Airspeed Acquisition and Hold Mode (IAS Mode) [3] of the AP and the existing airspeed of 82.5 kt was captured. One second later the ALT A Mode was armed (the target altitude of 1,500 feet had already been selected) causing an automatic engagement of the Vertical Speed Mode (VS Mode)[4] and the existing rate of climb of 1,200 feet per minute was captured. Passing 600 feet, the pilot reselected a lower target altitude of 1,200 feet via the ALT A Mode and increased the selected IAS to 101.5 kt. Sixteen

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[2] The HDG Mode was designed to acquire and hold a pre-set heading. Adjustment of the reference heading was achieved via a rotary knob on the mode selector box on the inter-seat console or via the 'beep trim' control on the cyclic stick.

[3] The IAS Mode was designed to hold the indicated airspeed of the helicopter at the time the Mode was engaged. Adjustment of the reference speed was achieved via the 'beep trim' control on the cyclic stick.

[4] The VS Mode was designed to hold the vertical speed of the helicopter at the time the Mode was engaged. Adjustment of the reference value was achieved via the 'beep trim' control on the cyclic stick.

seconds later this was increased again to 106 kt. Shortly before level off, there was some general crew chat that included a comment from the pilot in relation to the twenty-minute on-scene response time pledged by the GFS for such missions: he mentioned that achievement of the pledge would be “very marginal” at night. The aircrewman concurred. The pilot then mentioned that if any cloud were present over Tung Chung Gap to hinder their progress then achievement of the pledge would not be “OK”. Passing 1,008 feet, the selected altitude of 1,200 feet was captured and the Altitude Hold Mode (ALT Mode)[5] of the AP engaged automatically. The aircraft commenced an automatic level off, achieving an altitude of 1,200 feet at 14:30:39 hrs (22:30:39 hrs). The selected IAS was increased to 129.5 kt and four seconds later its final target value of 139.5 kt was selected, which was maintained for the final forty seconds of flight. Once level, there were several remarks between the two crewmembers concerning the visibility ahead. At 14:30:54 hrs (22:30:54 hrs) the aircrewman commented to the pilot that the way ahead “seems very marginal”. The pilot agreed. The aircrewman then commented “those road lights seem to be obscured”. The pilot replied “able to cross it………this is better than yesterday” (referring to a flight during the previous night shift (‘C’ shift) in which he abandoned an attempt to cross Lantau via Tung Chung Gap due to low cloud and routed via Silvermine Pass instead).

Throughout the flight, an unlit temporary wind anemometer located on the hillside approximately 100 metres to the West of Tung Chung Gap recorded

[5] The ALT Mode was designed to maintain the helicopter at the same pressure altitude as that which existed when the Mode was engaged.

the wind direction and speed as being steady at around 160 degrees and 20 kt respectively. This was consistent with information subsequently retrieved from the aircraft air data computer. Consequently the aircraft was pointing more or less into wind during its flight towards Tung Chung Gap at a groundspeed of slightly less than 120 kt.

At 14:31:15 hrs (22:31:15 hrs) ATC requested that Casevac five zero squawk 5260, which was acknowledged by the pilot, but instead he left the transponder switched to 'standby'. A comment recorded by the CVR at 14:31:24 hrs (22:31:24 hrs) indicated that the pilot was still in visual contact with the surface but that he would wait until after crossing the highest point of the Tung Chung Road before selecting the transponder to 'on'. The aircrewman then asked the pilot whether or not he was still visual below and the pilot replied "visual". At 14:31:33 hrs (22:31:33 hrs) the pilot remarked that the way ahead was "very marginal" but that he was still "visual". At 14:31:34 hrs (22:31:34 hrs) ATC asked Casevac five zero to confirm the routeing from Tung Chung Pass to Cheung Chau. The pilot confirmed the route. At 14:31:42 hrs (22:31:42 hrs) ATC transmitted to Casevac five zero "what altitude are you requesting?" The response was "one thousand five hundred [feet]" which was acknowledged by ATC with the instruction "casevac five zero roger maintain one thousand five hundred feet". However, the aircraft remained in level flight at 1,200 feet. At 14:31:53 hrs (22:31:53 hrs) the CVR and Flight Data Recorder (FDR) ceased recording. This timing coincided with the first point of contact with the surface.

The helicopter had impacted with terrain that sloped gently upwards both ahead and to the right of the helicopter. The first point of impact was at an elevation of 1,245 feet AMSL, approximately 150 metres to the west of the highest point of Tung Chung Road (elevation 1,097 feet AMSL): see Appendix C. At the time of impact, the helicopter was flying level at an altitude of 1,200 feet heading 167 degrees magnetic, with around 3.5 degrees of right bank selected. The ALT and IAS Modes of the AP were engaged. The Decision Height bug on the pilot's and co-pilot's Navigation Display (ND) was selected to zero: consequently no "Check Height" call was generated by the radio altimeter Automatic Voice Alert Device (AVAD). In addition, the AVAD "One Hundred Feet" advisory call was not transmitted to the pilot before impact.

The helicopter fuselage continued to travel forward in close contact with the ground surface and approximately in line with the flight path, for around 45 metres (see site 'A' in Appendix D). The duration of ground contact lasted for approximately 0.88 seconds (see Appendix L). All main rotor blades were severed within the first few metres of travel through contact with small trees and rocks. The underside and right side of the fuselage were damaged substantially. At the end of the 45 metre run, the terrain fell away moderately sharply. As a consequence, the helicopter became airborne again in an uncontrolled fashion and travelled a horizontal distance of approximately 100 metres whilst falling through a vertical height of some 100 feet before impacting with terrain for a second time in a nose high attitude at around 1,150 feet AMSL. The main body of the wreckage finally came to rest after travelling forward in contact with the surface for a further 30 metres (see site 'B' in Appendix D).

Throughout the flight, neither the CVR nor the FDR gave any indication of any aircraft system malfunction or failure. No distress call was made by the crew.

1.2. Injuries to Persons

	Crew	Passengers	Others
Fatal	2	-	-
Serious	-	-	-
Minor/None	-	-	-

1.3. Damage to Aircraft

The aircraft was destroyed.

1.4. Other Damage

Not applicable.

1.5. Personnel Information

1.5.1. Pilot

Pilot:	Male, aged 34 years
Licences:	Airline Transport Pilot's Licence (Helicopters/Gyroplanes) No limitations
Aircraft ratings:	Sikorsky S76; Sikorsky S70 Blackhawk; Eurocopter AS332L2 Super Puma; Eurocopter EC155B1
Last Licensing Flight Test on type:	4 August 2003, valid to 3 February 2004

Last Operator Proficiency Check on type:	4 August 2003, valid to 3 February 2004
Last Line/Role Check on type:	14 February 2003, valid to 13 March 2004
Medical Certificate:	Class 1, renewed 19 December 2002, valid to 31 December 2003. No limitations.

Flying Experience: (hours)	Total all types:	3900
	Total helicopter:	3350
	Total helicopter hours at night:	600
	Total helicopter instrument flying:	200
	Total on type by day as pilot-in-command (PIC):	100
	Total on type by night as PIC:	38
	Total on type in the previous month as PIC:	
	day	20
	night	5

Operating Experience: The pilot commenced his flying career as a cadet pilot with a local airline in 1992 before joining the GFS in 1995. He was issued with a Hong Kong commercial helicopter licence in 1996 and with a Hong Kong helicopter instrument rating in 1997. At the time of the accident, the pilot was in regular flying practice on both the AS332L2 Super Puma and EC155B1 as an aircraft commander. Prior to qualifying on these types, he was a commander on the S70 and S76.

Previous Duty: On the evening of the accident, the pilot was working his sixth consecutive shift in as many days, as follows:

21 August:	0010-0900 hrs (0810-1700 hrs)
	(8.8 hour day shift)
22 August:	0510-1400 hrs (1310-2200 hrs)
	(8.8 hour afternoon/evening shift)

23 August:	0510-1400 hrs (1310-2200 hrs) (8.8 hour afternoon/evening shift)
24 August:	1359-2259 hrs (2159-0659 hrs) (9 hour night 'C' shift)
25 August:	1359-2259 hrs (2159-0659 hrs) (9 hour night 'C' shift)
26 August:	1359-2259 hrs (2159-0659 hrs) (9 hour night 'C' shift)

During the eight consecutive days preceding 21 August, he worked one day shift, had three days off and was on sick leave for four days. His records of flying and duty complied with the GFS Flight Times Limitations (FTL) Scheme.

1.5.2. Aircrewman

Aircrewman:	Male, aged 31 years	
	Total hours as aircrewman in helicopters:	2230
	Total hours as aircrewman in the EC155B1:	120

Operating Experience: The aircrewman joined the GFS in 1997. His initial training was conducted in the S76 and S70 and he remained current on these types until they were phased out by the GFS in favour of the AS332L2 Super Puma and EC155B1. He was a qualified night winch operator in the AS332L2 Super Puma and a night winchman in the EC155B1.

Previous Duty: On the evening of the accident, the aircrewman was working his fifth consecutive shift in as many days, as follows:

22 August:	0010-0900 hrs (0810-1700 hrs) (8.8 hour day shift)
23 August:	0210-1100 hrs (1010-1900 hrs) (8.8 hour day shift)

24 August:	1359-2259 hrs (2159-0659 hrs) (9 hour night 'C' shift)
25 August:	1359-2259 hrs (2159-0659 hrs) (9 hour night 'C' shift)
26 August:	1359-2259 hrs (2159-0659 hrs) (9 hour night 'C' shift)

Immediately prior to this five-day period he had two consecutive days off. His records of flying and duty complied with the GFS FTL Scheme.

1.5.3. Training and testing

The pilot's conversion to the EC155B1 helicopter type was conducted in Hong Kong during January and February 2003. This was carried out by technical and flying instructors from Eurocopter, the helicopter manufacturer, and was carried out in accordance with Eurocopter's Joint Aviation Authorities (JAA) Type Rating Training Organisation (TRTO) approval. Use of the autopilot modes was emphasized throughout the course. The pilot's initial Licensing Flight Test and Operator Proficiency Check were carried out on 6 February 2003. No EC155B1 simulator existed at the time so all conversion training was of necessity undertaken in the aircraft and included two hours of instrument flying training.

The pilot held an instrument rating for the AS332L2 Super Puma and his last Instrument Meteorological Conditions (IMC) Operator Proficiency Check for this type was completed 11 days prior to the accident on 15 August 2003. The EC155B1 was certificated for single pilot flight in IMC but the GFS had elected not to utilize this capability of the helicopter. The mountainous nature of the terrain in Hong Kong, a shortage of alternates with a promulgated instrument approach, the fact that most tasks involved short sectors and the difficulty of conducting instrument flying training and testing in the aircraft in the congested airspace around HKIA led the GFS to take a policy decision not to qualify its crews for operations in IMC with the EC155B1. Hence the pilot was not required to hold an instrument rating for this type.

Commanders qualified on the EC155B1 type were authorized by the GFS to operate at night provided they held an instrument rating on the AS332L2 Super Puma and had completed the GFS instrument flying (IF) minimum continuation training (MCT) requirements. This amounted to a minimum of one hour of IF (either simulated or actual) every 30 days and was not specific to aircraft type. Records indicated that the pilot had satisfied this requirement, principally in the AS332L2 Super Puma. Since the completion of his type conversion he had flown three instrument training flights in the EC155B1, totalling approximately two hours.

The aircrewman's conversion to the EC155B1 was conducted in Hong Kong during December 2002 and January 2003.

Both the pilot and the aircrewman had completed, in February 2001 and December 2000 respectively, an initial two-day Crew Resource Management (CRM) training course conducted by the GFS. CRM was also assessed routinely during line / role training and checks but the GFS did not use Line Oriented Flight Training (LOFT) as a specific mechanism for the continuation training of its aircrew.

1.6. Aircraft Information

1.6.1. Leading particulars

Manufacturer:	Eurocopter
Type:	EC155B1
Aircraft serial no:	6635
Year of manufacture:	2002
Certificate of Registration:	Issued on 20 December 2002 in the ownership of the Government of the Hong Kong Special Administrative Region
Certificate of Airworthiness:	Issued on 20 December 2002 in the Transport Category (Passenger) and valid until 19 December 2003
Engines:	Two Turbomeca Arriel 2C2 turboshaft engines
Maximum Approved Gross Weight:	4,850 kg
Total airframe hours:	249.7 hours
Total flight cycles:	1,390

1.6.2. Technical log

The technical log of GFS helicopters was normally carried in the aircraft in a fireproof bag designed for the purpose. After manning the aircraft and before take off, the Operator's procedures required that the pilot check the appropriate details in the technical log and sign it (thereby indicating acceptance of the aircraft). The GFS refuelling staff had entered a fuel load of 500 kg in the technical log.

Immediately prior to the accident flight, the helicopter was fully serviceable in all respects and carried only two deferred defects of a very minor nature, which would have had no bearing on the accident.

1.6.3. Aircraft weights and centre of gravity

The standard load of 500 kg of fuel provided sufficient endurance for most routine eventualities. The computerised loading and Centre of Gravity (C of G) calculation was retrieved from the planning computer by GFS staff after the accident was notified, but the aircrewman was unaccounted for in the take off weight. Taking into account the additional weight of the aircrewman, the calculation indicated that the aircraft was within both longitudinal and lateral C of G limits and significantly below the Maximum Take Off Weight (MTOW) and Regulated Take Off Weight (RTOW). At this weight, International Civil Aviation

Organisation (ICAO) Class 1 performance was assured.

Maximum take off weight:		4850 kg
Take off weight recorded:		3768 kg
Comprising	APS weight	3193 kg
	Captain	75 kg
	Fuel	500 kg
	Total	3768 kg (without aircrewman)
Actual take off weight		3843 kg (including 75 kg for aircrewman)

1.6.4. Aircraft description

1.6.4.1. General

The accident aircraft was a twin-engined EC155B1 helicopter certificated for single-pilot operation by day and by night under Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). Although the certificated maximum number of seats was 15 (including the front right hand seat for the captain and front left hand seat for a co-pilot), the GFS had elected to operate the accident aircraft in a 10 seat configuration, that included the two pilot seats.

1.6.4.2. Engine controls

The helicopter was powered by two Turbomeca Arriel 2C2 turboshaft engines: each was controlled by a dual-channel Full Authority Digital Engine Control

(FADEC).

The electrical controls for the engines were grouped on the cockpit overhead panel. Two three-positioned OFF/IDLE/FLT ('flight') engine control switches allowed for starting and engine acceleration to the required power ratings. Each switch was fitted with a manually selected safety device that prevented inadvertent movement of the switch from the FLT position. In order to move the switch from FLT to IDLE or OFF, the safety device first had to be rotated through 90° from the 'safe' to the 'unsafe' position (see Appendix E, Figure 4).

During normal operation, the pump and metering unit (the hydromechanical unit or HMU) of the fuel system metered the fuel flow to the engine in accordance with commands made by the FADEC. The engine shutdown operation was controlled by a two-position, electrically controlled, stop electrovalve in the fuel valve assembly that connected the HMU to the fuel injection system. When engine shutdown was selected via the engine control switch, the stop electrovalve was energized closed, thus cutting the fuel supply to the injection system.

The fuel supply to each engine was also mechanically controlled by a red shutoff lever mounted aft of the overhead panel in the cockpit, which was linked to an airframe fuel shutoff valve. In normal operation, both control levers were positioned forward (with the corresponding fuel shutoff valves open) and were immobilised in this position with a snap wire. Movement of a lever to the fully aft position closed its fuel shutoff valve, which isolated the engine from its fuel supply (see Appendix E, Figures 1 and 2).

1.6.4.3. Electrical system controls

The helicopter was powered primarily by a DC electrical system, which consisted of three distribution sub-systems: the battery distribution system and the left and right distribution systems.

The controls for the system and its components were grouped in an electrical system control panel on the cockpit overhead panel (see Appendix E, Figure 3). The battery was controlled by an OFF/ON/RST ('reset') switch. A generator OFF/ON/RST switch was provided for the operation of each starter-generator. Emergency cut-off of the DC power system could be achieved via two three-positioned PWR OFF/EMER

SHED ('emergency shed')/PWR ON ('power on') switches, which were ganged together by a red switch bar. In normal system operation, the switch bar was placed at the PWR ON position. During certain emergency conditions, the switch bar could be positioned to EMER SHED to isolate the power supply to non-essential services. When the switch bar was moved to the PWR OFF position, all power supplies were isolated, except for the direct battery bus and number one essential bus.

1.6.4.4. Cockpit seats

The pilot's seats were manufactured from a laminate structure that included the seat cushion and the backrest. The backrest contained an individual survival kit and was fitted with a headrest. The height of the seats and their fore and aft position were adjustable. The safety harness could be locked manually. The seats met Technical Standing Order (TSO) C39A Specification and the minimum performance standards detailed in National Aircraft Standard (NAS) Specification 809, dated January 1, 1956, Type I - Transport (9 g forward load). The ultimate load factors used by the aircraft manufacturer for the seat and its installation were significantly lower than the latest, more stringent, Joint Airworthiness Requirements (JAR) 29 standards that existed at the date of the type certificate application.

1.6.4.5. Radio altimeter system with AVAD

It was a requirement of the AN(HK)O that helicopters registered in Hong Kong flying over water for more than a total of three minutes in any flight be equipped with a radio altimeter that incorporated an AVAD. Accordingly, the helicopter was equipped with a Thomson AHV 16 radio altimeter and Racal V694 AVAD, which received inputs from the radio altimeter and generated a “Check Height” audio voice warning when the preset decision height bug on the ND was reached during the descent. In addition, when the helicopter descended to 100 feet, a “One Hundred Feet” audio voice warning was generated. Since the AVAD was designed for overwater flight, and had no look forward or predictive ability, it was of limited use over land.

EC155B1 Rotorcraft Flight Manual (RFM) Supplement 35 contained information on the basic principles of operation of the AVAD but no recommended operating procedure.

1.6.4.6. Automatically Deployable Emergency Locator Transmitter (ADELT)

The generic term ‘Emergency Locator Transmitter’ (ELT) defines equipment that broadcasts distinctive signals on designated frequencies. A 406 MHz ELT is a radio beacon capable of transmitting distress signals on that frequency, which are detectable by instruments on board Cospas-Sarsat System satellites in geostationary and low-altitude Earth orbits. Ground receiving stations or ‘Local User Terminals’ (LUTs) receive and process the satellite downlink signal, using Doppler positioning and processing techniques, in order to pinpoint the exact location of the ELT that is emitting the distress signal. Mission Control Centers (MCCs) receive the alerts produced by LUTs and forward them to Rescue Coordination Centers (RCCs), Search and Rescue Points of Contacts (SPOCs) or other MCCs.

The ICAO requirements for carriage of the 406 ELT on helicopters involved in international operations were stated in Chapter 4 Section 4.10. of Part III of Annex 6. The technical specifications for ELTs were provided in Chapter 5 of the same Part. These requirements and specifications were cross-referred to EUROCAE document ED-62 “Minimum Operational Performance

Specification for Aircraft Emergency Locator Transmitters" dated May 1990.

The CAD requirements for the carriage of an ELT were published in Scale K(iii) of the Air Navigation (Hong Kong) Order 1995, and Hong Kong Airworthiness Notice No. 27 (Issue 2, dated 30 October 2001). Scale K(iii), which was relevant to the accident aircraft, stated that Performance Group A2 helicopters when beyond 10 minutes flying time over water were to be equipped with an emergency beacon which is automatically deployed and activated in the event of a crash.

Hong Kong Airworthiness Notice No. 27 (Issue 2, dated 30 October 2001) was identical to the Annex 6 requirements. The particular requirements relevant to the accident aircraft stated that Performance Class 1 and Class 2 helicopters for which the individual Certificate of Airworthiness was first issued after 1 January 2002 (the Certificate of Airworthiness for the accident aircraft was first issued on 20 December 2002), operating on flights over water at a distance from land corresponding to more than 10 minutes at normal cruise speed, and over designated land areas, were to be equipped with at least one automatic ELT that would activate automatically on impact (together with at least one Survival ELT in a raft).

An automatic ELT shall have the means to detect the occurrence of a crash, automatically activate the transmitter and radiate a signal through an antenna. There are three basic types of automatic ELT: Automatic Fixed, Automatic Portable, and Automatic Deployable. An Automatic Fixed ELT is to be permanently attached to the aircraft before, and remain with the aircraft after, a crash. An Automatic Portable ELT is to be rigidly attached to the aircraft before a crash, but readily removable from the aircraft after a crash. An Automatic Deployable ELT is to be rigidly attached to the aircraft before a crash and ejected and deployed either manually or automatically after a crash.

In the accident aircraft, a Cospas-Sarsat 406 MHz compliant ADELT, model Caledonian Airborne Systems CPT-609 equipped with an automatic release mechanism, was installed at the rear end of the tail boom (see Appendix G). Deployment of this device was designed to take place via the breakage of any one of four frangible switches or the operation of a hydrostatic switch under water pressure or a saline switch that would operate on contact with fresh or saline water. However, this ADELT was not designed to activate automatically at the time of deployment: this would only occur when its built-in saline switch was closed by the presence of water. There was neither automatic fixed ELT nor automatic portable ELT fitted on this aircraft.

