REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTRY OF TRANSPORT, COMMUNICATION AND PUBLIC WORKS

AIRCRAFT ACCIDENT REPORT

Controlled Flight into Terrain

Ilyushin IL-76 TD, RDPL-34141
Baucau, Timor-Leste
31 January, 2003

Prepared by:

Australian Government

Australian Transport Safety Bureau

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This report was produced by the Australian Transport Safety Bureau (ATSB), PO Box 967, Civic Square ACT 2608, at the request of the Ministry of Transport, Communication and Public Works of the Democratic Republic of Timor-Leste.

Readers are advised that the ATSB investigated the accident which is the subject of this report for the sole purpose of enhancing safety. Consequently, the report is confined to matters of safety significance and may be misleading if used for any other purpose.

CONTENTS

GLOSSARY

AC	Advisory Circular
ADF	automatic direction-finder
AGL	above ground level
AIB	Accident Investigation Board (Kingdom of Bahrain)
ALAR	Approach-and-Landing Accident Reduction
AMSL	above mean sea level
AOC	Air Operator Certificate
ARP	aerodrome reference point
ATC	air traffic control
ATS	air traffic services
ATSB	Australian Transport Safety Bureau
AWOS	automated weather observing system
BCAG	Boeing Commercial Airplane Group
BoM	Bureau of Meteorology (Australia)
CAD	Civil Aviation Division of the Ministry of Transport, Communication and Public Works, Timor-Leste
CAM	cockpit area microphone
CDI	course deviation indicator
CFIT	controlled flight into terrain
CI	course indicator
CIS	Confederation of Independent States
CVR	cockpit voice recorder
DGPS	differential global positioning system
DME	distance measuring equipment
DMSU	Defence Meteorological Support Unit of BoM
DSTO	Defence Science and Technology Organisation (Australia)
EGT	exhaust gas temperature
FAA	Federal Aviation Administration (US)
FDR	flight data recorder
FIR	flight information region
FL	flight level
ft	foot (feet)
fpm	feet per minute
FSF	Flight Safety Foundation
GPS	global positioning system
GPWS	ground proximity warning system
HDOP	horizontal dilution of precision
hPa	hectopascal
Hg	Mercury
HR	hour(s)

IAC	Interstate Aviation Committee, Air Transport Accident Investigation Commission (CIS)
IAF	initial approach fix
ICAO	International Civil Aviation Organization
IFR	instrument flight rules
IMC	instrument meteorological conditions
kHz	kilohertz
km/h	kilometres per hour
kt	knot(s)
Lao DCA	Department of Civil Aviation, Lao PDR
Lao PDR	Lao People's Democratic Republic
LSALT	lowest safe altitude
m	metre(s)
m/sec	metres per second
mb	millibar(s)
MDA	minimum descent altitude
MDA(H)	minimum descent altitude/height
MDH	minimum descent height
METAR	aviation routine weather report
MHz	megahertz
mm	millimetre(s)
MSA	minimum sector altitude
MTOW	maximum take off weight
N2	engine rotation speed
NDB	non-directional radio beacon
NLR	National Aerospace Laboratory (Netherlands)
NOTAM	notice to airmen (a notice distributed by means of telecommunicatio containing information concerning the establishment, condition or change essential to personnel concerned with flight operations)
NM	nautical mile(s)
NPA	non-precision approach
NTSB	National Transportation Safety Board (US)
OKTAS	the amount of cloud covering the sky measured in eights (OKTAS) from 1 to 8 oktas – 0 OKTAS means the sky is clear, 8 means it is completely covered.
QAR	quick access recorder
QFE	atmospheric pressure at aerodrome elevation or at runway threshold (the pressure setting to indicate height above aerodrome)
QNE	sea level standard atmospheric pressure
QNH	altimeter sub-scale setting to obtain elevation when on the ground (the pressure setting to indicate elevation above mean sea level)
RAIM	receiver autonomous integrity monitoring
SARPS	standards and recommended practices (ICAO)
TAF	terminal aerodrome forecast
TLA	thrust level angle
UAE	United Arab Emirates