1.6.5. Maintenance records

The following significant maintenance work was carried out during the period leading up to the accident:

TASK/DEFECT	AIRFRAME HOURS	DATE
No.1 engine chip light illuminated in flight – a tiny chip was found, the engine was confirmed satisfactory after the inspection	29.8	28/2/2003
Main gearbox over-torque – confirmed no damage after the inspection	46.7	18/3/2003
100 hour check	87.3	15/5/2003
100 hour check	175.9	15/7/2003
Tail gearbox chip light illuminated in flight – confirmed nuisance warning	249.1	26/8/2003

1.6.6. Operating procedures

1.6.6.1. Reporting time and aircraft commander's responsibilities

The standard day for GFS aircrew was divided into three main shifts as follows:

‘A’ Shift: 2300-0750 hrs (0700-1550 hrs)

‘B’ Shift: 0510-1400 hrs (1310-2200 hrs)

‘C’ Shift: 1359-2259 hrs (2159-0659 hrs) and which consisted of one EC155B1 crew only

In addition, a day (‘D’) shift lasted from 0010 – 0900 hrs (0810 – 1700 hrs)

There was no formal allowance in these times for incoming crews to prepare themselves for their duty (this included an assessment of the meteorological situation, preparation of the loadsheet, self-briefing about any new instructions to aircrew or changes to operating procedures, a check on any relevant Notices to Airmen (NOTAMs), a check of the aircraft and technical log and completion of the GFS authorization sheet). The time required for this preparation was not included in contracted hours or recorded in individual FTL records. Although the standard reporting time for aircrew stated in the Operations Manual was 45 minutes before first take off, in reality aircrew were required to be available to fly in response to an urgent casevac request as soon as their shift commenced.

At 2305 hrs (0705 hrs) and again at 0515 hrs (1315 hrs) a general briefing was held for all helicopter and fixed wing aircrew for the 'A' and 'B' shifts respectively. Since the 'C' shift comprised only one crew no such briefing was held and there was no formalized handover procedure from the aircrew on the previous 'B' shift. In addition, GFS procedures required that the aircraft commander carry out a specific briefing for all members of the crew before flight, although it was recognised that the duration and depth of the brief should be dictated by the urgency of the task. Custom and practice dictated that all briefings be carried out in the GFS flight planning room where reference was made to a briefing aide memoire. For urgent casevac missions, however, it was common practice for the pilot to make his way to the aircraft whilst the aircrewman gathered the relevant details from the operations officer. These details would subsequently be communicated to the pilot who would then carry out an abridged crew briefing in the aircraft via the intercom system. Prior to the accident flight it was unlikely that a crew briefing took place in the flight planning room since the pilot was unaware of the destination at the time of manning the aircraft and the CVR confirmed that no subsequent briefing or discussion relating to the management of the flight took place between the two crewmembers in the aircraft.

1.6.6.2. GFS helicopter weather minima

GFS self-imposed weather minima for the EC155B1 helicopter for a Type 'A' casevac (see paragraph 1.17.2.) at night in Class C airspace was a visibility of 5 km and a cloud base of 600 feet above the surface for single pilot operations. These minima were applicable at both the planning stage and the en route phase of the flight. Pilots were taught that if the actual weather conditions encountered during flight were below these minima, they should either turn back or alter course, but these actions were not detailed in the Operations Manual. When crossing Tung Chung Gap (elevation 1,097 feet AMSL), a minimum cloud base of at least 1,700 feet AMSL was required at that point in order to ensure compliance with the cloud base requirement.

1.6.6.3. Minimum operating heights

Rule 5(1)(e) of Schedule 14 to the Air Navigation (Hong Kong) Order 1995 (the 'Low Flying Rule') required that an aircraft fly no closer than 500 feet to any person, vessel, vehicle or structure, unless it was flying for the purpose of saving life (see Appendix N). This Rule existed only for the protection of third parties: if flying above a surface that was devoid of persons, vessels, vehicles or structures, there was no minimum height requirement. The GFS had been granted an exemption by the CAD against the requirements of Rule 5(1)(e) when engaged in casevac operations that were *not* for the purpose of saving life. This enabled GFS helicopters, when engaged in such tasks, to fly over Tung Chung Gap at a height of less than 500 feet above the surface without infringing the Rule.

There was no minimum en-route operating altitude or height specified in the GFS Operations Manual for night casevac flights, during which the pilot was required to maintain continuous visual contact with the surface.

1.6.6.4. Crossing of Lantau Island via Tung Chung Pass and Tung Chung Gap

Tung Chung Pass was one of several entry and exit points on the boundary of the HKIA ATZ that was created at the time of the opening of the new HKIA at Chek Lap Kok in 1998. The procedures for the use of Tung Chung Pass were published in the Hong Kong Aeronautical Information Publication (AIP) and were identical for flights by day and by night (see Appendix K). Only helicopters were permitted to use the Pass. They were required to fly not above 1,500 feet AMSL when flying outbound from the ATZ. Once outside the ATZ, they were then allowed automatically to operate up to 2,000 feet AMSL. The altitude for inbound flights to the ATZ was 2,000 feet AMSL. The route to fly was shown clearly on the Hong Kong Local Flying Chart.

The lower reaches of Tung Chung Valley were well illuminated at night by cultural lighting from the town of Tung Chung, but the higher reaches of the Valley had little in the way of such lighting and there were no lights at known elevations on the hillside above Tung Chung Gap that could provide an indication of the actual cloud base above the Gap. On a clear night the 'V' shape of the ridgeline could easily be seen against the night sky. However, moist southerly winds often caused the ridgeline of Lantau to be shrouded in orographic cloud, which was usually visible to the naked eye in the glow of the cultural illumination from Tung Chung (see Appendices J and O). In conditions of reduced visibility the Gap was less distinct and more reliance had to be placed by the pilot on other visual cues for navigation, such as the yellow sodium lights that illuminated the main Tung Chung road located in the floor of the valley. These lights reached a height of some 40 feet above the level of the road, which was initially orientated in a general direction of around 160 degrees magnetic but, nearing the top of Tung Chung Gap, this increased to nearly 170 degrees magnetic.

Approximately 220 metres before the first point of impact, the road changed direction somewhat abruptly towards the East by around 30 degrees (see ‘Segment C’ in Appendix C, Figure 2).

The teaching and common practice within GFS for helicopters using this route at night was to climb to and maintain an altitude of 1,500 feet QNH, exit the ATZ at Tung Chung Pass then continue to use the lights of the road across Tung Chung Gap as a visual aid to orientation. In the event that 1,500 feet could not be achieved, pilots were taught to turn back and attempt an alternative outbound route from the ATZ. In marginal conditions it was recommended that the aircraft be flown at a reduced speed rather than at normal cruise speed, in order to give the pilot greater response time and ability to manoeuvre and to reduce the radius of any escape turn. In such conditions, the lights of the road would normally be kept slightly to the right of the aircraft in order to provide the aircraft commander seated in the right hand seat with the best visual reference and assist in the execution of an escape turn to the right in the event of encountering bad weather. These procedures were informal and did not appear in a written form.

1.6.6.5. Actions in the event of inadvertent entry into IMC

The actions to be taken in the event of inadvertent entry into IMC were addressed during training and were included as an item in the standard pre-flight briefing aide memoire. In the event of such an occurrence, GFS pilots were taught to climb immediately to avoid terrain, squawk 2577 and call ATC for position and radar assistance.

1.6.6.6. Use of the AVAD

There was no standard operating procedure within the GFS Operations Manual that addressed the use of the AVAD during night casevac missions. The manner in which it was used was at the discretion of the pilot and based upon considerations of airmanship, which were taught during line training. When over the land, it was common practice for GFS pilots to permit the radio altimeter bug on the ND to remain at the default value of zero, in order to reduce the occurrence of the advisory "Check Height" calls.

1.6.6.7. Wearing of helmets

GFS aircrew were issued with helmets but since there was no formal guidance as to when these were to be worn, headsets were occasionally worn instead (for example, during temporary unserviceability or routine servicing of the helmet).

1.7. Meteorological Information

1.7.1. Weather reports

Prior to the accident flight, the crew had access to the full range of meteorological reports, issued by the Hong Kong Observatory, in the GFS Flight Planning Room. The Automatic Terminal Information Service (ATIS) was also transmitting on frequencies 128.2 MHz and 127.05 MHz.

The general forecast issued by the Hong Kong Observatory at 1345 hrs (2145 hrs) on 26 August 2003 was as follows:

"THE PACIFIC RIDGE OF HIGH PRESSURE IS GRADUALLY EXTENDING WESTWARDS TO THE SOUTHEASTERN PART OF CHINA. WEATHER FORECAST FOR TONIGHT AND TOMORROW CLOUDY TONIGHT. MAINLY FINE TOMORROW. THERE WILL ALSO BE A FEW ISOLATED SHOWERS. TEMPERATURES WILL RANGE BETWEEN 28 AND 32 DEGREES. MODERATE SOUTHEASTERLY WINDS, OCCASIONALLY FRESH AT FIRST. OUTLOOK: MAINLY FINE IN THE FOLLOWING FEW DAYS. DISPATCHED BY HONG KONG OBSERVATORY AT 21:45 HKT ON 26.08.2003"

The 24-hour Terminal Aerodrome Forecast (TAF) issued for HKIA at 1000 hrs (1800 hrs) on 26 August 2003 was:

Valid from 12 UTC 26 August 2003 to 12 UTC 27 August 2003
Surface wind 160 degrees (SSE) 10 knots

Visibility 10 km or above
No significant weather
Cloud amount and cloud base: 1 to 2 oktas at 1500 feet, 3 to 4 oktas at 2500 feet, 5 to 7 oktas at 8000 feet
Temporarily between 18 and 24 UTC visibility 4000 metres in showers of rain
Temporarily between 04 and 08 UTC surface wind 220 degrees (SW) 10 knots
Minimum temperature 27°C at around 22 UTC
Maximum temperature 32°C at around 06 UTC

The 9-hour TAF issued for HKIA at 1130 hrs (1930 hrs) on 26 August 2003 was:

Valid from 12 to 21 UTC 26 August 2003
Surface wind 160 degrees (SSE) 10 knots
Visibility 10 km or above
No significant weather
Cloud amount and cloud base: 1 to 2 oktas at 1200 feet, 3 to 4 oktas at 2500 feet, 5 to 7 oktas 8000 feet
Temporarily between 18 and 21 UTC visibility 4000 metres in showers of rain

The following METAR was issued at 1400 hrs (2200 hrs):

"METAR VHHH 261400Z 16008KT 120V240 9999 FEW014 SCT025 BKN100 29/24 Q1011 NOSIG="

Surface wind 160M / 8 kt, varying between 120 and 240 degrees, visibility 10 km or more, few (1 to 2 oktas) with a cloud base of 1,400 feet, scattered cloud (3 to 4 oktas) with a cloud base of 2,500 feet, broken cloud (5 to 7 oktas) with a cloud base of 10,000 feet, temperature +29°C, dew point +24°C, QNH 1011, with no significant meteorological conditions at or near the aerodrome.

1.7.2. Weather conditions in Tung Chung Gap

When Lantau Island was affected by moist southerly winds, orographic uplift typically caused the base of any cloud on the southern (windward) side of the island to be lower than that on the northern (leeward) side of the island, with cloud hanging over and obscuring the ridgeline (see Appendix O). Further towards HKIA, the cloud cover usually became increasingly broken. Under these conditions, the cloud base and visibility at HKIA were not a reliable indicator of the weather conditions over Tung Chung Gap.

At the time of the accident, Lantau was affected by south southeasterly winds. The aircraft commander of a commercial Sikorsky S76 helicopter who flew regularly on the helicopter passenger service between Hong Kong and Macao subsequently reported that, when operating on the designated helicopter routes to the South of Lantau, he habitually looked in the direction of the Island in order to gauge the actual cloud base in relation to the terrain and that, weather permitting, Tung Chung Gap was clearly visible at night when viewed from the South against the background of the cultural illumination from Tung Chung and HKIA. He stated that, on the night in question, the meteorological visibility below cloud was in excess of 10 km. At approximately 1412 hrs (2212 hrs) when in the cruise in an eastbound direction at an altitude of 1,000 feet and again at approximately 1440 hrs (2240 hrs) when cruising in a westerly direction at an altitude of between 500 feet and 900 feet he could not see through Tung Chung Gap to the North because it was obscured by low cloud. This was confirmed by the pilots of two GFS search helicopters that were launched shortly after the SAR operation commenced. The first rescue teams who arrived at the crash site subsequently described the weather at the site as 'foggy'.

1.8. Aids to Navigation

The accident flight was operated under Special Visual Flight Rules (Special VFR), although the departure clearance from ATC did not make this explicit. These ATC rules required that flights be conducted clear of cloud and in sight of the surface and in compliance with any instructions issued by ATC. Pilots were responsible for maintaining their own clearance from terrain and obstacles and so visual contact with the surface was the principal method of navigation (see Appendix I). Information from the CVR indicated that, after levelling at 1,200 feet AMSL, the flight visibility diminished progressively. Therefore it is probable that the most significant external visual cue available to the pilot during the latter stages of the accident flight would have been the road lights that led to the Gap. At the time of the accident all the road lights were functioning normally.

Subsequent analysis of the aircraft's Trimble Global Positioning System (GPS) showed that it was being used in the 'direct to' mode and that the destination waypoint entered by the pilot was landing site CC04, a user waypoint recorded in the database. There was no other intermediate waypoint selected.

1.9. Communications

1.9.1. ATC recording

A transcript of the transmissions between the aircraft and ATC at HKIA was made available to the investigation team. Throughout the flight, the aircraft remained on the HKIA Air Movements Controller (South) ('Tower South') frequency of 118.4 MHz, the radio transmission antennas for which were located at the airport island. The initial ATC departure clearance should have included the QNH but this was omitted (the pilot still managed to depart with the correct QNH set on his PFD, however). The clearance also did not state specifically that the flight was to comply with the requirements of Special VFR (see Appendix I, Rules 22 and 23).

1.9.2. Ground radar recording

Secondary Surveillance Radar (SSR) transponder codes were not mandated for aircraft engaged in local flying: any assignment of a code was at the discretion of the ATC controller in accordance with a specific air traffic procedure. The accident aircraft was not given a code in the departure clearance but was instructed subsequently to squawk '5260' when level in the cruise at 1,200 feet. However, the aircraft transponder remained switched to 'standby'. At no time therefore was ATC able to monitor the position or altitude of the aircraft by reference to SSR. The aircraft was first detected by primary radar at an early stage of the climb. It was seen turning towards Tung Chung but the primary return disappeared when the aircraft was over the landmass of Lantau Island. For operational reasons, to reduce the amount of clutter caused by terrain, the radar was set so that primary returns below a certain attenuation value would be suppressed from display on radar screens. It was possible that the returned signals from the accident aircraft were below the threshold of detection. However, since the flight was not subject to radar service, the responsibility for weather and terrain clearance rested with the pilot.

The reference radar head was located at 22°20.7' N 113°53.4' E, on Sha Chau Island to the north of HKIA. It was operating at 12 rpm and its tilt angle was set at 5 degrees. It had a coverage of up to 80 nm depending upon the mode of operation.

1.10. Aerodrome Information

Not applicable.

1.11. Flight Recorders

The aircraft was equipped with an Allied Signal AR602C combined solid-state cockpit voice and flight data recorder (SSCVFDR), which was integrated with a simplified Health and Utilisation Monitoring System (HUMS) known as the Modular Aircraft Recording Monitoring System (M'ARMS). The SSCVFDR complied with European Organisation for Civil Aviation Electronics (EUROCAE) Document ED55. In the event of an accident, all recordings would cease via the triggering of either an immersion sensor or an inertia contact. The inertia contact was designed to stop the flight recorder at an impact of 3 g or greater. In the following paragraphs separate reference is made to each of the two elements of the system (the CVR or FDR), as appropriate.

1.11.1. Flight Data Recording (FDR) system

The FDR was located in the tail boom with an underwater locator beacon attached to its protective casing. It was capable of recording 12 hours of flight data parameters. These parameters were collected and processed by the Miscellaneous Flight Data Acquisition Unit (MFDAU) computer, prior to recording by the FDR. 28 Volt DC was supplied to the FDR by both Essential Bus 1 (ESS 1) and Primary Bus 2 (PB 2), which were powered by the battery and No.2 starter-generator respectively. An inertia switch and an immersion electronic box connected with sensors were in series with the FDR along this power supply line. In the event of an incident, the sensors would detect the immersion of the helicopter in water or the inertia switch would detect the impact of the helicopter. Activation of either the immersion sensor or the inertia switch would stop the FDR so that any recordings made prior to the incident would not be erased.

Vertical speed was recorded with an accuracy of ± 64 feet per minute and selected altitudes were recorded with an accuracy of ± 64 feet. The recorded value of these parameters was the closest multiple of 16 of the actual displayed value.

The flight path of the helicopter was reconstructed from GPS information retrieved from the FDR and plotted (see Appendix C). The point at which the FDR ceased recording is consistent with the point of first impact with terrain.

1.11.2. Cockpit Voice Recording system

The CVR was capable of recording one hour of cockpit voice data. The cockpit voice was detected via one wide band area channel and three narrow band voice channels. The wide band channel captured all the audio signals generated in the cockpit acoustic environment via an area microphone on the aft cockpit ceiling. Two narrow band channels detected the voice of the pilot and the co-pilot through their headset microphones, while the last narrow band channel captured the voice of the crewman through the headset microphones connected to the inter-communication system. The audio signals captured by the area microphone were transmitted directly into the CVR. Those signals picked up through the crew microphones were acquired by a summing amplifier and then input into the CVR. There was no buffer for the recording of audio signals into the CVR, which ceased recording immediately after the first impact.

1.11.3. Recording quality

All the recorded flight data were retrieved from the FDR. With a few exceptions, all the verbal communications recorded via the CVR were clear and intelligible. Some conversation in Cantonese, when translated into English (see Appendix C, Figure 1), may not accurately convey the full range of nuances in meaning.

1.11.4. Accident flight

The SSCVFDR ceased recording at the time of the first impact with terrain at 14:31:53 hrs (22:31:53 hrs). Prior to this event it had been recording satisfactorily. It was determined that the recorder had lost its power supply as a result of operation of the g-switch due to ground contact. Electrical power was cut to the SSCVFDR in such a way that the audio effects of the ground impact were not recorded on the audio tracks of the SSCVFDR. The SSCVFDR maintained a record of the last 12 hours of aircraft data, together with the last hour of audio from the commander and the aircrewman. Following the incident, the recorder was recovered without any damage to its protective casing and was sent immediately to the UK Air Accidents Investigation Branch (AAIB) where, with the assistance of both BEA and EC, it was replayed successfully using normal replay techniques.

The recording indicated that there was no failure or malfunction of any of the aircraft systems at any stage of the flight.

1.12. Wreckage and Impact Information

1.12.1. Examination of the wreckage

The wreckage was located in two main areas, which were subsequently designated 'Site A' and 'Site B' (see Appendix D).

Site 'A', on the Western hillside above Tung Chung Gap at an elevation of 1,249 feet above Hong Kong Principal Datum, or 1,245 feet AMSL, was the point of first impact[6]. The terrain in the area sloped upwards in a westerly direction from Tung Chung Road. The surface was rich in vegetation and there were numerous rocks of up to a metre or so in diameter, embedded in sandy soil.

At the point of impact with gently rising terrain, it was evident from the cut marks made by the main rotor blades in a number of small trees that the helicopter was flying level, with the nose pitched just below the horizon in a normal cruise configuration and, possibly, with a small amount of bank to the right. The aircraft continued to skid along the side of the slope, which resulted in the creation of a distinct score-mark in the ground.

[6] The apparent discrepancy between the elevation of the first point of impact at 1,245 feet AMSL and the indicated aircraft altitude of 1,200 feet can be explained as follows. The actual QNH at the time of the accident was 1011.77 hPa. With the reported QNH of 1011 set on the PFD (1010.9 according to the FDR), the actual altitude of the helicopter was 1,224 feet AMSL. The remaining difference was within the ALT A Mode equipment tolerances of ± 30 feet.

Various parts of the aircraft structure became detached at this time and rupturing of the fuel tanks was followed by a rapid and massive leakage of fuel. After 45 metres, the terrain fell away into a small valley. A considerable amount of debris from the fuel system was located at the end and down slope side of the score-mark at Site ‘A’.

Site ‘B’ was located on the opposite side of the valley, approximately 100 feet below and 100 metres horizontally beyond the end of the ground mark at Site ‘A’. The vegetation around this site was denser than that at Site ‘A’. The main bulk of the fuselage had travelled through the air towards this second point of impact where the ground sloped downwards in the direction of travel and to the left. At this point all the fenestron tail rotor blades and other debris from the tail were discovered, including the ADELT antenna, indicating that the aircraft had impacted with the ground in a nose high attitude. The fuselage continued to travel forward and downwards for a further 30 metres, thus creating a second score-mark in the ground which was aligned a few degrees to the left by comparison with the orientation of the mark at Site ‘A’. The forward motion of the upper part of the aircraft was retarded through contact between the stubs of the main rotor blades and small trees. The aircraft finally came to rest with the tail boom orientated in the general direction of travel on the down slope side of the wreckage and the nose of the aircraft pointing in the reverse direction. The floor of the cockpit section was sitting upright and the cabin section was completely deformed: the fuselage had folded at the rear bulkhead. The engines and main rotor gearbox were still attached to each other and to the transmission platform but this structure fell on the uphill side to the main wreckage with the engine exhausts pointing vertically upwards.

Leakage of residual fuel had occurred in the area of the wreckage at Site ‘B’ but there was no evidence of a post-impact fire except for a small flash fire at the forward top area of module two around the fuel valve assembly of the right hand (number two) engine.

All cockpit switches were in the normal position for flight with the following exceptions (see Appendix E, Figures 2 and 4):

Left hand (number one) engine (ENG 1):

- The fuel shut off control lever was in the aft (‘shutoff’) position.
- The safety device for the engine control switch was in the ‘unsafe’ position and the switch was in the centre (IDLE) position.
- The DC emergency cut off on the overhead panel was in the PWR OFF (‘power off’) position.

The left hand generator switch was in the OFF position.

The control switch for the number two engine had broken off in the

FLT position, presumably through the force of the impact or during intervention by the rescue crews.

The switch on the pilot's collective lever controlling the right hand landing light was selected to 'white'. When the switch was in this position, the landing light would illuminate in white light.

A setting of 1010 hPa was found on the standby altimeter instead of the QNH, which was 1011.

The pilot did not wear a helmet at any time during the flight: his personal headset was discovered in the wreckage. Although the aircrewman was once seen to be wearing his helmet prior to manning the aircraft, his helmet was discovered underneath the wreckage, separated from the wearer: the chin strap was undamaged. A GFS-issue headset was found which had signs of bloodstains.

The technical log was lying on the ground in close proximity to the cockpit, but it was not in its fireproof bag (which was also found in the wreckage).

1.12.2. Detailed examination

1.12.2.1. Pilot's seat and associated structure

The structure of the cockpit and cabin failed during this accident (see Appendix F). One of the major lines of failure ran laterally through the floor of the rear cabin, resulting in the fuselage folding double. The pilot's seat and the running rails on which the seat was mounted were severely damaged as a result of the accident. The back of the seat was broken and displaced forwards. This breakage would have seriously degraded the restraint offered by the five-point harness even had the seat remained attached to the aircraft floor. The two 65 cm long seat mounting rails were each attached to the composite sandwich panel floor of the aircraft by 18 crosshead screws, nine each side of the rail, through countersunk holes in the base plate. The screws located with inset nuts cemented into the composite sandwich panels. None of the fixings was made to a hard structure.

The pilot's seat inner rail was found to have broken 42 cm behind the cyclic stick, at a point coinciding exactly with a joint in the floor panel. The 36 cm x 25 cm piece of floor panel immediately in front of this break was found completely detached, along with the front end of the seat rail. The back portion of the rail, which was also detached completely from the floor, had a retained portion of the broken seat runner still attached to it.

1.12.2.2. Landing lights

The left hand landing light suffered severe damage. Scratch marks and crushing were evident. All the light bulbs were broken. The light was detached from its motor mechanism.

The damage to the right hand landing light was relatively less severe. The light was still attached to the driving/swivelling mechanism although it was angled from the fully retracted position (level with the lever arm). One of the bulbs was still present and was removed for detailed examination. It was confirmed subsequently that the filament had been subjected to a cold break and so the light was 'off' at the time of the accident, but it is not known at what point the pilot made this selection.

1.12.2.3. Automatically Deployable Emergency Locator Transmitter (ADELT)

At the second point of impact, the antenna of the device separated from the main body, which remained in its mounting bracket at the end of the tail cone. The ADELT master switch in the cockpit was found in the ARM position but the squib of the deployment circuit had not been activated. The Rescue Coordination

Centre of the Hong Kong Civil Aviation Department confirmed that no ELT signal was received from the crash site. The frangible switches at the left hand fuselage, right hand fuselage and underside of the tail boom were not located due to the extensive damage that had been inflicted on the airframe and tail boom and were probably destroyed shortly after the first impact. The fourth breakable switch was found intact on the rear bulkhead of the nose gear wheel well. This switch was almost completely surrounded by soil which probably entered the wheel well as the aircraft slid over the ground immediately after the first impact. The hydrostatic switch and the saline switch in the ADELT compartment did not activate the squib due to lack of water at the crash site.

1.12.2.4. Personal Locator Beacons (PLB)

The connection between the aerials and the main bodies of both SARBE 7 (BE549) PLBs had severed through the force of the impact.

1.13. Medical and Pathological Information

There was no evidence of any pre-existing medical condition in either crewmember that could have contributed to the cause of the accident. The pilot was on sick leave from 16 to 19 August 2003 (inclusive dates) but it is not believed that this brief illness was related in any way to the accident.

The post mortem examination established that the pilot and aircrewman died as a result of multiple injuries. The aircrewman was not restrained in a seat and suffered more severe injuries than the pilot. However, both crewmembers survived for a period of time, possibly up to one hour, after the second impact but remained either unconscious or otherwise incapacitated.

Toxicological analysis revealed no evidence of drug or alcohol ingestion in either the pilot or aircrewman, and there was no evidence of exposure to toxic gases.

1.14. Fire

There was no post crash explosion or fire, other than a small flash fire that occurred around the number two engine.

1.15. Survival Aspects

1.15.1. Search and Rescue

No emergency locator transmitter signal was received from the accident aircraft and its crew. Commencing at 1449 hrs (2249 hrs), alerting actions were taken by ATC. The GFS, Police, Fire Services, Marine Police (MARPOL), Marine Rescue Co-ordination Centre (MRCC) and Civil Aid Service (CAS) were alerted. However, search action by commercial helicopters in the vicinity had already started prior to this time (around 10 to 15 minutes after loss of radio contact with the accident aircraft).

Helicopters and vessels commenced an air and sea search to the south of Lantau Island. The first GFS SAR helicopter became airborne 41 minutes after the accident occurred. Two more GFS helicopters took part in the search later. The Marine Police were informed 25 minutes after the accident and four vessels were deployed to search in at least three different areas to the south of Lantau. Two more vessels from Marine Department joined in a little later. Personnel from Fire Services, Police, the GFS and CAS commenced a ground search within an hour of the accident along Tung Chung Road to the south of Lantau Island.

Crash sites ‘A’ and ‘B’ were finally located on a remote hillside to the West of Tung Chung Gap. The first sighting of wreckage was recorded at Site ‘A’ at 1717 hrs (0117 hrs), two hours and forty-five minutes after the accident. Search efforts were then concentrated on the hillside west of Tung Chung Road. The main wreckage and the occupants of the aircraft were located at Site ‘B’ at 1846 hrs (0246 hrs), an additional one hour and twenty-nine minutes later (see Table 1).

Organization	**Time alerted (local time)**	**Resources deployed**	**Search area**	**Search commencement time (local time)**	**Stand down time (local time)**
Helicopters Hong Kong	2237 hrs	Helicopter B-HJR	Cheung Chau	2237 hrs	2245 hrs
GFS	2249 hrs	Rescue helicopter 84	South Lantau (Silvermine coastline, Cheung Chau, LT06 and LT04 helipads	Took off at 2313 hrs	Landed 0023 hrs
		Rescue helicopter 83	Tung Chung Bay	Took off at 0007 hrs	Landed 0126 hrs
		Pilots, engineer and ground crew	Along Tung Chung Road and hill side near Pak Kung Au		
		Rescue helicopter 51	Tung Chung Bay	Took off at 0143 hrs	Landed 0151 hrs
Police	2321	Mobile patrol cars	Cheung Chau Island, Tung Chung Road and adjacent villages, Pak Kung Au, Shek Mun Kap, Cheung Sha, Chi Ma Wan and Pui O Beaches, Lantau Road South Landing Sites LT01-04, 07, 09, 11,12, 16, 32 and 33	2326	2341
Police	2328	Officers from Lantau North South Division	Lantau Island	2326	0123

Organization	Time alerted (local time)	Resources deployed	Search area	Search commencement time (local time)	Stand down time (local time)
FSD	2317 hrs ATC informed FSCC that they had lost contact with a GFS helicopter at 2233 hrs at Tung Chung Pass. (No FS assistance required at that moment) Requested FS assistance at 2330 hrs.	Personnel and equipment, fire appliances, ambulances and fireboats from various FSD echelons.	Along Tung Chung Road to South Lantau until Cheung Sha. An area of about 2000 x 1500m at hillslope of Lantau Peak, and coastal area between Lantau Island and Cheung Chau.	2331 hrs	0116 hrs found wreckage on hillside adjacent to Fung Wong Trail 300 metres from Tung Chung Road. 0246 hrs found main wreckage. 0252 hrs found crew. 0310 hrs stood down (stop message dispatched).
MARPOL	2256 hrs	4 vessels	Areas defined by MARPOLOC: (i) 1356 – 1358 (ii) 1256 – 1201 (iii) 1156 – 1101		0125 hrs
MRCC	2322 hrs by MARPOL	2 vessels (MD22 and MD30)		0013 hrs	0125 hrs
CAS	2335 hrs	Mountain Rescue Company	Pak Kung Au	0128 hrs	1800 hrs

Table 1 – Summary of the search and rescue operation

1.15.2. Aircrew helmets

The pilot was not wearing a helmet at the time of the accident. His helmet was serviceable but he elected to leave it in the flying clothing store. The aircrewman was once seen to be wearing his helmet prior to manning the aircraft but the pattern of head injuries sustained, coupled with the discovery of a bloodstained GFS-issue headset, and the fact that the helmet was found separated from the aircrewman underneath the wreckage, indicated the possibility that he was not wearing his helmet at the time of the first impact.

1.15.3. Crew seats and restraints

The two pilot seats consisted of a laminate structure that included the seat cushion and the backrest. Each of the seats was attached to two running rails made of aluminium alloy. The rails were bolted onto the inset nuts in the composite sandwich floor panels. The floor panels were mounted onto the floor structure by bolts and nuts.

The pilot was restrained by a five-point harness. This harness was attached wholly to the pilot's seat and a quick release box mounted on the lower strap secured the two shoulder straps and two lap straps. Witness statements from the rescue teams confirmed that the harness was still fastened after the impact.

The aircrewman was wearing an air despatcher ('monkey') harness and not a seat harness at the time of the impact. The monkey harness consisted of a heavy-duty waistband that incorporated a quick-release fastening and an ‘umbilical cord’ that could be attached to any one of a number of hard points in the cabin. It was designed for use by an aircrewman who needed to operate, for example, next to an open cabin door whilst retaining a high degree of mobility in operations such as winching. The harness would not have offered any significant restraint during the crash.

1.16. Tests and Research

After the accident the engines were returned to Turbomeca for analysis and the transmission system and the reconstructed rotor blades were analysed by the Hong Kong City University. It was confirmed that all these systems were functioning normally at the time of first impact.

The HMUs of both engines were tested by the engine manufacturer in accordance with the acceptance test specifications, and were found to be functioning normally. The data stored in the memories of both FADECs were retrieved by the BEA and indicated that the FADEC of the number one engine was shut down approximately five seconds before the number two engine. The examination of the engines by the engine manufacturer confirmed that the engines were operating and delivering power normally before the first impact. The laboratory analysis of the soot deposits around the number two engine indicated that if there was a fire, it was non-sustained.

The GPS was tested by BEA and the manufacturer: the system was operating correctly at the time of the first impact with terrain, in the ‘direct to’ mode with CC04 as the next waypoint.

The two personal locator beacons of the crew were tested. The 'self-test' facility functioned correctly but no signal was emitted due to the fact that both semi-rigid aerials had fractured at the joint between the aerial and the main body of the device.

The one remaining landing light bulb (located in the right hand landing light) was removed for detailed examination: it was confirmed that the filament had been subjected to a cold break and so the light was 'off' at the time of the accident.

A functional test of the AVAD system was carried out using another GFS EC155B1 helicopter. Both the "One Hundred Feet" and "Check Height" messages functioned correctly (see paragraph 2.1.3.2.). It was also confirmed that the device was not fitted with a 'mute' facility.

The primary cockpit instrument display for the aircraft and engine systems (the 'Vehicle and Engine Management Display' or VEMD) was tested by the BEA and was found to have been functioning correctly at the time of the accident.

The firing squib was removed from the ADELT deployment mechanism and was found to be undamaged. When tested, it fired successfully.

1.17. Organizational and Management Information

1.17.1. Government Flying Service

The GFS is a disciplined service department of the Government of the Hong Kong Special Administrative Region employing over 200 staff. Specific roles include Search and Rescue, aeromedical services, aerial fire fighting, tactical police support, other law enforcement activities and the carriage of VIPs.

A mixed helicopter fleet was operated at HKIA at the time of the accident, comprising three Eurocopter AS332L2 Super Puma and five EC155B1 helicopters. The Super Puma was introduced to service during the period late 2001 / early 2002 and the EC155B1 was introduced during the period late 2002 / early 2003. These types replaced the previous Sikorsky S76 and S70 Blackhawk fleets. Two Jetstream 41 aeroplanes were also operated.

1.17.2. Classifications of casevac by the GFS

The GFS classified its casevac missions in its Operations Manual as follows:

Type A+ : Casualty evacuation involving life-threatening or limb-threatening cases.

Type A : Casualty evacuation involving emergency medical conditions other than life-threatening or limb-threatening.

Type B : Casualty evacuation involving conditions of a lesser emergency.

1.17.3. GFS performance targets

The GFS published comprehensive key performance targets for their public service activities together with measures of achievement of those targets. The performance target for a casevac task was the ‘on-scene’ arrival time (the time between the receipt of the tasking request by GFS operations and the arrival of the helicopter at its initial destination for patient pick-up). The on-scene time for Type A+ and Type A casevacs was 20 minutes for any GFS helicopter landing site within the Island Control Zone (CTR Island Zone) and 30 minutes for any such site outside the Island Control Zone.

1.17.4. Safety Management Systems

Although the GFS had a quality system for the internal monitoring of standards within flight operations, there was no documented system for the proactive identification of hazards and systematic management of risk.

1.18. Additional Information

1.18.1. Previous activity

On the evening of the accident, the pilot was working a sixth consecutive shift of duty and had just commenced the third consecutive night shift. The next three days were rostered ‘off’. On the first night shift, there was no call and the pilot slept most of the time. He had commanded a casevac flight in an EC155B1 helicopter during the early hours of the morning of the second night shift with a different aircrewman. This involved the same intermediate and final destinations as the accident flight. The aircraft departed from HKIA on 25 August at 1725 hrs (26 August at 0125 hrs) destined for landing site CC04 for patient pick up. The pilot attempted to route via Tung Chung Pass and Gap, which was marginally more direct than via Silvermine Pass, but he was prevented from doing so by low cloud and so he decided to turn back and take Silvermine Pass instead. The aircraft then continued to Central Heliport on Hong Kong Island for patient disembarkation. On completion, the helicopter returned to HKIA and landed at 1755 hrs (0155 hrs). The pilot then slept until the end of the shift.

Pilots and aircrewmen were expected to have gained sufficient sleep during the rest period immediately preceding a ‘C’ shift. It was known that the pilot possessed a folding camp bed that could be used for the purpose of achieving rest at the GFS. During the subsequent rest period that commenced on the morning of 25 August, the pilot is known to have gained two hours sleep at some time in the afternoon. During the ‘C’ shift commencing 1359 hrs (2159 hrs) 25 August, he flew a casevac mission in the early hours of the morning and slept after the flight for a period that totalled not more than four hours. The shift ended on 25 August at 2259 hrs (26 August at 0659 hrs) and the pilot went off duty at 2309 hrs (0709 hrs). On arrival at home, between approximately 0001 hrs (0801 hrs) and 0200 hrs (1000 hrs), there was an additional two-hour opportunity for sleep. It is not known if he actually managed to sleep during this time. There were detailed witness statements to suggest that after this he remained awake and active until reporting for duty later that night on 26 August (see Figure 1). There was also one witness statement indicating that the pilot was in his bedroom during the period 0700 hrs (1500 hrs) to 1000 hrs (1800 hrs).

On the evening of 26 August, the pilot returned to work by car with a GFS colleague. In conversation during the journey the pilot expressed his growing concern in relation to the difficulties of achieving the various performance targets that had been set by the GFS (see paragraph 1.17.3.).

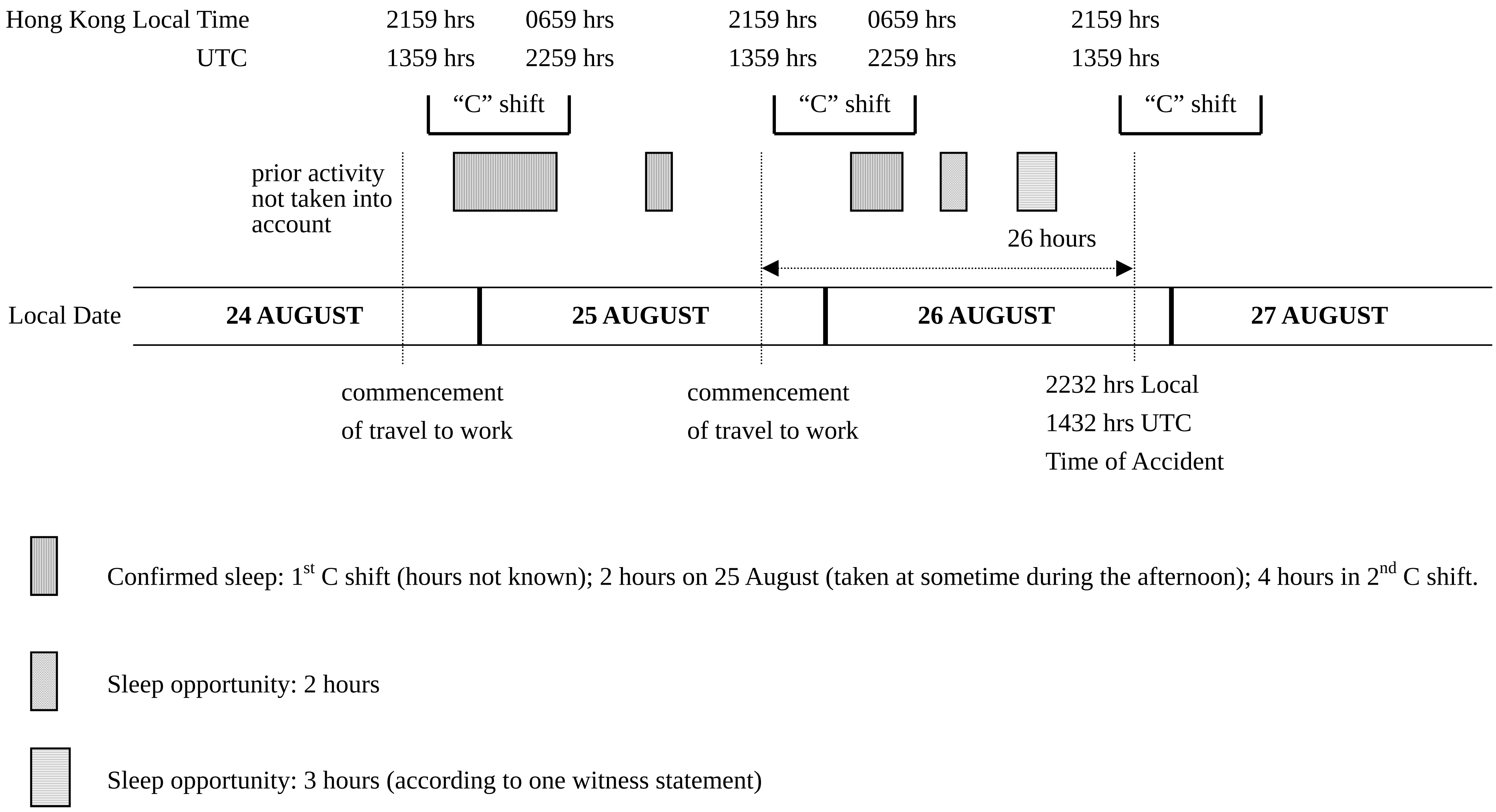
1.18.2. Crew's night vision

The pilot and aircrewman left the well-lit building of the GFS just after 1420 hrs (2220 hrs). The accident occurred around ten minutes later at 14:31:53 hrs (22:31:53 hrs). In such a short time the night vision of both crewmembers would not have developed to its full extent.

1.19. Useful or Effective Examination Techniques

Not applicable.

Figure 1


Hong Kong Local Time
UTC
2159 hrs
1359 hrs
0659 hrs
2259 hrs
2159 hrs
1359 hrs
0659 hrs
2259 hrs
2159 hrs
1359 hrs
"C" shift
"C" shift
"C" shift
prior activity not taken into account
26 hours
Local Date
24 AUGUST
25 AUGUST
26 AUGUST
27 AUGUST
commencement of travel to work
commencement of travel to work
2232 hrs Local
1432 hrs UTC
Time of Accident
Confirmed sleep: 1st C shift (hours not known); 2 hours on 25 August (taken at sometime during the afternoon); 4 hours in 2nd C shift.
Sleep opportunity: 2 hours
Sleep opportunity: 3 hours (according to one witness statement)

2. ANALYSIS

2.1. Operation of the aircraft

2.1.1. Crew qualifications, experience and training

The pilot and aircrewman were properly qualified and appropriately experienced in their respective roles in order to be able to undertake the casevac task. Both were entirely familiar with the terrain surrounding HKIA.