UN	United Nations
UNMISET	United Nations Mission of Support in East Timor
UNPOL	United Nations Police
UNTAET	United Nations Transitional Administration in East Timor
URL	uniform resource locator
UTC	coordinated universal time
USSR	Union of Soviet Socialist Republics
VDOP	vertical dilution of precision
VHF	very high frequency (30 to 300 MHz)
VMC	visual meteorological conditions
VOR	VHF omnidirectional radio range
VREF	landing reference speed

CONVERSIONS

The flight instruments fitted in the occurrence aircraft provided readings of height, distance, and speed in metric units. The Convention on International Civil Aviation (the *Chicago Convention*) was signed at Chicago on 7 December 1944. Standards and recommended practices are contained in annexes to the *Chicago Convention*, and specify that height is expressed as feet (ft), distance in nautical miles (NM), speed in knots (kts), and altimeter subscale settings in hectopascals (hPa). Consequently, the following conversions are used in this report:

To convert	***into***	***multiply by***
metres	feet	3.2808
kilometres	nautical miles	0.5396
kilometres per hour	knots	0.5396
mm Mercury	hectopascals	1.3331

INTRODUCTION

On 31 January 2003, an Ilyushin 76TD aircraft impacted terrain during a landing approach to runway 14 at Cakung Airport, Baucau, Timor-Leste. The six aircraft occupants were fatally injured by the impact forces.

Within hours of the event, the government of Timor-Leste sought Australia's assistance to conduct the accident investigation. The Australian Minister for Transport and Regional Services agreed to the appointment of an investigator from the Australian Transport Safety Bureau (ATSB) as Australia's Accredited Representative to the investigation. The advisers to the Australian Accredited Representative included three investigators from the Directorate of Flying Safety – Australian Defence Force, two scientists from the Australian Defence Science and Technology Organisation (DSTO), other ATSB investigators, and several specialist advisers from other Australian and overseas organisations.

The Australian investigation team conducted the investigation in accordance with Annex 13 to the *Convention on International Civil Aviation* and the Australian *Air Navigation Act 1920, Part 2A*, for and on behalf of the Civil Aviation Division of the Ministry of Transport, Communication and Public Works (CAD), Timor-Leste. The ATSB prepared the draft Final Report, and the CAD is the authority releasing the Final Report.

A flight data recorder and two cockpit voice recorders were recovered from the aircraft wreckage during the early stages of the on site investigation. On advice from the Australian Accredited Representative, CAD forwarded the recorders to the Interstate Aviation Committee, Air Transport Accident Investigation Commission (IAC) of the Commonwealth of Independent States for readout and analysis. The IAC subsequently provided a detailed report and analysis of the recorded data, which included a transcript of the recorded voice data[1], and a series of flight path and flight data plots. Relevant information from the IAC report is included in this Final Report to assist understanding of the factors leading up to the occurrence.

It is not the object of an investigation under Annex 13 to apportion blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and conclusions reached. That material will, at times, contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the investigation endeavoured to balance the use of material that could imply adverse comment, with the need to clearly explain what happened, and why, in a fair and unbiased manner so that safety lessons may be learned.

This report includes findings, and significant factors. Findings include those conditions, events and circumstances that could have induced the accident, or if removed, would have prevented the accident. Findings also include deficiencies that did not contribute to the accident, but had the potential to significantly degrade safety of flight. Significant factors were the factors that directly contributed to the development of the occurrence. Unless otherwise indicated, recommendations included in this Final Report are addressed to organisations having responsibility for the matters with which those recommendations are concerned. It is for those organisations to decide what action to take with respect to those recommendations.

1 The transcript of the recorded voice data provided by the IAC was a translation from the Russian language into the English language.

This report uses the 24-hour clock to describe time of day as particular events occurred. Coordinated Universal Time (UTC) is the time reference, and local time at Baucau was UTC + 9 hours.

EXECUTIVE SUMMARY

On 31 January 2003, at 0621 UTC (1521 local time), an Ilyushin 76TD (IL-76TD) aircraft, registered RDPL-34141, impacted terrain near Caicido village during a landing approach, about 1 NM (1.87 km) to the northwest of Cakung Airport, Baucau, Timor-Leste. The pilot in command was the handling pilot during the descent and approaches at Baucau. The aircraft was destroyed by impact forces and a severe post-impact fire, and the six occupants were fatally injured. The occupants included the flight crew, which comprised the pilot in command, the copilot, the flight navigator and the flight engineer, and two loadmasters who did not form part of the flight crew.