The pilot was an experienced helicopter pilot and, although relatively new to the EC155B1, had accumulated 138 hours PIC on this type. It is not believed that his experience level on the EC155B1 had any bearing on the causes of the accident.

Since there was no requirement for the GFS to operate their EC155B1 helicopters in IMC, none of the GFS pilots who flew the type held an instrument rating for this helicopter. The pilot of the accident flight had accumulated a total of 4 hours of IF in the EC155B1 (including those hours flown during the type conversion) and had achieved the operator's IF MCT requirements through regular training flights in the AS332L2 Super Puma. He had passed an IMC operator proficiency check in this type only 11 days previously. Consequently, his basic instrument flying skills and knowledge should have been more than adequate to enable him to fly the EC155B1 safely at night.

2.1.2. Crew duty

Although the pilot's duty and rest periods preceding the accident flight complied with the GFS FTL Scheme, there was some doubt as to whether or not he was properly rested before commencing the night shift on the evening of 26 August 2003. During the preceding 'C' shift that lasted from 1359 hrs to 2259 hrs (2159 hrs on 25 August to 0659 hrs on 26 August), he had flown one casevac mission from 1725 hrs to 1755 hrs (0125 to 0155 hrs): see Figure 1 in paragraph 1.18.1. He then slept after the flight for about 4 hours. The shift ended at 2259 hrs (0659 hrs) and he departed the GFS at 2309 hrs (0709 hrs). Between 1300 hrs (2100 hrs) on 25 August, and the time of the accident (a period of 26 consecutive hours: see Figure 1), the pilot achieved a maximum of four hours of unbroken sleep.

It is unlikely that the pilot gained sufficient undisturbed sleep during this period of duty. It would have been important for him to gain adequate sleep during the following rest period, but there is evidence to suggest that, apart from a sleep opportunity of two hours, he remained fully awake and active throughout the day. However, one witness statement raised the possibility of a further 3-hour sleep opportunity. The investigation team was unable to resolve the discrepancies between the statements.

It is not possible to determine with certainty if crew tiredness contributed to the accident, but there are significant indicators suggesting that this may have been a factor. Even accounting for the possibility of the short sleep opportunities during the day, the pilot had experienced a shift in his work/rest cycle over the previous 72 hours. Circadian disruption is particularly marked when a transition takes place with a 12-hour swap from day to night schedules. Adaptation to such changes takes several days[7].

Performance deficits following such a disruption would be insidious, unlikely to be noticed by the pilot, and more likely to occur after prolonged wakefulness.

In addition, it is known that "……fatigue can create variable performance effects, not necessarily just a smooth and consistent decline over time. Therefore, good performance can be punctuated with significant decrements. If a particular performance lapse coincides with an operational demand that is not met successfully (e.g. slowed reaction, memory loss, decreased vigilance), an error, incident or accident could result. Therefore, fatigue-related performance decrements create operational safety risks."[8]

The causes and consequences of fatigue were addressed during the two-day GFS CRM course attended by the pilot in 2001, so he would have been aware of the need to ensure that he was adequately rested before commencing a shift. It is recommended that GFS

[7] Supplement to National Transportation Safety Board, Aircraft Accident Report Number PB-94-910406 NTSB/AAR-94/04. Uncontrolled collision with terrain. American International Airways Flight 808, Douglas DC-8-61 Registration N814CK. U.S. Naval Air Station, Guantanamo Bay, Cuba. August 18, 1993.

[8] Bagian, T.D., & Rosekind, M.R. (2002). Human Factors in Aerospace Systems Design and Operations. In Fundamentals of Aerospace Medicine, 3rd edition, edited by Roy L. DeHart and Jeffrey R. Davis, published by Lippincott Williams & Wilkins, Chapter 24.

should reinforce CRM training on the subject of sleep hygiene.

2.1.3. The accident flight

2.1.3.1. Pre-flight

The aircrewman reported for duty 37 minutes prior to the shift commencement time of 1359 hrs (2159 hrs) and the pilot arrived with 13 minutes to go. The request for the casevac was received at 1420 hrs (2220 hrs). This probably afforded sufficient time for the pilot to change into flying clothing and carry out his pre-flight duties in an unhurried manner in preparation for the possibility of an emergency callout.

However, it was noted that GFS procedures could lead to the launch of an emergency response flight with the crew being inadequately prepared for the task. On the one hand the Operations Manual recognized the importance of pre-flight preparation by stating a standard reporting time of 45 minutes before first take off and yet, on the other hand, there was no such allowance immediately prior to the commencement of a shift. A crew could be tasked to carry out an emergency response flight as soon as their shift commenced, and since any duty worked immediately before shift commencement time was not included in contracted hours or FTL records, there was little or no incentive for pilots and aircrewmen to arrive at work before the unofficial 15 minute report time. Furthermore since there was no formal handover from aircrew on the ‘B’ shift to the solitary crew on the ‘C’ shift, any relevant information of a practical nature (such as weather conditions) that was obtained during the earlier shift was not highlighted and passed on. It is recommended therefore that the GFS change the timings of their aircrew shifts in order to provide pilots and aircrewmen with an officially sanctioned period of time at the beginning of a shift that will enable them to carry out their pre-flight duties in an unhurried manner and, during which, they will not be required to fly.

It was clear from the CVR that the pilot had no knowledge of the destination at the time intra-crew communications were established via the intercom in the aircraft. It was evident therefore, that no pre-flight crew briefing or intra-crew communication regarding the mission took place either in the flight planning room or elsewhere prior to manning the aircraft. At no stage subsequently, did the pilot articulate to the aircrewman any plan or strategy concerning the intended management of the flight. For example, the earliest time that the aircrewman had any knowledge of the route that the pilot had decided on was during the ground taxy to the take off point. The pilot also did not brief the planned altitude or any contingency actions in the event that the actual weather conditions encountered were worse than anticipated. These omissions are considered to be highly significant. The 1400 hrs (2200 hrs) METAR issued for HKIA (see paragraph 1.7.1.), which the pilot probably read during his self-briefing prior to flight, gave the lowest amount of cloud over the airfield as FEW (that is to say, a maximum of 1/4 cover) with a base of 1,400 feet. However, a wind from the South South East should have alerted him to the likelihood of significantly greater amounts of orographic cloud over the hills of Lantau with a lower cloud base on the windward side of the Island. This is particularly relevant since he had to abandon his attempt to cross Tung Chung Gap during the previous night at around 1730 hrs (0130 hrs) when the cloud base over HKIA was only marginally lower. The METAR issued immediately prior to this flight for HKIA on 25 August at 1700 hrs (0100 hrs on 26 August) was as follows:

Surface wind 150M / 16 kt gusting to 26 kt, visibility 10 km or more, FEW (1 or 2 oktas) with a cloud base of 1,200 feet, scattered cloud (3 or 4 oktas) with a cloud base of 2,500 feet, temperature +29°C, dew point +24°C, QNH

1008, with no significant meteorological conditions in the approach and departure areas.

It is highly likely that the lack of effective communication prior to departure between the two crewmembers contributed to the pilot's subsequent lack of situational awareness and adversely affected his decision-making processes during the flight.

Although ATC did not include the QNH in the departure clearance and the pilot did not listen to the ATIS before departure, he set the correct QNH (1011 hPa) on the PFD. This indicated that he consulted the 1400 hrs (2200 hrs) METAR issued for HKIA in the GFS flight planning room during his self-briefing before manning the aircraft. However, the subscale on the standby altimeter was found to read 1010 hPa instead of 1011 hPa. The reasons for this discrepancy are unknown but it is possible that, in a dim cockpit, the pilot misread the instrument subscale graduations. Neither the omission in the ATC clearance nor the incorrect pressure setting was considered to have any bearing on the subsequent accident.

2.1.3.2. After takeoff and cruise

When exiting the ATZ at Tung Chung Pass at night, pilots were expected to climb to 1,500 feet. This would ensure that both the requirements of the AIP (see Appendix K) and the informal procedures of the GFS (see paragraph 1.6.6.4.) were complied with.

Before take off, the pilot selected 1,500 feet on the ALT A Mode of the AP. It is clear that initially he intended to level off at that altitude but subsequently reselected a figure of 1,200 feet when passing 600 feet in the climb, presumably because he judged that he would be unable to remain clear of cloud at 1,500 feet AMSL. The decision to maintain a lower altitude of 1,200 feet AMSL complied with the AIP but was inconsistent with GFS teaching. Moreover, it guaranteed a maximum of only 100 feet terrain clearance when crossing Tung Chung Gap, which equated to a clearance of around 60 feet from the top of the road light poles. Given that the casevac was classified as Type 'A' (non-life-threatening) this represented an unnecessary level of risk for a night mission, especially in view of the marginal weather conditions ahead. Whilst a crossing altitude of 1,200 feet AMSL was in compliance with the exemption to the Low Flying Rule (see paragraph 1.6.6.3.), the fact that the GFS specified no minimum en route operating height above the surface for night casevac missions gave an excessive amount of discretion to the pilot. It is recommended that the GFS specify an absolute minimum en route height above the surface for night casevac operations.

Immediately after take-off, the pilot noted that the weather over Tung Chung Gap looked "OK". Passing 880 feet in the climb he made a comment in relation to the difficulty of achieving the twenty-minute performance pledge at night and that if there were any cloud to "hinder" their progress to Cheung Chau via the Gap then it would not be "OK". This indicated that he had not yet formed a judgement as to the suitability of the weather conditions over the Gap.

Given that the meteorological visibility at HKIA was in excess of 10 km and the cloud cover and base in the immediate vicinity of the aerodrome were only FEW and 1,400 feet respectively, it is likely that the aircraft was initially flying clear of cloud after levelling. If so, the pilot's decision to accelerate to nearly 140 kt IAS was not unreasonable. It is not possible to draw any definitive conclusions about the actual external visual scene that existed at this time but the brief communications between the pilot and aircrewman suggested that they might have been interpreting the scene ahead of the aircraft in a slightly different manner. Both crewmembers would at first have been able to see the general outline of the valley and the road lights leading into the distance towards Tung Chung Gap. However, it was clear from the CVR that the aircrewman (who would have been positioned behind the pilot's seat, assisting with lookout) was soon concerned that the conditions ahead seemed "very marginal" and that the road lights seemed to him to be obscured. The pilot concurred that the conditions ahead were "very marginal". Even at this relatively early stage of the flight, when there was ample opportunity to turn away and attempt an alternative routeing via Silvermine Bay, both crewmembers were already aware of the deteriorating conditions ahead. The pilot's comment "able to cross it – this is better than yesterday" (referring to the flight during the previous night) indicated, however, that he believed that he had sufficient external visual cues to permit a successful crossing of the Gap. It is difficult to reconcile the pilot's failure to perceive a potential hazard directly ahead in the flight path of the aircraft with the aircrewman's observation that the road lights ahead were obscured, although short-term fatigue may have contributed to the pilot's lack of situational awareness. If the lights were indeed obscured, a safe crossing of the Gap would not have been possible. The pilot may have been affected by *confirmation bias,* a form of cognitive tunnel vision, which would have interfered with his ability to analyse the visual scene ahead (see paragraph

2.4.1.). In any event, the comment from the pilot seems to have elicited the tacit endorsement of the aircrewman for a continuation of the flight towards the Gap for he only made one subsequent brief interjection to ask if the pilot was still visual (which suggests that the aircrewman had by this stage lost contact with the visual references ahead). In spite of the pilot's apparent confidence it seems very likely that from the time of levelling at 1,200 feet the road lights that illuminated Segment 'C' of the road (see Appendix C) at the very top of the valley, which would have been critically important as visual cues, were obscured by low cloud (see Appendix M). It is possible that the shape of the cloud hanging over and obscuring the ridgeline could have been perceived by the pilot as the ridgeline itself.

On two subsequent occasions the pilot indicated that he was still in visual contact, and although the CVR gave no clue as to which external visual references he was using to navigate, the recording provided clear indications of a progressive worsening of the forward visibility for the remainder of the flight. It is logical to conclude that the cloud base was gradually lowering and the cloud cover gradually increasing as the helicopter approached the Gap, such that the aircraft was eventually flying at the very base of the cloud. Even if the crew had not been aware of their exact terrain clearance at an altitude of 1,200 feet AMSL over Tung Chung Gap, they would certainly have understood that a safe crossing of the Gap would depend critically on the helicopter remaining precisely over the lights of the road, which were all functioning normally at the time of the accident. Therefore it is highly likely that, as the flight progressed, the pilot was becoming increasingly reliant on these lights as his primary external visual reference. Accordingly, the helicopter followed a flight path towards the Gap that initially followed the general direction of the road. As the aircraft approached the Gap, the flight path became progressively more closely aligned with the road (see Appendices C and M).

The further the helicopter continued towards Tung Chung Gap, the narrower the valley became. At an indicated airspeed of just less than 140 kt, the necessary airspace for a 180-degree escape turn was rapidly reduced. Shortly after take off the pilot had noted that it would be difficult at night to meet the twenty-minute response time specified for this casevac mission, which suggested that he felt under pressure to achieve this target and may help to explain why he remained at an IAS that was increasingly inappropriate for the conditions. It would have been more prudent to reduce the airspeed, commensurate with the reduction in visibility, to a minimum of around 60 to 80 kt. This was particularly relevant given that the mission was for a non life-threatening case and so should have had an associated level of risk little different to that of a commercial air transport flight.

During the last 37 seconds of the flight, ATC made four radio transmissions to the pilot of the accident aircraft, three of which were made in the last 19 seconds of flight. The first of these requested that he squawk but instead he made a conscious decision to leave the transponder switched to standby until past the Gap, presumably because he did not want his concentration to be broken from the task of navigating by reference to the road lights. All of the calls were of a routine nature and were acknowledged immediately by the pilot in a calm and confident manner so it is unlikely that they added significantly to his workload. Indeed, throughout the flight there was no detectable anxiety or stress in the pilot's R/T transmissions or his comments recorded on the CVR.

With just over 1,200 metres to run to the first point of impact, the pilot commented to the aircrewman that the way ahead was "very marginal" but that he was still "visual". It must be assumed that the pilot still believed that he could distinguish a way through the Gap and that, until the final seconds of the flight, sufficient external visual references were continuously available to enable the aircraft to be navigated. Had the pilot lost visual contact completely with the external cues on the surface before crossing the Gap he would presumably have taken the standard actions to be followed in the event of inadvertent entry into IMC (detailed in paragraph 1.6.6.5.) and initiated an immediate climb to minimum safe altitude.

With 600 metres to run the track of the helicopter was now precisely over the lights of the road (see road Segment 'B' in Appendix C, Figure 2, and Appendix M) but with a little over 200 metres to run the direction of the road changed rather abruptly by some 30 degrees to the left whilst still climbing to its highest point at Tung Chung Gap (see road Segment 'C' in appendix C, Figure 2). Had the pilot been in visual contact with the lights of road Segment 'C', he would undoubtedly have turned the aircraft to the left to follow them in order to maximize his terrain clearance. Instead, the track of the helicopter continued unchanged (see Appendix C, Figure 2, and Appendix M). It is reasonable to conclude that the pilot lost visual reference with the road lights within the last seconds of the flight, possibly due to a momentary distraction or inadvertent entry into IMC. Had the aircraft been flown at a lower IAS that was more appropriate to the conditions, it is possible that the change in road direction would have been detected. Instead, he continued to maintain his track, possibly in the belief that the helicopter had already passed the highest point of the road at the Gap and was now safely in the clear airspace beyond. In reality and in relative terms the track of the aircraft diverged from the road and towards the high ground to the west of the road and the first point of impact. There was no evidence from the FDR of significant turbulence that could have caused an unintended flight path deviation or that the pilot was aware of the rising ground ahead of the aircraft since the aircraft impacted with terrain in an essentially straight and level configuration. Additionally, the CVR indicated that the crew believed the flight to be proceeding normally.

Appendix P shows the display on the cockpit ND screen with the point of departure (at GFS) and destination (CC04) connected by a blue track line and the accident site ‘A’ significantly to the right of this track. Since the GPS was operating in the ‘direct to’ mode with CC04 as the next waypoint, it is clear that the GPS was not being used to provide navigational assistance.

When looking towards the head of Tung Chung Valley in the direction of flight the pilot's lack of fully developed night vision may have led to a marginal reduction in his ability to perceive a clear outline of the terrain. However, this was not considered to have been a significant contributory factor in the sequence of accident causation since his primary external visual cues for the purposes of orientation and navigation in the latter stages of the flight were the road lights. At an altitude of only 1,200 feet AMSL, if the visibility had deteriorated to the extent that these visual references on the surface were no longer available even fully developed night vision would not have enabled the pilot to see the outline of the terrain ahead.

Over the Gap the lowest point of cloud was significantly less than 1,700 feet AMSL and it can be deduced from the available evidence that the flight visibility was significantly less than 5 km. Consequently the pilot contravened the GFS Operations Manual by flying with a cloud base of less than 600 feet AGL and a visibility of less than 5 km (see paragraph 1.6.6.2.).

Since the radio altimeter bug on the ND was set to zero (which was the normal practice within the GFS for night casevac operations) no "Check Height" transmission was made by the AVAD to alert the pilot to the proximity of rising ground and no “One Hundred Feet” advisory call was transmitted to the pilot, probably as a consequence of the rapid rate at which the ground came up to meet the aircraft. During the last 19 seconds of flight the terrain clearance immediately underneath the helicopter flight path decreased by a total of 660 feet and the 100 feet figure was reached with only 1.9 seconds of flight remaining to the time of first impact. It should be noted, however, that the AVAD was designed for use over water and not for use over hilly terrain.

The indications from the radio altimeter itself would probably not have been of any material benefit to the pilot. Since he was attempting to maintain visual contact with the surface it is unlikely that he would have managed to include the instrument in his scan. Even if he had been consciously aware of its readings, the indicated rate of reduction of the terrain clearance would have been relatively constant, irrespective of the actual altitude of the aircraft.

2.1.3.3. Post impact

After the first impact with terrain, the helicopter rapidly became uncontrollable due to the loss of the main rotor blades.

The analysis of the FADECs of both engines confirmed that the number one engine was shut down approximately five seconds before the number two engine. The earlier shutdown probably occurred as a result of the activation by the pilot of the left hand fuel shut off control lever. The number two engine shutdown was probably caused by massive loss of fuel that resulted from the damage to the fuel tanks during contact with the surface at Site ‘A’.

The post-accident positions of the left hand engine and electrical system controls were consistent with the theory that the pilot remained conscious immediately after the first point of impact and made an attempt to shut down the main aircraft systems before impacting with the surface for a second time. Whilst it is possible that the DC emergency cut off switch on the overhead panel could have been knocked to the PWR OFF position by force of the impact or by the rescue crews, it is most unlikely that the left hand engine control switch could also have been moved accidentally. Examination of the wreckage indicated that the safety device was still intact and had been moved to the ‘unsafe’ position. The switch had then been placed to IDLE (see Appendix E, Figure 4). The position of the left hand engine fuel shut off control lever (at shut off) provided further confirmation of the theory.

The guarded landing light switch on the pilot's collective lever may also have been selected 'on' by the pilot, but it is equally possible that the switch was inadvertently knocked into that position by the rescue crews.

There were three main reasons for the absence of a post crash fire at Site 'B' (other than a small post impact flash fire around the number two engine). First, much debris from the fuel system was located at the end and down slope side of the score-mark at Site 'A' indicating that massive and rapid fuel leakage had occurred immediately after first impact with the ground surface. Second, atmospheric conditions had moistened the ground vegetation, thus reducing its flammability. Third, at Site 'B' the aircraft came to rest with the engines pointing vertically upwards and not in contact with any flammable material.

2.2. Airworthiness considerations

2.2.1. Impact load analysis

With reference to the aircraft speed at the first impact at Site 'A' and the dimensions of the crash sites, the aircraft speed and the duration at different phases of the crash can be estimated. The results of the estimation are presented in Appendix L.

At the first contact point at Site 'B' (Point 3 in the diagram in Appendix L), the helicopter made contact with the ground at an estimated downward vertical speed of approximately 25 metres per second, and a forward speed of 40 metres per second.

According to an analysis carried out by the aircraft manufacturer, the bottom structure of the EC155B1 was capable of withstanding an impact load at a speed of 7 metres per second (equivalent to a deceleration of around 20 g) without upper structure collapse. Their analysis indicated that the deceleration levels experienced at Site B (corresponding to a downward velocity in the order of 25 metres per second) exceeded 30 g. They concluded that the impact at this site was outside the survivable crash envelope of this helicopter type. However, this analysis is theoretical in nature and the Report concludes elsewhere that the accident was potentially survivable.

2.2.2. ADELT

The ADELT was not deployed and remained locked inside the carrier underneath the tail fenestron. It was revealed during the investigation that the left, the right, and the aft frangible switches were totally separated from the badly damaged fuselage during impact. The glass tube of the front frangible switch remained intact and the electrical wires connecting to it were broken. In a severe impact as experienced in this accident, the destruction of a frangible switch or breakage of its electrical wires would necessarily prevent the completion of the squib triggering circuit and consequently the deployment of the ADELT. The frangible switches were designed to sense the impact by the breakage of the glass tubes and eventually deploy the ADELT. However, even though they were damaged as a result of the impact the device was still not deployed. The fact that the squib fired successfully when subsequently tested demonstrates that if any of the frangible switches, the hydrostatic switch or the saline switch had been closed at the time of the accident, the ADELT would have been ejected from the ADELT compartment by spring force.

2.2.3. Automatically Activated ELT

In accordance with the definitions in EUROCAE ED-62, an automatic ELT shall have the means to detect the occurrence of a crash, automatically activate the transmitter and radiate a signal through an antenna. To be more precise, an automatic ELT should be referred to as an Automatically Activated ELT. An Automatically Activated ELT can only be classified as an Automatic Fixed ELT or an Automatic Portable ELT, neither of which was installed on the accident aircraft. If either had been installed, a distress signal would have been transmitted shortly after the crash to allow the search and rescue units to locate the wreckage.

Hong Kong Airworthiness Notice No. 27 Issue 2, dated 30 October 2001 only required Performance Class 1 and Class 2 helicopters for which the individual Certificate of Airworthiness was first issued after 1 January 2002 (the Certificate of Airworthiness for the accident aircraft was first issued on 20 December 2002), operating on flights over designated land areas, were to be equipped with at least one automatic ELT. Since there were no designated land areas in Hong Kong, this requirement was not applicable to the accident helicopter. However, the post-accident search and rescue activity indicated that it could be difficult to locate wreckage over land areas in Hong Kong at night in conditions of relatively low visibility. Therefore, it is recommended that the CAD review the requirement for Performance Class 1 and Class 2 helicopters flying for the purposes of public transport to be equipped with an Automatically Activated ELT.

2.2.4. Seat and floor structure

The Eurocopter EC155B and EC155B1 were the latest variants of the Aerospatiale SA365 family. The SA365C, the first aircraft model of the family, was type certificated by the Direction General de l’Aviation Civile (DGAC) on 4 July 1978. The type certification basis for the SA365C was FAR 29 Amendments 1 through 11.

Eurocopter applied to DGAC for type certification of the EC155B on 20 November 1997. The certification basis of the EC155B was

Joint Airworthiness Requirements (JAR) 29, first issue effective on 5 November 1993. However, due to a request by Eurocopter, the requirements of the 'Emergency Landing Conditions' reverted to the FAR 29.561(b)(3) Standard at amendment 29-16, dated 13 October 1964, which prescribed the emergency landing ultimate load factors as 1.5 g upward, 4 g forward, 2 g sideward, and 4 g downward. The JAR 29.561 Standard, at the first issue dated 5 November 1993, prescribed emergency landing ultimate load factors as 4 g upward, 16 g forward, 8 g sideward, 20 g downward and 1.5 g rearward. The information provided by Eurocopter indicated that the emergency landing ultimate load factors demonstrated for structural substantiation of the seat installations were 3 g upward, 6 g forward, 3 g sideward, and 6 g downward.

Eurocopter applied to the DGAC for type certification of the EC155B1 on 7 February 2001. It inherited the same reversions to the FAR 29 Standard as the EC155B as mentioned above[9].

The following table presents a comparison of ultimate load factors from the above-mentioned requirements.

[9] The only significant difference between the EC155B1 and the EC155B was the choice of engines. The EC155B1 was fitted with Turbomeca Arriel 2C2 turboshaft engines, which delivered more power than the Arriel 2C1 turboshaft engines that equipped the EC155B.

Requirements / Load Directions	FAR 29.561 (b)(3) at Amendment 29-16, dated 13 October 1964	JAR 29.561 (b)(3) at the first issue, 5 November 1993	Ultimate Load Factors demonstrated by the Aircraft Manufacturer
Upward	1.5 g	4 g	3 g
Forward	4 g	16 g	6 g
Sideward	2 g	8 g	3 g
Downward	4 g	20 g, after the intended displacement of the seat device.	6 g
Rearward	-	1.5 g	-

Table 2 - Comparison of Ultimate Load Factors

When considering the request for the above-mentioned reversions, DGAC and Eurocopter chose to use the principles detailed in the Notice of Proposed Amendment (NPA) 21-7: “Certification procedures for changed products”. This NPA was the result of the harmonisation between the FAA and JAA through the International Certification Procedures Task Force (ICPTF) Working Group formed in 1989. The aim of these principles was to provide guidance for establishing the certification basis for changed products including identifying the conditions under which it would be necessary to apply for a new type certificate. One of the principles was that the applicant for a change to a type certificate would not be required to demonstrate compliance with a later amendment to an airworthiness standard if the applicant could show that such compliance would be “impractical”. Compliance with a later amendment would be considered "impractical" if the applicant could establish that the cost of the design change and related changes necessary to demonstrate compliance with the amendment would not be commensurate with the resultant safety benefit. Based on the argument presented by Eurocopter, DGAC granted the related reversions.

In September 2003 European Aviation Safety Agency (EASA) Implementation Rules Part 21 and the associated Acceptable Means of Compliance and Guidance Material (AMC and GM), which incorporated the principles of the above NPA, were adopted by the major civil aviation authorities in Europe for the certification of changes to aircraft, related products and parts. The AMC and GM gave detailed procedures and guidance for the evaluation and in-depth analysis required to substantiate the impracticality of complying with the latest airworthiness standards. The evaluation, analysis and substantiation had to be documented as part of the applicant's compliance review document. These revised procedures and guidance will require future aircraft variants to be certificated to the latest airworthiness standards applicable at the time.

2.2.5. Personal Locator Beacons

Both the pilot and the aircrewman each carried a PLB in his lifejacket, in accordance with GFS requirements. The aerials of the PLBs were of a semi-rigid type, which were found to have broken at the connector and were separated from the main body of the device. Post accident tests indicated that, although the self-test facility of the PLBs was satisfactory, no distress signals could be transmitted as a result of the loss of the aerials. Had a flexible type of aerial connector been fitted to the PLBs, the aerials would probably have remained attached to their beacons and could have successfully transmitted distress signals upon manual activation. However, since both members of the crew were unconscious or incapacitated, neither was capable of activating his PLB. It is recommended that the manufacturers of the SARBE 7 Personal Locator Beacon review the design of the aerial connector with a view to ensuring that the device continues to function following an accident.

2.3. Air Traffic Control

The departure clearance from ATC did not include an assigned altitude since there was no separation issue at the time, nor did it state specifically that the flight was cleared in accordance with Special VFR. Nevertheless, from his knowledge of local flight operations, the pilot would have recognised the implied need to act in accordance with the requirements of Special VFR, by remaining clear of cloud and in sight of the surface and complying with any instructions issued by ATC. He would also have understood his own responsibility for maintaining clearance from terrain and obstacles.

Since there was no requirement for the pilot to report his altitude, ATC were unaware that he had levelled at 1,200 feet. Later in the flight, when asked by ATC as to what altitude he was requesting, the pilot replied “1,500 feet”. This suited ATC since 1,000 feet vertical separation was, by that time, required between the accident aircraft and another helicopter that was routeing from Hong Kong to Macao along the south coast of Lantau at 500 feet over water. Accordingly, ATC cleared the accident aircraft to "maintain 1,500 feet". The pilot acknowledged this transmission, but instead he remained in level flight at 1,200 feet. The reasons for this decision are unknown, but the weather conditions were already "very marginal" so it seems highly probable that the aircraft was by then flying at the base of the cloud and therefore the pilot felt compelled to remain at that level so as to avoid entering IMC.

2.4. Human factors

2.4.1. Crew Resource Management

The crew did not adhere to a number of the basic tenets of CRM, including intra-crew communication and coordination, decision-making, and the maintenance of situational awareness, despite having attended a CAD-approved CRM course approximately two and a half years previously. For example, a highly significant factor in the promotion of the principles of CRM and a fundamental error management technique is a pre-flight briefing from the aircraft commander. A shared mental model for the flight is more likely to be created if the expectations of the crewmembers are clarified and areas of concern are identified before departure.

Before the accident flight, there was no evidence of a discussion at any time between the two crewmembers as to the manner in which the flight would be conducted. This omission was probably due to complacency generated by the familiarity between the pilot and aircrewman who flew together regularly and the fact that the mission was perceived by the crew as being routine in nature and over a familiar route. It is possible that use of the autopilot also contributed in some way to this complacency. It is likely that the absence of explicit interpersonal communication before departure contributed to the pilot's lack of situational awareness and prevented the creation of a shared mental model for the flight. In consequence it is likely that the two crewmembers had a different understanding, for example, about the significance of the obscured road lights ahead of the aircraft once level at 1,200 feet in the cruise. Despite the aircrewman's apparent concerns, the CVR indicated that the pilot did not recognise the existence of a potential hazard ahead. He may have been affected by *confirmation bias* which would have interfered with his ability to analyse the visual scene ahead: after having committed himself at an early stage to cross Tung Chung Gap he allowed himself to seek only the information that would confirm the correctness of that decision, and ignore any contradictory information. Consequently the alternative option of following a more prudent course of action was not even considered.

The lack of intra-crew communication prior to departure also hindered subsequent crew co-ordination: despite their mutual recognition of the deteriorating conditions during their progress towards Tung Chung Gap, neither crew member suggested selecting an alternative route. The CVR indicated that the level of arousal of both crewmembers remained low throughout the accident flight and that the necessary transition from the informality associated with good weather operating conditions to the heightened state of crew alertness necessary for marginal conditions did not occur. Tiredness of one or both of the crewmembers could have contributed to this low level of arousal.

It is recommended that the GFS reinforce the effectiveness of its CRM training. In particular, threat and error management, situational awareness, intra-crew communication and co-ordination and decision-making training should be emphasised, especially for crews comprising one pilot and one aircrewman.

2.4.2. Pressure to achieve organisational objectives

When interviewed after the accident, the pilot's spouse stated that the pilot had previously expressed his concerns to her about the risks involved in GFS operations and about performance pledges and the significant contribution that they made to stress at work. The issue of performance targets was also at the forefront of the pilot's mind both immediately before and during the accident flight. During the early hours of the morning of 26 August (Hong Kong local time), on his previous night shift, the pilot had abandoned an attempt to cross Lantau Island via Tung Chung Pass and Gap. He turned back and routed via Silvermine Pass instead. Consequently, the GFS 20-minute performance pledge for this flight had not been achieved.

This failure may have been playing on his mind later that evening, for the issue of performance targets was discussed at length with a GFS colleague in the car on the way to work only an hour or so before the accident. Again, just 90 seconds before the time of first impact, the pilot noted that achievement of the pledge would be "marginal".

The most likely explanation for the selection by the pilot of Tung Chung Pass as an outbound route in preference to Silvermine Pass and the reason for continuing towards Tung Chung Gap at normal cruise airspeed, when the more prudent course of action would have been to reduce airspeed and turn back, is that he was anxious to meet the on-scene target time (20 minutes) for the flight.

Although GFS performance targets were not unreasonable, it is clear that the pilot felt himself to be under pressure to perform and that this pressure had its origins in the norms of the GFS. The organisation understandably took pride in its record of achievement in Search and Rescue and other emergency response tasks. A high degree of discretion was granted to aircraft commanders in determining the manner in which an aircraft should be operated on a given mission. However, instructions to crews were unclear in respect of threat and error management and how to minimise risk. As a result, the level of risk for casevac missions was not necessarily matched to the operational need. For example, it was noted that GFS procedures permitted two-pilot night casevac missions to be carried out with no weather minima and no absolute minimum en route height above the surface for non life-threatening medical conditions: weather minima and operating height were left to the discretion of the aircraft commander. For the accident flight, the condition of the patient was not life-threatening: this was essentially a routine air ambulance flight. Given that the level of aviation risk is determined by the degree of urgency of a casevac task, this flight should have been no riskier than a commercial air transport flight.

It is recommended that the GFS establish a documented system for the proactive identification of hazards and systematic management of risk in flight operations.

2.5. Search and Rescue and Survivability

2.5.1. SSR Transponder

There is a specific air traffic procedure regarding the operation of transponders by VFR flights at HKIA. Pilots are normally expected to operate their transponder when instructed. Usually, in order to avoid the activation of the Airborne Collision Avoidance System of international traffic in the vicinity of HKIA, ATC do not instruct a local VFR flight to operate the transponder until clear of international movements.

For single pilot operations, setting the transponder code would require the pilot momentarily to redirect his attention to the transponder control panel. However, a pilot has freedom to delay setting of the transponder until he is comfortable to do so. If the transponder of an aircraft is not turned on, its position in space will not be captured by SSR. Such information may serve as an additional clue for estimation of the last known position of the aircraft in the case of search and rescue following an accident.

During the accident flight, when the helicopter was clear of international traffic, ATC provided the pilot with a transponder code and instructed him to turn on the transponder. As the helicopter was approaching Tung Chung Gap, the pilot elected to delay setting of the transponder until after crossing the Gap. Therefore, the request from ATC to set a transponder code did not impose additional workload on, or distraction for, the pilot. Without the transponder code being transmitted, the position of the helicopter was not displayed on the ATC radar screen.

Although the use of the transponder at this stage of flight was not required, it had some bearing on the subsequent search and rescue effort due to the lack of other positional information regarding the accident helicopter. It is therefore recommended that the CAD review the current practice regarding the operation of the transponder by local VFR traffic to enhance the effectiveness of search and rescue services.

2.5.2. Search and Rescue

A precise location of the accident site could not be established for the following reasons:

i. The ADELT did not activate since it was designed to be activated only when in contact with water. In addition, there was no Automatically Activated ELT installed on the accident helicopter.

ii. The PLBs were not activated due to the crew being unconscious or incapacitated. In any case, the aerials were broken and so no emergency signal would have been transmitted even if one or both of the devices had been activated.

iii. No emergency radio transmission was received from the crew of the helicopter thus the ATC controller had no accurate information on the accident time and the location of the accident site.

iv. The primary radar returns of the helicopter were lost when the aircraft was over the landmass of Lantau Island.

v. There were no SSR returns from the helicopter.

vi. There was no post crash explosion or fire, other than a small flash fire that occurred around the number two engine.

vii. The accident site was in a remote location with no nearby residences.

Without the aforementioned information, the effectiveness and efficiency of the search and rescue effort were seriously hampered. It was also complicated by night-time conditions, rough terrain, rich vegetation and poor visibility. However, it should be noted that only items i and ii were designed specifically for search and rescue.

2.5.3. Survivability

2.5.3.1. Aircraft structural standards

This accident was potentially survivable (see paragraphs 1.13. and 2.2.3.). Survivability is mainly dependent on the g-forces applied to the occupants, and the available evidence suggests that these forces were within the envelope of human tolerance (see Appendix Q). However, survival from the effects of these forces is also dependent on performance of the container, restraints, cabin environment, energy absorbing features and post-crash factors (CREEP). This performance is particularly significant where the crash forces do not exceed 1.25 times the human tolerance limits, as was likely in this accident. According to the US Naval Flight Surgeon's Accident Investigation Reference Manual, 5th. Edition (2001), the goal of a crashworthiness system is to attenuate the impact forces to the human tolerance levels of 25 g in the Gz axis and 45 g in the Gx axis.

The aircraft, being the latest variant of the type, certificated as recently as July 2002, was constructed to a structural airworthiness standard (FAR Part 29 Section 29.561) which first became effective in 1965. Part (b) of the Standard specified that the aircraft structure be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing only.

Analysis of the actual injury severity of the occupants showed that neither had suffered injuries that would necessarily have resulted in certain death. However, the evidence of failure of the pilot's seat, associated floor structure and cabin integrity indicated that the accident was unlikely to have been survivable at the 1965 level of crashworthiness. Had the aircraft been manufactured to the latest standards, which required a stronger structure and seat support, the probability of survival of the pilot in particular would have been high. The outcome for the unrestrained aircrewman was less predictable, even had the higher specification applied.

2.5.3.2. Air despatcher harness

The aircrewman was attached to the aircraft only by means of an air despatcher or 'monkey' harness, consequently his injuries were more severe than if had he been strapped into a passenger seat in the cabin. However, since many operational tasks carried out by the GFS require that aircrewmen be free to move around in the cabin of a helicopter it is impractical for them to be seated and strapped in at all times. Nevertheless, since GFS helicopters are frequently involved in operations that entail significantly higher levels of risk than those associated with commercial air transport, it is recommended that the GFS conduct a risk assessment in order to identify those periods of flight when aircrewmen should be seated in a passenger seat and properly restrained by a seat belt.

2.5.3.3. Helmets

The aircrewman sustained some injuries to the forehead, which would have been unlikely to occur had he been wearing a helmet at the time of the accident. This did not exclude the possibility of an unfastened helmet being ripped off through the force of the impact. However, the absence of specific neck injuries and of helmet strap damage suggested that, if the helmet was being worn, it was not fastened via the chin strap. Its remote location under the wreckage and the fact that a blood-spotted

GFS-issued headset (in addition to the pilot's headset) was discovered, imply that the aircrewman may have been wearing a headset instead of his helmet at the time of the accident. If so, it is not known at what stage of flight the exchange occurred.

There is no doubt that the probability of survival for the pilot would have increased significantly had he been wearing a helmet at the time of the accident.

Since GFS helicopters are frequently involved in operations that entail significantly higher levels of risk than those associated with commercial air transport, it is recommended that the GFS consider making compulsory the wearing of helmets by helicopter aircrew for all tasks.

3. CONCLUSIONS

Numbers in parenthesis refer to the relevant paragraph number in Sections 1 and 2 of this Report.

(a) Findings

1. This accident may be classified as an example of Controlled Flight Into Terrain (CFIT).

2. The aircraft was fully serviceable in all respects. During the accident flight, there was no evidence of failure or malfunction of any of the

aircraft components or systems. (1.6.2., 1.11.4. and 1.16.)

3. Throughout the flight the pilot was both calm and confident and his workload was not excessive. (2.1.3.2.)

4. The helicopter was correctly loaded, sufficient fuel was carried for the flight and the performance of the helicopter complied with ICAO Class 1 standards. (1.6.3.)

5. The pilot was properly licensed, trained and tested and in regular flying practice on the EC155B1 and the aircrewman had met all the GFS training and testing requirements for this type. (1.5. and 2.1.1.)

6. The pilot was experienced overall but, as with all GFS pilots at the time of the accident, he had limited experience on the EC155B1 helicopter type due to its recent introduction to service. (1.5.1. and 2.1.1.)

7. GFS operating minima for single pilot operations at night, in terms of cloud base and visibility, afforded an acceptable level of safety. However, the actual weather conditions over Tung Chung Gap at the time of the accident were significantly worse than these minima. (1.6.6.2., 1.7.2. and 2.1.3.2.)

8. Crew report times did not provide sufficient allowance for pilots and aircrewmen to carry out their pre-flight duties if they were required to fly on an emergency response mission (e.g. casevac) immediately after the commencement of a shift. (1.6.6.1. and 2.1.3.1.)

9. There was no evidence of a crew briefing prior to the accident flight. (1.1. and 2.1.3.1.)

10. There was no evidence that the pilot was suffering from long-term fatigue but there was evidence to suggest that he was insufficiently rested. Combined with circadian disruption, this factor may have impaired his reasoning power and decision-making capabilities. (1.18.1 and 2.1.2.)

11. By attempting to cross Tung Chung Gap with a cloud base of less than 600 feet AGL and a flight visibility of less than 5 km, the pilot did not comply with the weather minima specified in the GFS Operations Manual. (1.6.6.2., 1.7.2. and 2.1.3.2.)

12. The GFS Operations Manual did not specify a formal procedure for flight via Tung Chung Gap at night. (1.6.6.4. and 2.1.3.2.)

13. The pilot did not comply with the teaching and common practice within the GFS for navigating via Tung Chung Pass and Gap at night. (1.6.6.4. and 2.1.3.2.)

14. GFS performance targets were at the forefront of the pilot's mind, both immediately before and during the flight, to the extent that he was affected by mission pressure to achieve the GFS on-scene target times. (1.1., 2.1.3.2., and 2.4.2.)

15. The GFS did not have a documented system for the proactive identification of hazards and systematic management of risk in flight operations. (1.17.4. and 2.4.2.)

16. The level of risk for casevac missions was not necessarily matched to the operational need. (1.17.4. and 2.4.2.)

17. The GFS Operations Manual contained no standard operating procedure or guidance addressing the use of the AVAD for night casevac missions. (1.6.6.6. and 2.1.3.2.)

18. The GFS Operations Manual did not specify an absolute minimum en route height above the surface for night casevac missions. (1.6.6.3. and 2.1.3.2.)

19. The initial ATC clearance omitted the QNH and did not specifically state that the pilot should fly in accordance with the provisions of 'Special VFR'. (1.9.1. and 2.3.)

20. The crew did not adhere to a number of the basic tenets of CRM. (1.1., 1.5.3., 2.1.3.1., 2.1.3.2., and 2.4.1.)

21. A degree of complacency existed, created by the fact that the pilot and the aircrewman flew regularly together, that the accident flight was over a familiar route and was perceived by the crew as being routine in nature. (2.4.1.)