At the time of the occurrence, there was low cloud near the aerodrome.[2] Witnesses at the aerodrome estimated the cloud base to be about 1,000 ft (305 m) above ground level, and visibility to be about 1,500 m (0.8 NM).

Before the aircraft's departure from Macau, the flight crew was provided with notices to airmen (NOTAMs) and weather forecast information for the planned flight. The weather information provided to the flight crew did not include a terminal aerodrome forecast (TAF), or an aviation routine weather report (METAR) for Baucau. Those weather forecasts were not produced for Baucau.

The investigation determined that the flight crew's compliance with procedures was not at a level to ensure the safe operation of the aircraft. Before the flight crew commenced the descent into Baucau, the pilot in command briefed them that he would conduct a non-precision instrument approach at Baucau, with reference to the Baucau non-directional beacon (NDB).[3] The flight instruments fitted in the occurrence aircraft provided readings of height, speed and distance in metric units. The pilot in command's briefing included information on the relevant heights for the missed approach procedure expressed in feet, and not in their metric equivalents. None of the other crewmembers commented on that fact. The cockpit voice recorder (CVR) data revealed that the pilot in command did not refer to the source of data that he used for the briefing on the intended NDB approach at Baucau. The pilot in command's arrival briefing also contained no information or discussion on:

- the planned altimeter subscale settings for the descent to Baucau
- the applicable minimum sector altitude (MSA) within 10 NM (18 km) of the Baucau NDB; the MSA was 9,300 ft (2,834 m) above mean sea level (AMSL)
- the commencement altitude for the runway 14 NDB approach at Baucau, which was 5,500 ft (1,676 m) AMSL
- the lowest safe altitude (LSALT) for the last route sector into Baucau, which was 4,500 ft (1,372 m) AMSL
- the applicable minimum descent altitude (height) (MDA(H)) for the approach
- the expected weather at Baucau
- the Baucau NOTAMs.

2 The term 'aerodrome' is used in this report to define an area of land (including any buildings, installations and equipment) used either wholly or in part for the arrival, departure and surface movement of aircraft.

3 An NDB is a ground-based radio beacon that transmits non-directional signals. The pilot of an aircraft equipped with automatic direction-finder (ADF) can determine the aircraft's relative bearing to or from an NDB, and use that information to assist in enroute navigation or to track the aircraft to or from the NDB.

The CVR data revealed that none of the other crewmembers commented on the omission of this critical information. As a result, the arrival briefing was not effective.[4]

Controlled airspace was established at Baucau, but air traffic services (ATS) at Baucau was only available for UN aircraft on UN troop rotation days. The NOTAMs for Baucau included that information. The occurrence aircraft was not engaged in UN troop rotation operations, and no troop rotations took place during the aircraft's approach to Baucau.

When the aircraft was about 300 km from Baucau, the pilot in command instructed the copilot to call Baucau ATS. Over the next 23 minutes, the copilot called Baucau Tower 25 times, but received no response to those calls. The flight navigator then called Baucau Tower. A controller, who was present at Baucau aerodrome at the time, but not on operational duty, advised the flight crew that ATS was not available and that landing would be at the discretion of the flight crew. The flight navigator acknowledged the controller's advice, but did not seek information from the controller about the prevailing weather at the aerodrome. That was a missed opportunity for the flight crew to obtain updated information on the weather at Baucau. Had the flight crew sought and received that information, it may have provided them with an improved situational awareness of the prevailing weather.

During the descent in Timor-Leste airspace, none of the flight crew monitored the Timor Common High frequency of 123.45 MHz while the aircraft was above 10,000 ft (3,048 m). They also did not monitor the Timor Common Low frequency of 127.1 MHz while the aircraft was below 10,000 ft, or broadcast their intentions and traffic information on that frequency. Therefore, the flight crew had no assurance that there was no conflicting traffic. The flight crew's disregard of the requirement for traffic information broadcasts within Timor-Leste airspace increased the potential risk of an inflight collision.