22. The pilot suffered from confirmation bias. (2.1.3.2. and 2.4.1.)

23. The crew was affected by low levels of alertness and arousal. (2.4.1.)

24. At the time of the accident, the pilot was flying at a low altitude in

relation to terrain and at a high cruise speed, at night, in marginal meteorological conditions. (2.1.3.2.)

25. The pilot suffered from a loss of situational awareness. (2.1.3.2.)

26. All main rotor blades were severely damaged immediately upon initial impact with terrain and consequently the helicopter immediately became uncontrollable. (1.1. and 2.1.3.3.)

27. After the first impact and prior to the second impact, the pilot possibly initiated an attempt to shut down the main aircraft systems. (1.1., 1.12. and 2.1.3.3.)

28. The accident was potentially survivable. The pilot's seat, seat mountings and aircraft structure were not designed to the latest "Emergency Landing Conditions" certification standards. Had these latest standards been applied, the probability of survival of the pilot would have been high. (1.12.2.1., 1.13., 1.15.3., 2.2.4. and 2.5.3.1.)

29. The probability of survival of the pilot would have been raised significantly had he been wearing his helmet. (1.1., 1.15.2. and 2.5.3.3.)

30. The aircrewman was attached only to an air despatcher harness instead of being strapped into a seat. Consequently his injuries were more severe than they would otherwise have been. (1.15.3. and 2.5.3.2.)

31. The search for the wreckage was hindered by a number of factors including poor visibility, remoteness and nature of the terrain at the two

accident sites, the fact that no emergency radio transmission was received from the crew, absence of primary radar returns and SSR information, and no distress signal was transmitted from the ELT or PLBs. (1.12.2.4., 2.2.2., 2.2.5. and 2.5.1.)

32. The ADELT did not deploy or activate and an Automatically Activated ELT for use over land was not installed. (1.6.4.6., 1.12.2.3., 2.2.2., 2.2.3 and 2.5.2.)

33. As a result of the accident, the semi-rigid aerials of the personal locator beacons of both crewmembers became separated from the main bodies of the devices at the connector, which rendered them unusable. (1.12.2.4., 2.2.5. and 2.5.2.)

(b) Causal factors (active and latent failures)

1. The pilot did not conduct a pre-flight briefing. (1.1., 2.1.3.1., and Finding 9)

2. The pilot made an inappropriate decision to navigate via Tung Chung Gap at a low altitude and high cruise speed, at night, in marginal meteorological conditions. (1.6.6.2., 1.7.2., 2.1.3.2., and Findings 7 and 24)

3. The pilot suffered from an error of perception (confirmation bias). (2.1.3.2., 2.4.1., and Finding 22)

4. The pilot did not comply with GFS weather minima. (1.6.6.2., 1.7.2.,

2.1.3.2., and Finding 11)

5. The pilot did not comply with GFS teaching and common practice for navigating via Tung Chung Pass and Gap at night. (1.6.6.4., 2.1.3.2., and Finding 13)

6. The pilot suffered from a loss of situational awareness. (2.1.3.2. and Finding 25)

7. The pilot was affected by mission pressure to achieve the GFS on-scene target times. (1.1., 2.1.3.2., 2.4.2. and Finding 14)

8. The crew accepted an unnecessary hazard. (2.1.3.2. and Finding 24)

9. A degree of complacency affected both crewmembers, created by the fact that they flew regularly together and that the accident flight was over a familiar route and was perceived by the crew as being routine in nature. (2.4.1. and Finding 21)

10. The pilot showed impaired reasoning power and decision-making capabilities. This may have been due to insufficient rest combined with circadian disruption. (1.18.1., 2.1.2. and Finding 10)

11. Both crewmembers were affected by low levels of alertness and arousal. (2.4.1. and Finding 23)

12. The crew did not adhere to a number of the basic tenets of CRM. (1.1., 1.5.3., 2.1.3.1., 2.1.3.2., 2.4.1., and Finding 20)

13. The GFS Operations Manual did not include an absolute minimum en route height above the surface for night casevac operations. (1.6.6.3., 2.1.3.2., and Finding 18)

14. The GFS did not have a documented system for the proactive identification of hazards and systematic management of risk in flight operations. (1.17.4., 2.4.2., and Finding 15)

15. The discretion given to pilots, in relation to the level of risk associated with casevac missions carried out by the GFS, was not necessarily matched to the operational need. (1.17.4., 2.4.2., and Finding 16)

4. SAFETY RECOMMENDATIONS

Numbers in parenthesis refer to the relevant paragraph number in Sections 1 and 2 of this Report and the relevant Finding and Causal Factor.

4.1. Recommendation 2006-01

It is recommended that the GFS amend its operating procedures to specify an absolute minimum en route height above the surface for night casevac missions. (1.6.6.3., 2.1.3.2., Finding 18 and Causal Factor 12)

4.2. Recommendation 2006-02

It is recommended that the GFS reinforce the effectiveness of its CRM training. In particular, sleep hygiene, threat and error management, situational awareness, intra-crew communication and co-ordination and decision-making training should be emphasised, especially for crews comprising one pilot and one aircrewman. (1.1., 1.5.3., 1.18.1., 2.1.2., 2.1.3.1., 2.1.3.2., 2.4.1., Findings 9, 10, 20 and 23, and Causal Factors 1, 10 - 12)

4.3. Recommendation 2006-03

It is recommended that the GFS establish a documented system for the proactive identification of hazards and systematic management of risk in flight operations. (1.17.4., 2.4.2., Finding 15 and Causal Factor 13)

4.4. Recommendation 2006-04

It is recommended that the GFS consider making compulsory the wearing of helmets by helicopter aircrew for all tasks. (1.1., 1.15.2., 2.5.3.3. and Finding 29)

4.5. Recommendation 2006-05

It is recommended that the GFS conduct a risk assessment in order to identify those periods of flight when aircrewmen should be seated in a passenger seat and properly restrained by a seat belt. (1.15.3., 2.5.3.2. and Finding 30)

4.6. Recommendation 2006-06

It is recommended that the GFS change the timings of their aircrew shifts in order to provide pilots and aircrewmen with an officially sanctioned period of time at the beginning of a shift that will enable them carry out their pre-flight duties in an unhurried manner and, during which, they will not be required to fly. (1.6.6.1., 2.1.3.1., and Finding 8)

4.7. Recommendation 2006-07

It is recommended that the manufacturers of the SARBE 7 Personal Locator Beacon review the design of the aerial connector with a view to ensuring that the device continues to function following an accident. (1.12.2.4., 2.2.5., 2.5.2 and Finding 33)

4.8. Recommendation 2006-08

It is recommended that the CAD review the requirement for Performance Class 1 and Class 2 helicopters flying for the purposes of public transport to be equipped with an Automatically Activated ELT. (1.6.4.6., 1.12.2.3., 2.2.2., 2.2.3, 2.5.2. and Finding 32)

4.9. Recommendation 2006-09

It is recommended that the CAD review the current practice regarding the operation of transponders by local VFR traffic to enhance the effectiveness of search and rescue services. (1.9.2., 1.15.1., 2.5.1., 2.5.2 and Finding 31)

5. APPENDICES AND FIGURES

A Photograph of EC155B1 B-HRX

B Map of Lantau Island

C Ground plot of the flight path (Figures 1 and 2)

D Photographs of the accident site (Figures 1-4)

E Cockpit controls (Figures 1-4)

F Photograph of pilot's seat mounting

G ADELT Installation

H Schematic Diagrams of Frangible Switch (Figures 1 and 2)

I Air Navigation (Hong Kong) Order 1995, Schedule 14, Rule 22 ('Choice of VFR or IFR') and Rule 23 ('The Visual Flight Rules')

J A pilot's view approaching Tung Chung Gap (Figures 1 and 2)

K Hong Kong AIP (AD2-VHHH-54, dated 28 November 2002): Procedures for the use of Tung Chung Pass

L Estimation of helicopter speeds from Site A to Site B

M Wreckage Site A in relation to Tung Chung Road (night view)

N Air Navigation (Hong Kong) Order 1995, Schedule 14, Rule 5 ('Low Flying')

O Orographic Clouds over Tung Chung Gap in Southerly Winds

P Simulated Navigation Display – Waypoints of the Crash Site and CC04

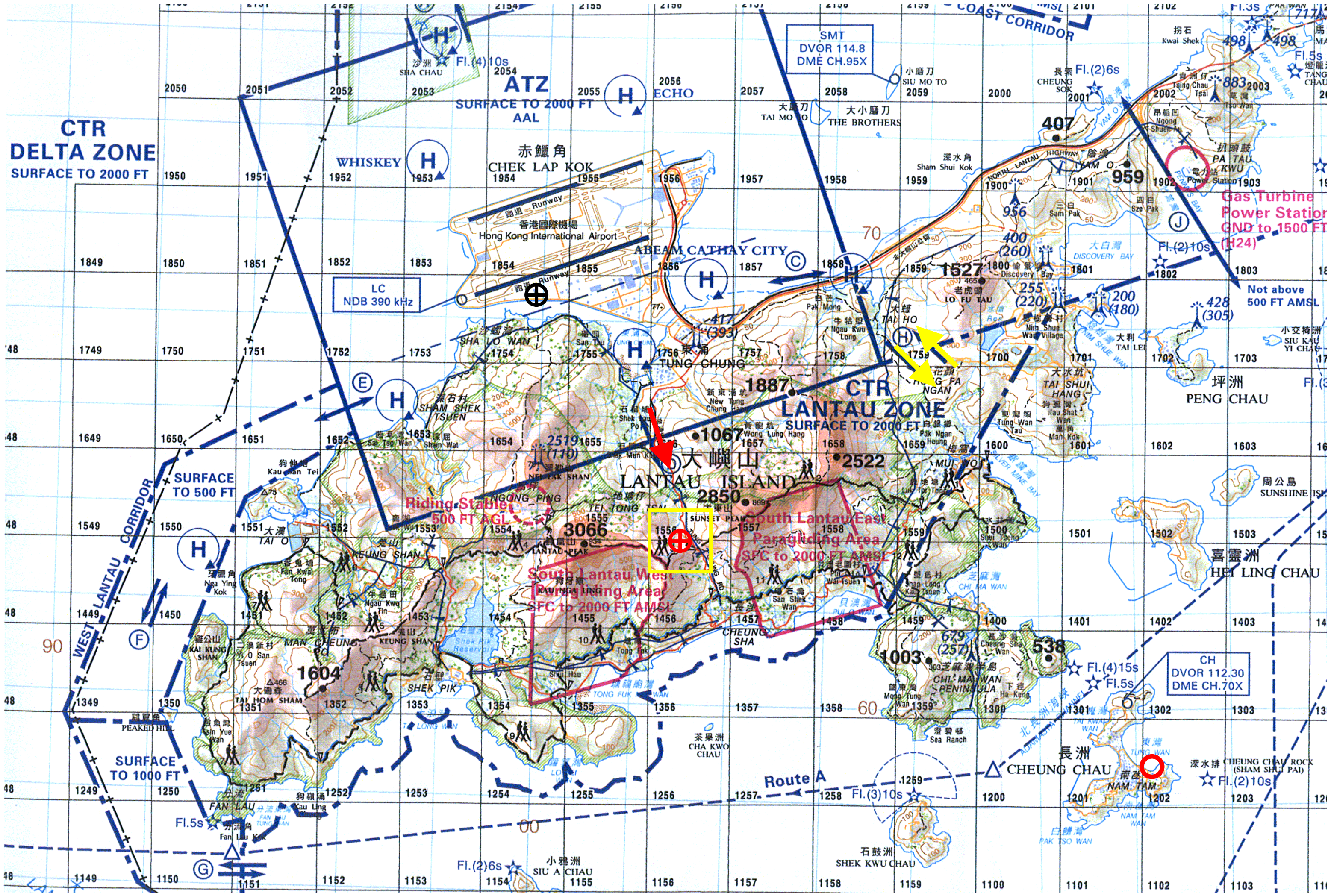
Q Human tolerance to g forces

Appendix A

Photograph of EC155B1 B-HRX

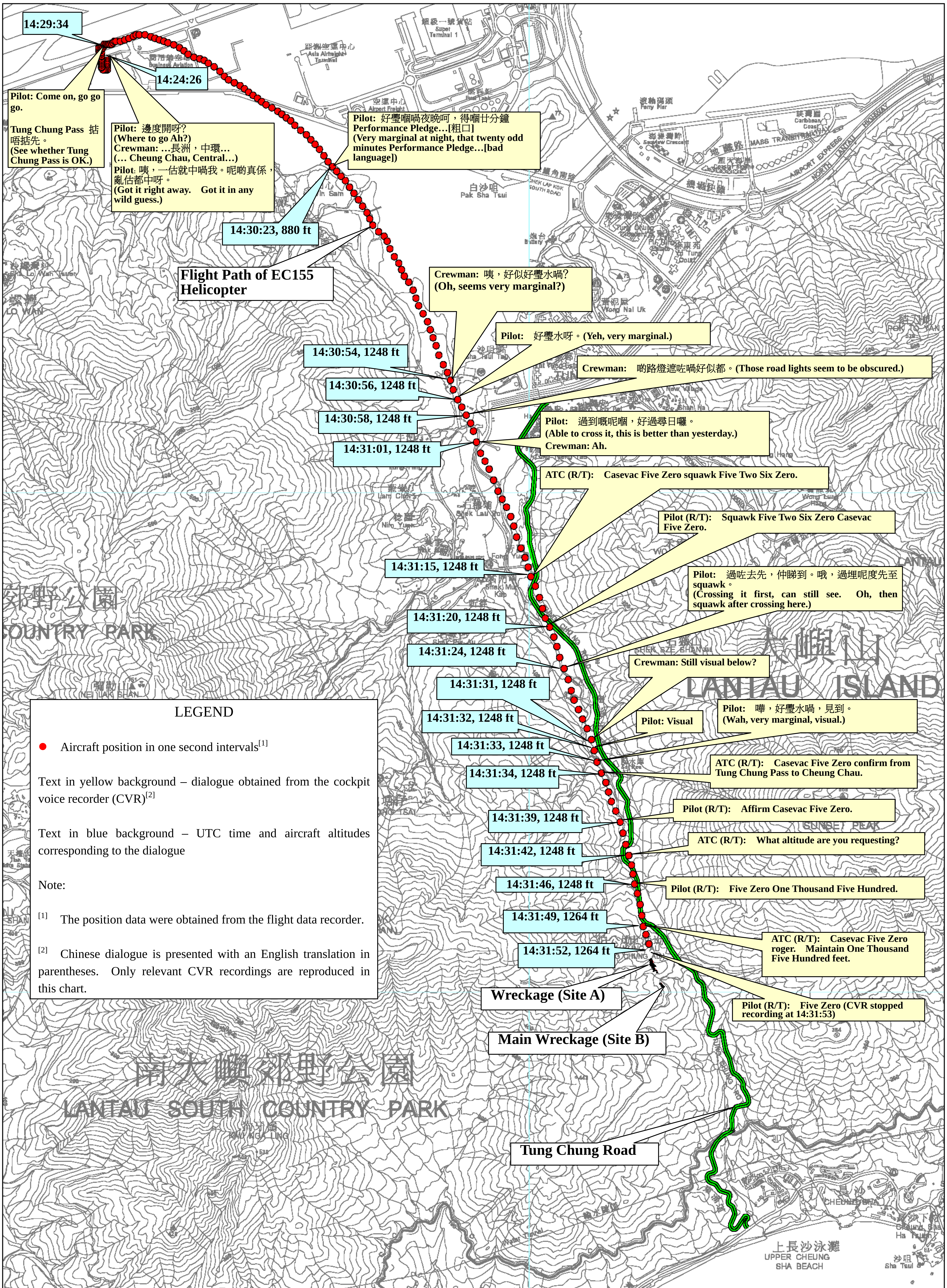
Picture source: SoftRepublic

Map of Lantau Island



⊕	Accident Site	Latitude: 22° 14.9' N Longitude: 113° 56.5' E	→ (red arrow)	Tung Chung Pass	→ (yellow arrow)	Silvermine Pass
⊕	GFS Base		□ (yellow square)	Tung Chung Gap	○ (red circle)	CC04

Appendix B



Flight Path of EC155 Helicopter

Plan Number: M668-2c

Survey & Mapping Office, Lands Department, The Government of HKSAR

200 0 200 400 Meters

1:20000

Map printed 8/04/2004

N

Appendix C
Figure 1

Last Section of the Flight Path in relation to Tung Chung Road

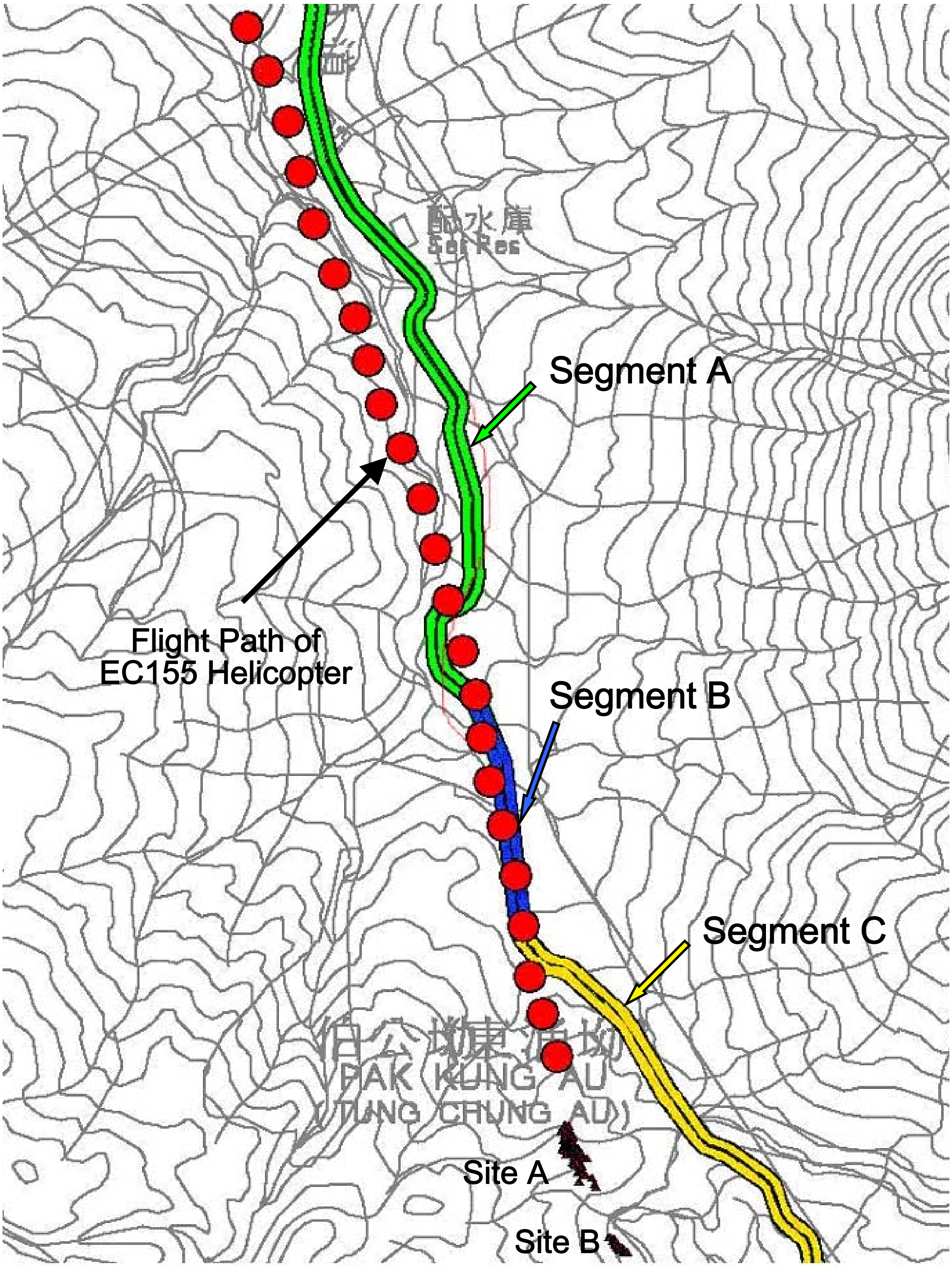


Figure 2

General view of Wreckage Sites A and B

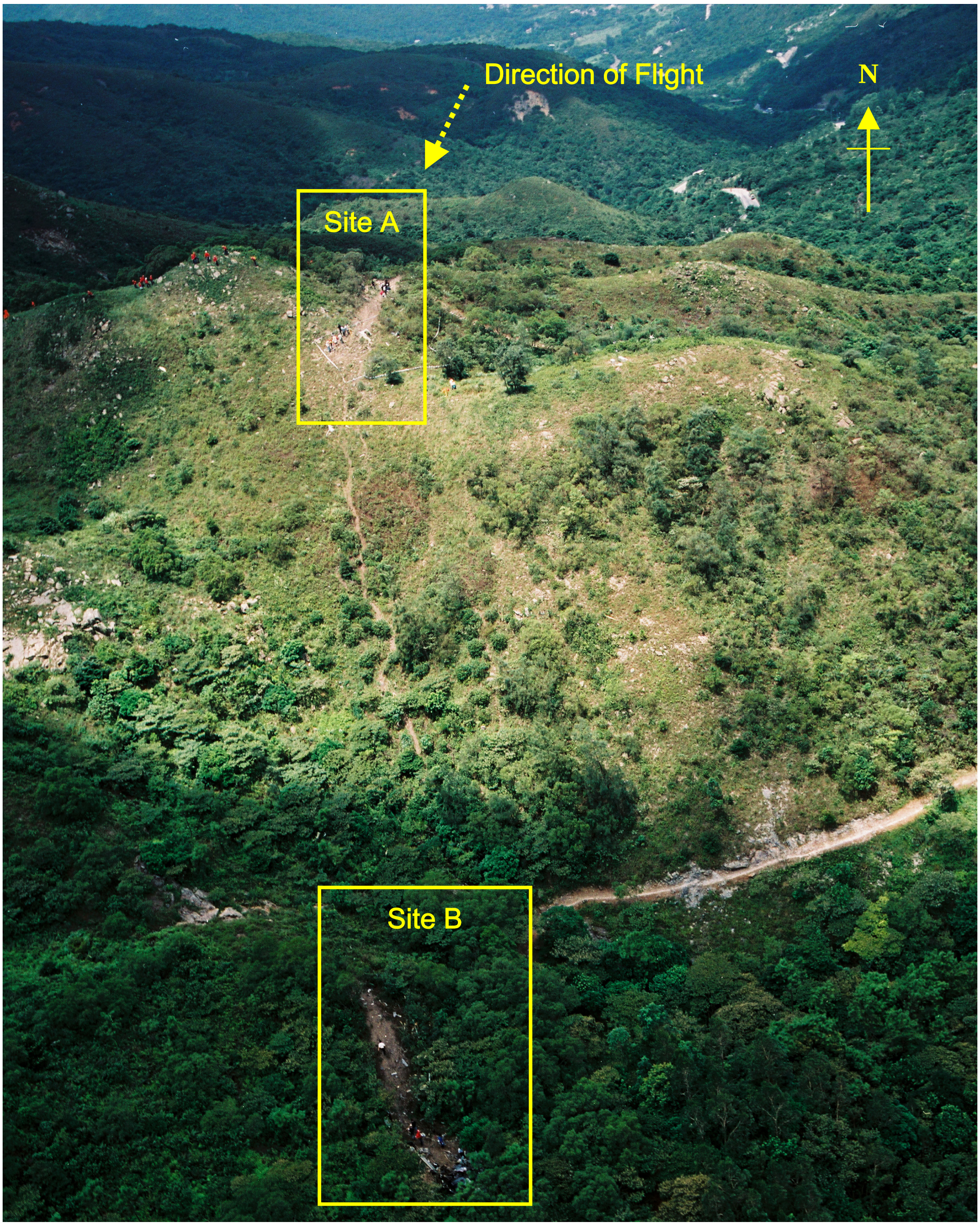


Figure 1

Wreckage Sites A and B in relation to Tung Chung Road

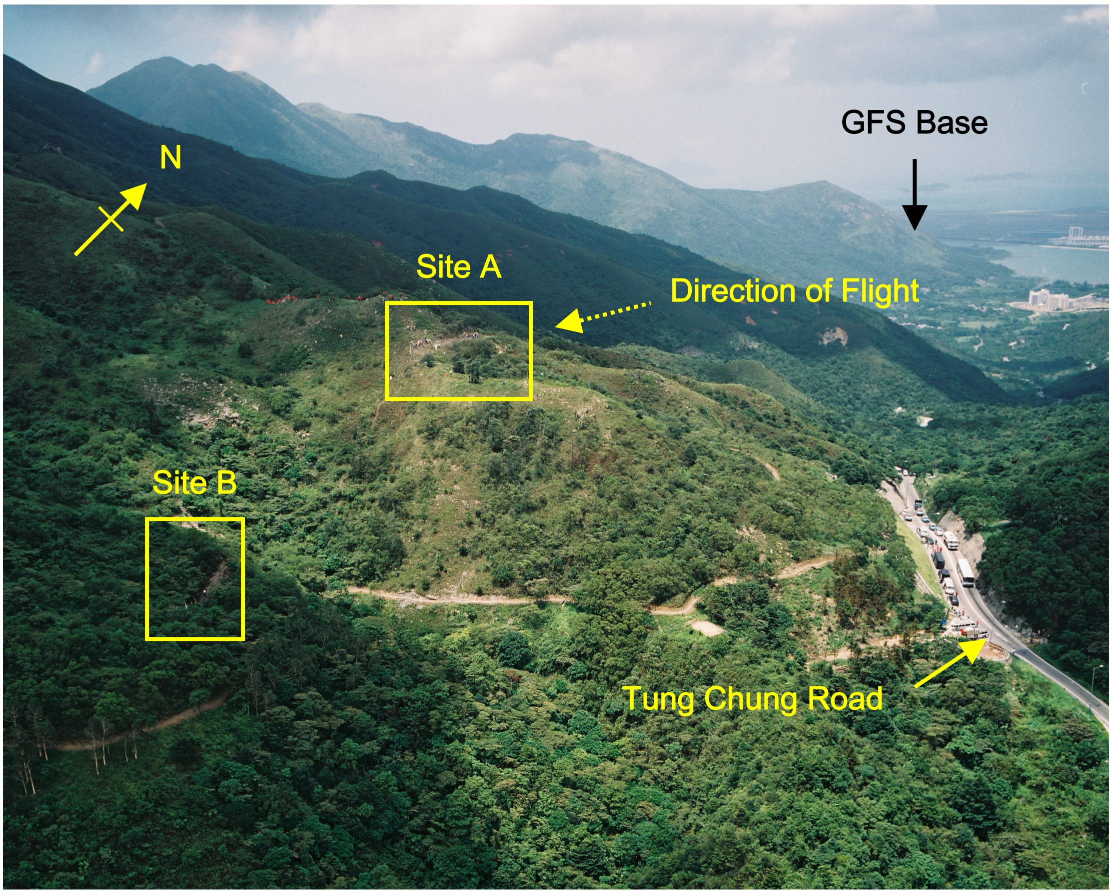


Figure 2

Wreckage Site A

Figure 3

Wreckage Site B

Figure 4

EC155B1 Engine Controls (Reference)

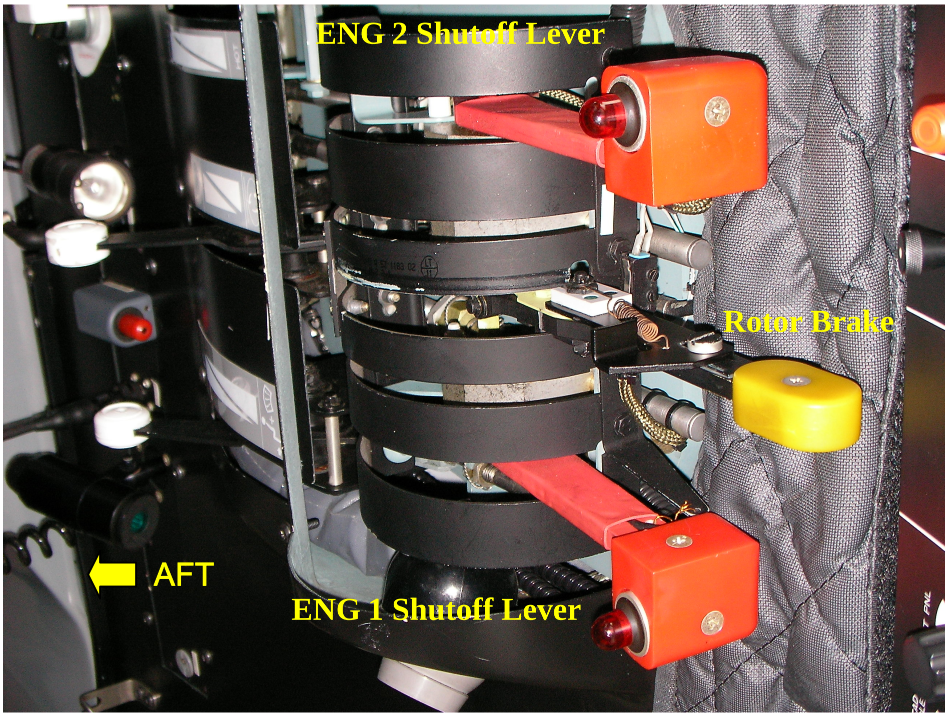


Figure 1

Left hand engine (ENG 1) Shutoff Lever at aft position as observed on the accident helicopter

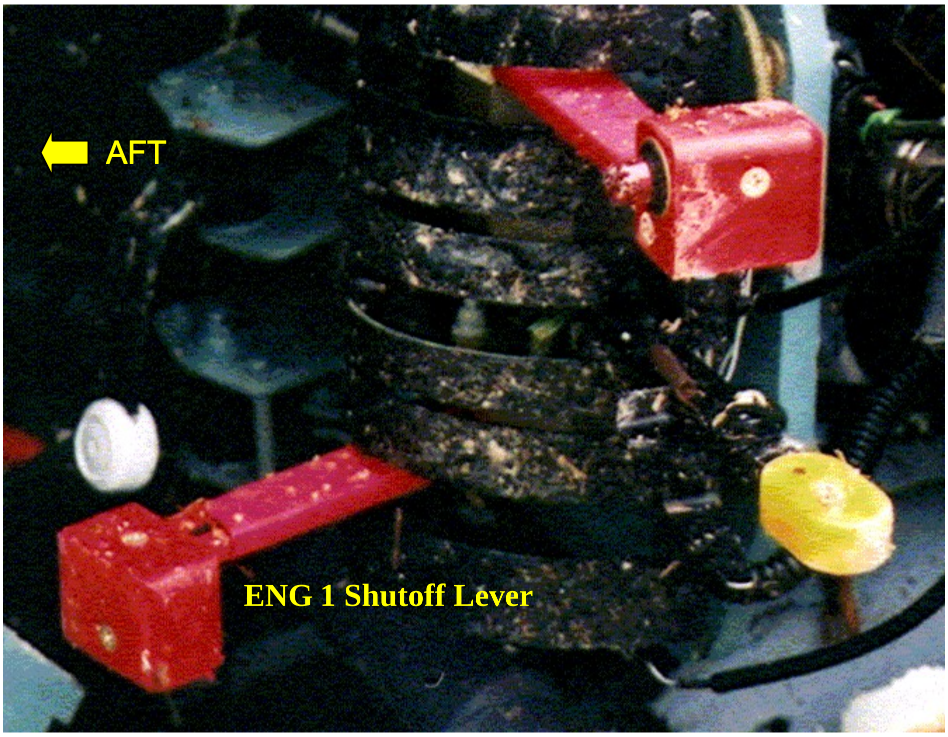


Figure 2

EC155B1 Cockpit Overhead Panel

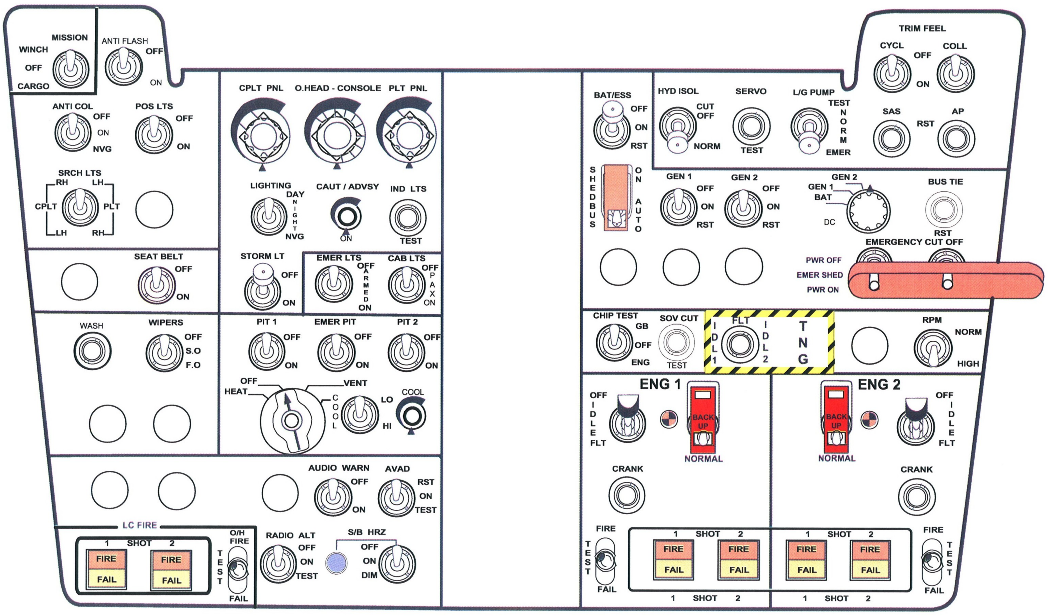


Figure 3

Engine 1 – IDLE (A), Generator 1 – OFF (B)
Safety Device – Unsafe Position (C), Emergency Cut Off – PWR OFF (D)

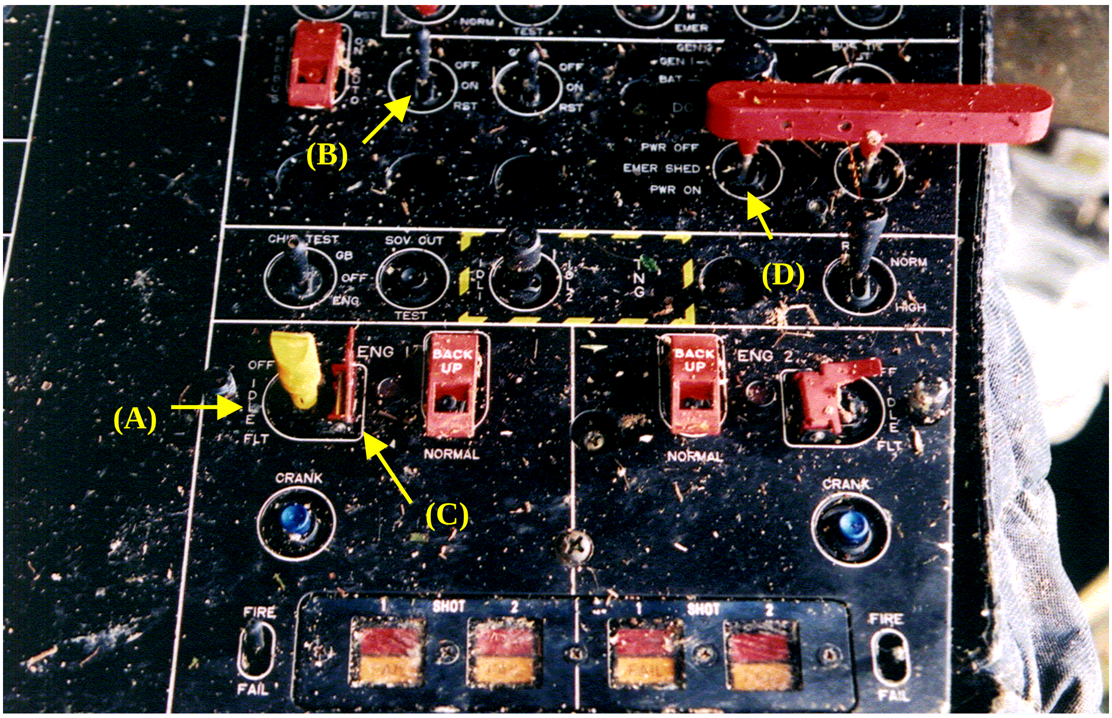
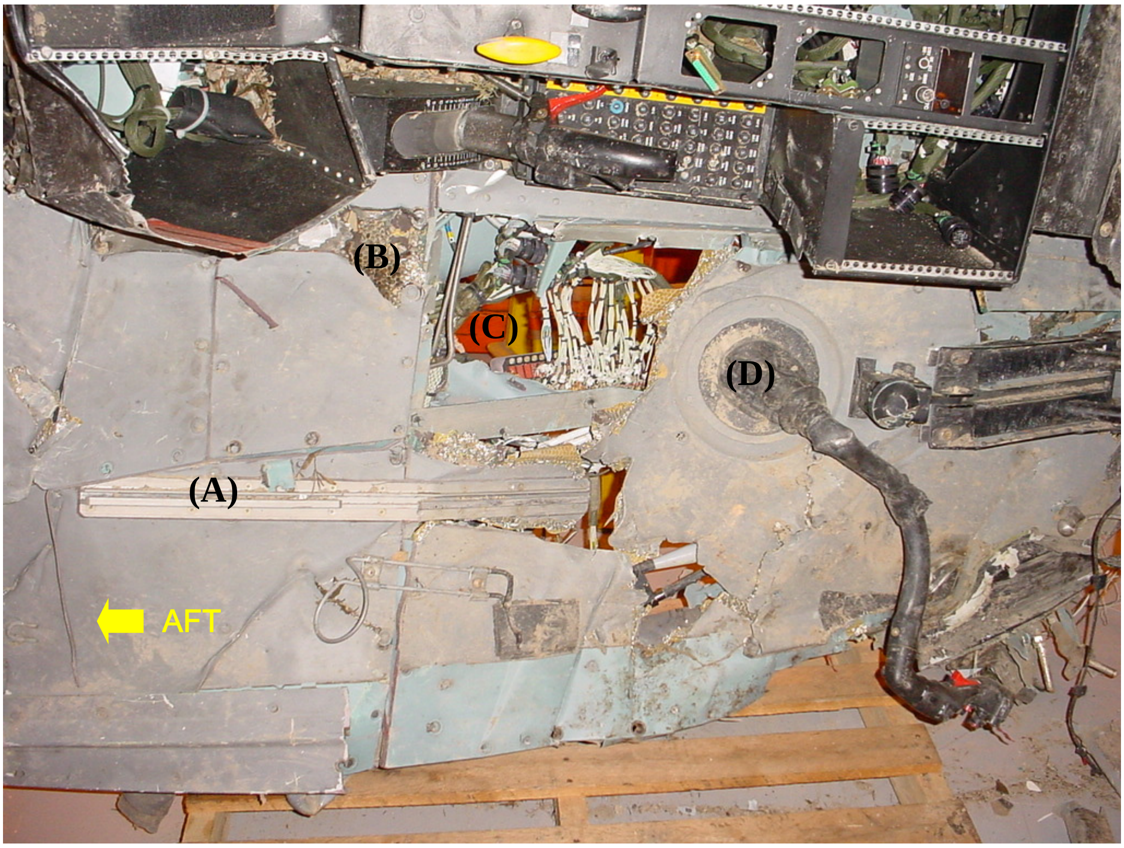


Figure 4

Aircraft floor showing the position of the outer seat mounting rail (A), area of missing back portion of inner seat rail (B), missing panel (C), and cyclic control (D)



ADELT Installation on GFS EC155B1 Helicopter

Legends:

- CONTACT (A)
- CONTACT (B)
- GLASS COVER (C)
- SPACER (D)
- SLEEVE (E)

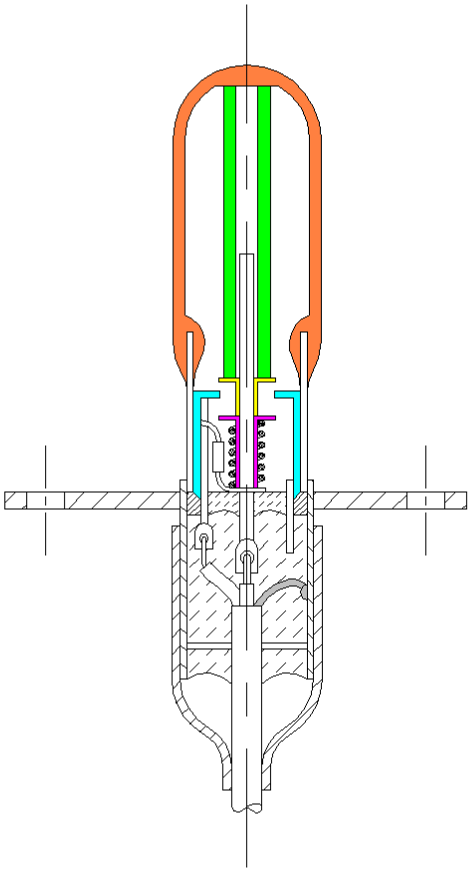


Figure 1 - Frangible Switch in Open Position with

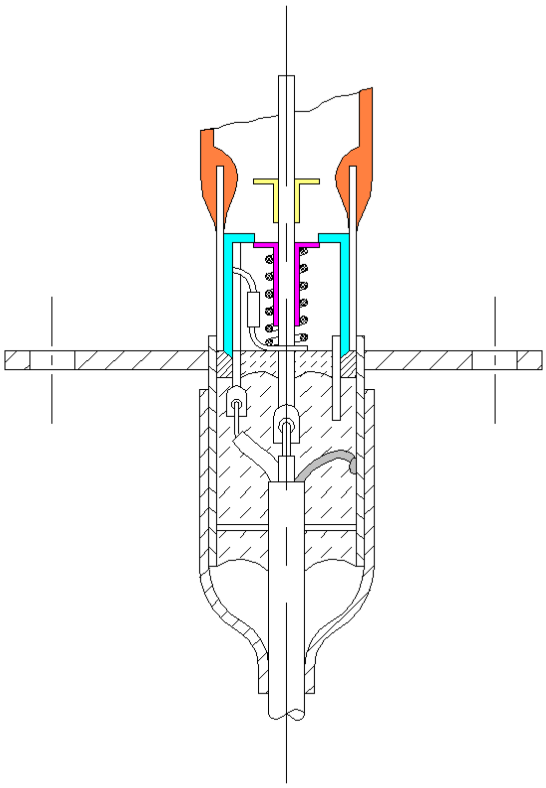


Figure 2 - Frangible Switch in Closed Position with Glass Tube Broken

22. Choice of VFR or IFR

Subject to the provisions of Rule 21 of these Rules an aircraft shall always be flown in accordance with the Visual Flight Rules or the Instrument Flight Rules:

Provided that in Hong Kong an aircraft flying at night:

(*a*) outside a control zone shall be flown in accordance with the Instrument Flight Rules; or

(*b*) in a control zone shall be flown in accordance with the Instrument Flight Rules unless it is on a Special VFR flight.