The pilot in command diverted the aircraft from the published inbound track to the Baucau NDB, and descended the aircraft below the published 10 NM MSA. He continued descending the aircraft through the commencement altitude for the published non-precision instrument approach for runway 14, and through the LSALT. None of the other crewmembers commented that the pilot in command had breached those relevant safety heights.

The Baucau NOTAMs included information that instrument approach charts for Baucau were available from the Civil Aviation Division (CAD) of the Ministry of Transport, Communication and Public Works, Timor-Leste. However, the investigation determined that the flight crew used Jeppesen instrument and approach charts, and not the CAD-issued charts.

As the aircraft approached Baucau, the flight crew decided to conduct an overflight of the aerodrome before making a landing approach, and during the overflight, the flight crew realised that the runway was not where they expected it to be.

The investigation determined that the flight crew did not conduct the overflight of the aerodrome, or either of the landing approaches, with reference to the Baucau NDB. The flight crew used selected data from their instrument approach charts for Baucau to formulate a user-defined non-precision approach using the onboard global positioning system (GPS).[5] That

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4 Subsequent to but not as a direct result of the occurrence, the US Federal Aviation Administration published Advisory Circular (AC) 120-74A (dated 26 September 2003), Flightcrew Procedures During Taxi Operations. The AC contained information regarding aerodrome arrival briefings, and stated that:

> …an effective arrival briefing can increase crew performance by highlighting those potential areas that need special attention and consideration.

5 A user-defined approach is an instrument approach that is not flown with reference to an approved published instrument approach procedure.

user-defined procedure was a non-approved procedure. It deviated from normal practice, bypassed all the safety criteria and risk treatments inbuilt into the design of the published non-precision approach procedures, and increased the risk of a controlled flight into terrain (CFIT) accident.

The flight navigator provided the pilot in command with distance to run and lateral offset distance from the runway centreline during the overflight and the first landing approach. The flight navigator's reference to distance and lateral offset during those manoeuvres corresponded to the position of the aircraft in relation to the threshold of runway 14 as depicted on the Jeppesen charts. The navigation data provided by the flight navigator was therefore accurate in terms of where he expected the threshold of runway 14 to be, based on the Jeppesen charts. However, erroneous data on the Jeppesen charts meant that it was inaccurate in terms of where the threshold of runway 14 was actually located. The flight crew's inappropriate reliance on that data therefore increased the risk of a CFIT event.

Had the flight crew followed the non-precision runway 14 NDB approach procedure as published on either the CAD or Jeppesen charts, and not descended below the relevant MDA(H) until visual flight was assured, the position of the runway, as depicted on the Jeppesen charts would have been irrelevant. Although the runway would not have appeared where the flight crew expected it to be at the MDA(H), in visual meteorological conditions (VMC) a safe approach could have been conducted to the actual threshold of runway 14. Alternatively, if a visual approach could not be made from the relevant MDA(H), a safe missed approach could have been conducted by following the published missed approach procedures.

During the overflight and the subsequent (first) landing approach, the flight crew realised that the runway was not where they expected it to be as it was depicted on the Jeppesen charts. The pilot in command discontinued the landing approach, and the flight navigator stated that he would apply a 4 km correction to position the aircraft for a second landing approach to where he thought the runway was located. By applying the 4 km correction, the flight navigator was providing the pilot in command with inaccurate data, and resulted in the aircraft being repositioned towards a point about 1.65 km (0.88 NM) northwest of the actual position of the threshold of runway 14. That incorrect data substantially increased the hazards of the user-defined approach procedure, and the risk of a CFIT event at that stage of the flight increased to a high degree. The flight crew did not appear to identify the hazards associated with the intended improvised approach procedure, and were therefore not in a position to manage the associated risks.

As the aircraft turned on to the final approach heading during the second landing approach, the flight navigator stated that the aircraft was high on the approach profile, based on his assumption of the location of the threshold of runway 14. The pilot in command increased the rate of descent of the aircraft to about 18 m/sec (3,543 fpm), and stated 'Increased'. None of the other crewmembers commented on the high rate of descent, or drew the pilot in command's attention to the fact that the approach was unstabilised at that point. The risk of a CFIT event is diminished by a stabilised approach, and the high descent rate in close proximity to terrain at that stage of the flight increased the risk of a CFIT event to the point where impact with terrain was almost certain. The CVR data provided no evidence that the flight crew was monitoring the increasing risk and evaluating whether to discontinue the approach to treat that risk.