22A. Speed Limitations

(1) Subject to paragraph (3) an aircraft shall not fly below flight level 100 at a speed which according to its air speed indicator is more than 250 knots unless it is flying in accordance with the terms of a written permission of the Chief Executive. *(36 of 1999 s. 3)*

(2) The Chief Executive may grant a permission for the purpose of this Rule subject to such conditions as he thinks fit and either generally or in respect of any aircraft or class of aircraft. *(36 of 1999 s. 3)*

(3) Paragraph (1) shall not apply to:

(*a*) flight in Class A airspace;

(*b*) flight in Class B airspace;

(*c*) IFR flight in Class C airspace;

(*d*) VFR flight in Class C airspace or VFR flight or IFR flight in Class D airspace when authorized by the appropriate air traffic control unit;

(*e*) the flight of an aircraft flying in accordance with the "A Conditions" or the "B Conditions" set forth in Schedule 2 to the Ordinance, when authorised by the appropriate air traffic control unit.

SECTION V

VISUAL FLIGHT RULES

23. The Visual Flight Rules

The Visual Flight Rules shall be as follows:

(*a*) Within Class B airspace:

(i) an aircraft flying within Class B airspace at or above flight level 100 shall remain clear of cloud and in a flight visibility of at least 8 kilometres;

(ii) an aircraft flying within Class B airspace below flight level 100 shall remain clear of cloud and in a flight visibility of at least 5 kilometres;

(*b*) Within Class C, Class D or Class E airspace:

(i) an aircraft flying within Class C, Class D or Class E airspace at or above flight level 100 shall remain at least 1 500 metres horizontally and 1 000 feet vertically away from cloud and in a flight visibility of at least 8 kilometres;

(ii) an aircraft flying within Class C, Class D or Class E airspace below flight level 100 shall remain at least 1 500 metres horizontally and 1 000 feet vertically away from cloud and in a flight visibility of at least 5 kilometres;

(*c*) an aircraft flying outside controlled airspace at or above flight level 100 shall remain at least 1 500 metres horizontally and 1 000 feet vertically away from cloud and in a flight visibility of at least 8 kilometres;

(*d*) an aircraft flying outside controlled airspace below flight level 100 shall remain at least 1 500 metres horizontally and 1 000 feet vertically away from cloud and in a flight visibility of at least 5 kilometres:

Provided that this sub-paragraph shall be deemed to be complied with if:

(i) the aircraft is flying at or below 3 000 feet above mean sea level and remains clear of cloud and in sight of the surface and in a flight visibility of at least 5 kilometres;

(ii) the aircraft, other than a helicopter, is flying at or below 3 000 feet above mean sea level at a speed which according to its air speed indicator is 140 knots or less and remains clear of cloud and in a flight visibility of at least 1 500 metres; or

(iii) in the case of a helicopter, the helicopter is flying at or below 3 000 feet above mean sea level flying at a speed, which, having regard to the visibility, is reasonable, and remains clear of cloud and in sight of the surface.

For the purposes of this Rule "Special VFR flight" means a flight made in Instrument Meteorological Conditions or at night in a control zone notified for the purposes of Rule 21 of these Rules in respect of which the appropriate air traffic control unit has given permission for the flight to be made in accordance with special instructions given by that unit instead of in accordance with the Instrument Flight Rules.

23A. VFR Plans and air traffic control clearance

(1) Unless otherwise specified by the appropriate air traffic control unit before an aircraft flies within Class B, Class C or Class D airspace during the notified hours of watch of the appropriate air traffic control unit, the commander of the aircraft shall cause a flight plan to be communicated to the appropriate air traffic control unit and shall obtain an air traffic control clearance to fly within the said airspace.

(2) The flight plan shall contain such particulars of the flight as may be necessary to enable the air traffic control unit to issue a clearance and for search and rescue purposes.

(3) Whilst flying within the said airspace during the notified hours of watch of the appropriate air traffic control unit the commander of the aircraft shall:

(*a*) cause a continuous watch to be maintained on the notified radio frequency appropriate to the circumstances; and

(*b*) comply with any instructions which the appropriate air traffic control unit may give in a particular case.

SECTION VI

INSTRUMENT FLIGHT RULES

24. The Instrument Flight Rules shall be as follows:

(*a*) Within controlled airspace:

In relation to flights within controlled airspace Rules 25, 27 and 28 shall apply.

(*b*) Outside controlled airspace:

In relation to flights outside controlled airspace Rules 25 and 26 shall apply.

25. Minimum height

Without prejudice to the provisions of Rule 5, in order to comply with the Instrument Flight Rules an aircraft shall not fly at a height of less than 1 000 feet above the highest obstacle within a distance of 5 nautical miles of the aircraft unless:

(*a*) it is necessary for the aircraft to do so in order to land; or

(*b*) the aircraft is flying on a route notified for the purpose of this Rule; or

(*c*) the aircraft has been otherwise authorised by the competent authority; or

(*d*) the aircraft is flying at an altitude not exceeding 3 000 feet above mean sea level and remains clear of cloud and in sight of the surface.

26. Semi-circular Rule

In order to comply with the Instrument Flight Rules, an aircraft when in level flight above 3 000 feet above mean sea level or above the appropriate transition altitude, whichever is the higher, shall be flown at a level appropriate to its magnetic track, in accordance with the appropriate Table set forth in this Rule. The level of flight shall be measured by an altimeter set according to the system published by the competent authority in relation to the area over which the aircraft is flying:

A pilot's view approaching Tung Chung Gap

Figure 1

A pilot's night view approaching Tung Chung Gap at 1,200 feet

Figure 2

25.2.3 Flights in Ma Wan Zone above 500 ft AMSL and Lantau Zone above 2 000 ft AMSL, including operations at landing sites above these levels, are subject to specific approval from Hong Kong Zone.

25.3 ATZ and CTR Entry and Exit Routes

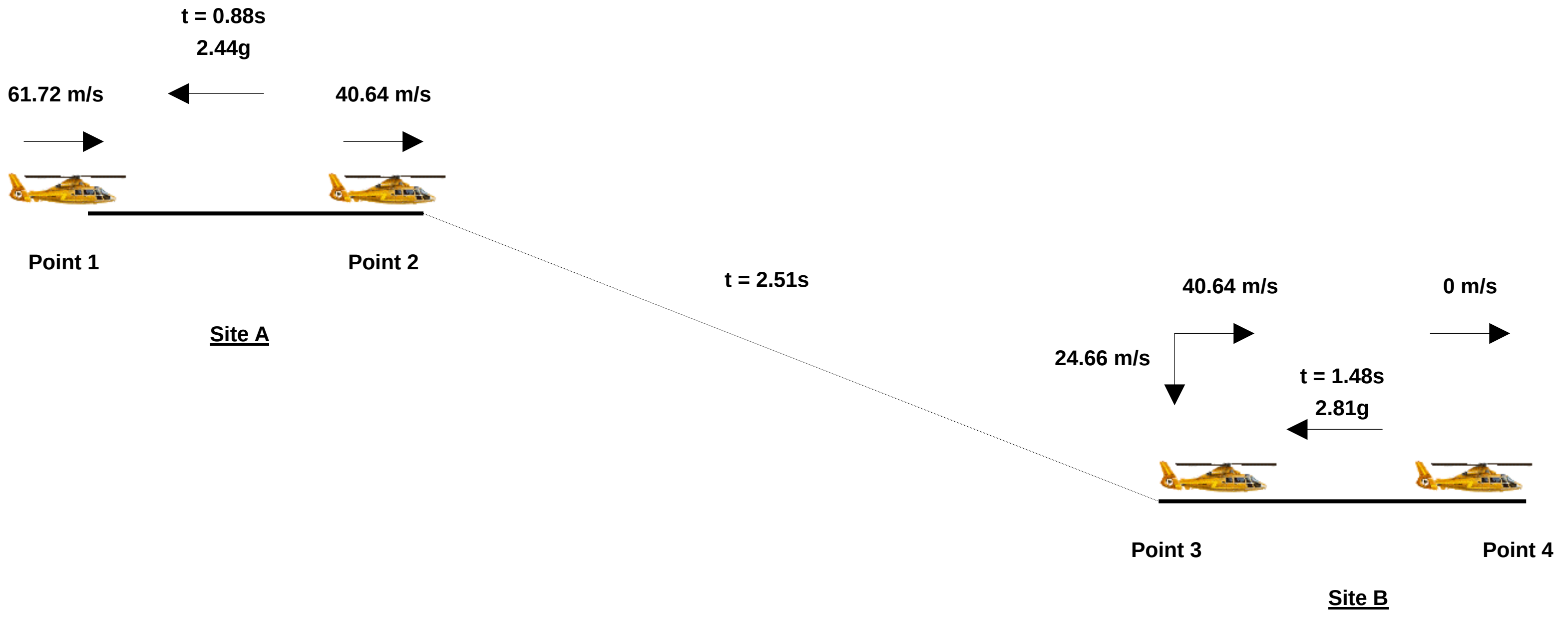
25.3.1 Subject to ATC approval, pilots shall normally comply with the following standard exit and entry routes and altitudes within the ATZ and CTR Zones (see chart AD2-VHHH-103) :

Radio Callsign	Route Direction	Routeing
Tung Chung Pass	In/Out	Entering/Leaving ATZ for Lantau Zone Helicopters only Inbound to ATZ 2 000 ft AMSL Outbound from ATZ not above 1 500 ft AMSL (If weather conditions preclude the use of 2 000 ft inbound, operations shall be restricted to one direction at a time)

Estimation of helicopter speeds from Site A to Site B

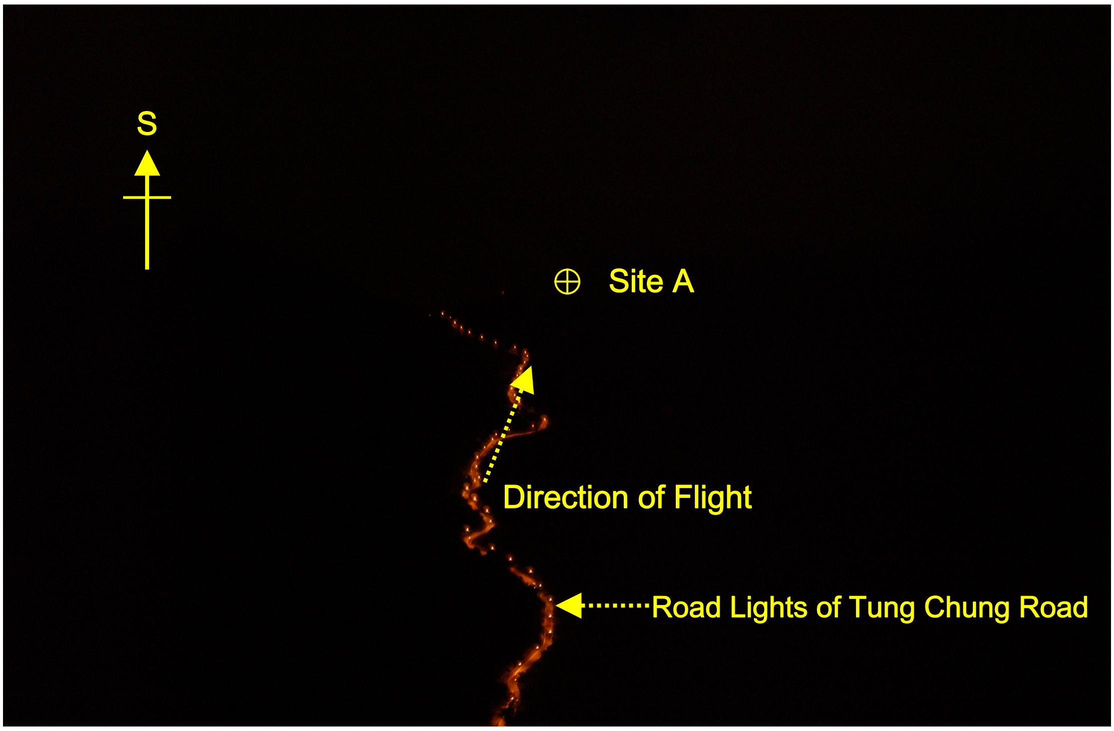
Assumptions:

1. The altitude differences between Point 1 and Point 2 at Site A and Point 3 and Point 4 at Site B is insignificant and negligible for the estimation.
2. For calculation purpose, the helicopter was subject to an average deceleration due to sliding on the terrain.
3. When the helicopter left point 2, it acted as a projectile and landed at point 3.
4. During the airborne time between point 2 and point 3, the drag force acting on the helicopter was insignificant and negligible.



Appendix L

Wreckage Site A in relation to Tung Chung Road



"Runway" means an area, whether or not paved, which is provided for the take-off or landing run of aircraft.

"VFR Flight" means a flight conducted in accordance with the Visual Flight Rules in Section V of these Rules.

SECTION II

GENERAL

2. Application of Rules to Aircraft

These Rules, in so far as they are applicable in relation to aircraft, shall, subject to the provisions of Rule 29 of these Rules, apply in relation to—

(*a*) all aircraft within Hong Kong; and

(*b*) all aircraft registered in Hong Kong wherever they may be.

3. Misuse of Signals and Markings

(1) A signal or marking to which a meaning is given by these Rules, or which is required by these Rules to be used in circumstances or for a purpose therein specified, shall not be used except with that meaning, or for that purpose.

(2) A person in an aircraft or on an aerodrome or at any place at which an aircraft is taking off or landing shall not make any signal which may be confused with a signal specified in the Rules and, except with lawful authority, shall not make any signal which he knows or ought reasonably to know to be a signal in use for signalling to or from any of Her Majesty's naval, military or air force aircraft.

4. Reporting hazardous conditions

The commander of an aircraft shall, on meeting with hazardous conditions in the course of a flight, or as soon as possible thereafter, send to the appropriate air traffic control unit by the quickest means available information containing such particulars of the hazardous conditions as may be pertinent to the safety of other aircraft.

5. Low flying

(1) Subject to the provisions of paragraph (2) and (3) of this Rule:

(*a*) An aircraft other than a helicopter shall not fly over any congested area of a city, town or settlement below—

(i) such height as would enable the aircraft to alight clear of the area and without danger to persons or property on the surface, in the event of failure of a power unit and if such an aircraft is towing a banner such height shall be calculated on the basis that the banner shall not be dropped within the congested area; or

(ii) a height of 1 500 feet above the highest fixed object within 2 000 feet of the aircraft, whichever is the higher.

(*b*) A helicopter shall not fly below such height as would enable it to alight without danger to persons or property on the surface, in the event of failure of a power unit.

(*c*) Except with the permission in writing of the Chief Executive and in accordance with any conditions therein specified a helicopter should not fly over a congested area of a city, town or settlement below a height of 1 500 feet above the highest fixed object within 2 000 feet of the helicopter. *(36 of 1999 s. 3)*

(*d*) An aircraft shall not fly—

(i) over, or within 3 000 feet of, any assembly in the open air of more than 1 000 persons assembled for the purpose of witnessing or participating in any organised event, except with the permission in writing of the Chief Executive and in accordance with any conditions therein specified and with the consent in writing of the organisers of the event; or *(36 of 1999 s. 3)*

(ii) below such height as would enable it to alight clear of the assembly in the event of the failure of a power unit and if such an aircraft is towing a banner such height shall be calculated on the basis that the banner shall not be dropped within 3 000 feet of the assembly:

Provided that, where a person is charged with an offence under this Order by reason of a contravention of this sub-paragraph, it shall be a good defence to prove that the flight of the aircraft over, or within 3 000 feet of, the assembly was made at a reasonable height and for a reason not connected with the assembly or with the event which was the occasion for the assembly.

(*e*) An aircraft shall not fly closer than 500 feet to any person, vessel, vehicle or structure.

(2) (*a*) The provisions of paragraphs (1)(*a*)(ii) and (1)(*c*) of this Rule shall not apply to an aircraft flying—

(i) on a route notified for the purposes of this Rule, or

(ii) on a special VFR flight as defined in Rule 23 of these Rules in accordance with instructions given for the purposes of that Rule by the appropriate air traffic control unit.

(*b*) Paragraphs (1)(*d*) and (*e*) of this Rule shall not apply to an aircraft which is being used for police purposes.

(*c*) Paragraphs (1)(*d*) and (*e*) of this Rule shall not apply to the flight of an aircraft over or within 3 000 feet of an assembly of persons gathered for the purpose of witnessing an event which consists wholly or principally of an aircraft race or contest or an exhibition of flying, if the aircraft is taking part in such race, contest or exhibition or is engaged on a flight arranged by, or made with the consent in writing of, the organisers of the event.

(*d*) Paragraph (1)(*e*) of this Rule shall not apply to—

(i) any aircraft while it is landing or taking off in accordance with normal aviation practice;

(ii) any glider while it is hill-soaring;

(iii) any aircraft while it is flying in accordance with proviso (*f*) of Article 40(2) of this Order;

(iv) any aircraft while it is flying in accordance with the terms of an aerial application certificate granted to the operator thereof under Article 42 of this Order;

(v) any aircraft while it is flying for the purpose of picking up or dropping tow ropes, banners or similar articles at an aerodrome in accordance with Articles 39(2) or proviso (*e*) of Articles 40(2) of this Order.

(3) Nothing in this Rule shall prohibit an aircraft from flying in such a manner as is necessary for the purpose of saving life.

(4) Nothing in this Rule shall prohibit any aircraft from flying in accordance with normal aviation practice, for the purpose of taking off from, landing at or practising approaches to landing at, or checking navigational aids or procedures at, a Government aerodrome or a licensed aerodrome in Hong Kong or at any aerodrome elsewhere:

Provided that the practising of approaches to landing shall be confined to the airspace customarily used by aircraft when landing or taking off in accordance with normal aviation practice at the aerodrome concerned.

(5) Nothing in this Rule shall apply to any captive balloon or kite.

Simulated instrument flight

(6) An aircraft shall not be flown in simulated instrument flight conditions unless—

(*a*) the aircraft is fitted with dual controls, which are functioning properly;

(*b*) an additional pilot (in this Rule called "a safety pilot") is carried in a second control seat of the aircraft for the purpose of rendering such assistance as may be necessary to the pilot of the aircraft; and

Appendix N

Orographic Cloud over Tung Chung Gap in Southerly Winds

Viewed from Hong Kong International Airport

Simulated Display – Waypoints of the Wreckage Site A and CC04 in relation to the Aircraft Heading

Note: Point A is a simulated input. It was not programmed in the accident flight.

Human Tolerance To Impacts

Whole body Impacts

Position		*Limit*	*Duration*
Eyeballs out	$(-G_x)$	45 G	0.1 sec
		25 G	0.2 sec
Eyeballs in	$(+G_x)$	83 G	0.04 sec
Eyeballs down	$(+G_z)$	20 G	0.1 sec
Eyeballs up	(-Gz)	15 G	0.1 sec
Eyeball left/right	$(+/-G_y)$	9 G	0.1 sec

1. Note - Fully restrained subjects exposed to whole-body impacts at up to 250 G/sec onset rates. Injuries are known to occur if limits are exceeded. For lap belt restraint only, $-G_x$ tolerance may be reduced to 1/3.

Regional Body Impacts:

Body Area	*Limit*	*Duration*
Head (Frontal Bone, 2" diameter)	180 G	0.002 sec
	57 G	0.02 sec
Nose	30 G	*
Maxilla	50 G	*
Teeth	100 G	*
Mandible	40 G	*
Brain (Concussion)	100 G	0.005 sec
	180 G	0.002 sec
* Duration figures not available.		

1. Human tolerance to abrupt acceleration depends on the direction, magnitude, duration and rate of onset of the acceleration force. The manner in which the occupant's body is supported during the acceleration is critical.

2. If the calculated crash forces on the airframe exceed the human tolerance limits by a factor of 2 or more, survivability is unlikely. If the limits are exceeded by a factor of 1.5, survivability is doubtful. If the limits are exceeded by a factor of 1.25 or less, survivability can be dependent on specific CREEP factors. If the limits are not exceeded, survivability is expected, although individual variations and CREEP factors remain.

Reference: Extract from page 98 of the US Naval Flight Surgeons' accident investigation reference manual, 5th Edition (2001).