The flight engineer misinterpreted the pilot in command's statement 'Increased' to be an instruction for him to increase the engine thrust, and he advanced the thrust levers. It took about 2 seconds for the pilot in command to realise that engine thrust had been increased, and he reacted by calling 'No, I increased vertical speed' and reduced the engine thrust. The flight engineer's action in increasing engine thrust was a significant distraction to the pilot in command at that stage of the flight, and probably diverted his attention from the primary task of flying the aircraft to restoring the thrust to the proper setting.

At about the same time, the aircraft descended through 162 m, which was the published MDH for a straight-in landing on the runway 14 NDB approach. Neither the pilot in command nor the copilot appeared to notice that the aircraft had descended through the MDH, and it is probable that both were distracted by the flight engineer's erroneous action. The risk of a CFIT event is diminished if an approach is flown no lower than the published MDA(H) of an instrument approach procedure until visual flight can be assured and maintained. At that stage of the flight, descent below the MDH in instrument meteorological conditions (IMC) at a high rate of descent meant that the risk of a CFIT event had increased to an unacceptably high level and could not be treated. Impact with terrain was almost certain from that point onwards.

The high rate of descent continued unchecked until slightly less than 2 seconds before impact. It is probable that the pilot in command and the copilot were each unaware of the high rate of descent, because neither was monitoring the flight instruments while they were looking ahead of the aircraft and trying to establish visual contact with the ground.

The pilot in command applied back elevator to increase the aircraft pitch attitude in response to the copilot's urgent expression of concern that impact with terrain seemed almost certain. However, the pilot in command did not simultaneously increase the engine thrust, and it remained unchanged. Consequently, the pilot in command's attempt to avoid impact with terrain was unsuccessful because of the inertia of the aircraft and its close proximity to terrain.

The aircraft's impact with terrain was a direct consequence of the pilot in command descending the aircraft below the published minimum descent height for the runway 14 non-precision instrument approach procedure in an unstabilised manner. Furthermore, it was also as a result of poor planning by the flight crew and less than effective crew coordination. During that landing approach, the actions of the flight crew steadily increased the risk of a CFIT to an extreme level, yet they seemed unaware that the likelihood of impact with terrain was almost certain until about 2½ seconds before it occurred.

Research conducted by an aviation industry task force, under the patronage of the International Civil Aviation Organization (ICAO), has credited the main reasons for accidents involving aeroplane hull losses to CFIT and approach-and-landing accidents. In recent years, CFIT-reduction has been the focus of organisations such as ICAO and the Flight Safety Foundation (FSF). The findings of the FSF approach-and-landing accident reduction (ALAR) task force resulted in several conclusions and recommendations, and from those, the production of the FSF ALAR Tool Kit.

This report highlights that deviations from recommended practice are a potential hazard, particularly during the approach and landing phase of flight, and increase the risk of a CFIT event. It also highlights that crew coordination is less than effective if crewmembers do not work together as an integrated team, and that support crewmembers have a duty and responsibility to ensure that the safety of a flight is not compromised by non-compliance with recommended practices.

The potentially serious to catastrophic consequences of a CFIT event remain constant, irrespective of likelihood of the event. The potential risk of CFIT can be diminished by using current technology and equipment, by implementing adequate standard operating procedures, by assessing and managing CFIT risk factors, and by developing effective crew decision-making and risk management processes.

Safety recommendations from many investigations of CFIT events and serious incidents have related to the prevention of CFIT and approach-and-landing accidents. The Australian Transport Safety Bureau (ATSB) and CAD Timor-Leste endorse those recommendations and their implementation.

This report includes a number of recommendations made by the ATSB with the intention of enhancing the safety of flight within Timor-Leste airspace. The report also includes a recommendation by CAD Timor-Leste that ICAO publicise the safety information contained in this report.

1 FACTUAL INFORMATION

1.1 History of the flight

On 31 January 2003 at 0621 UTC (1521 local time), an Ilyushin 76TD (IL-76TD), registered RDPL-34141, impacted terrain near Caicido village during an approach to land on runway 14 at Cakung Airport, Baucau, Timor-Leste. The accident site was located at position E126° 22' 57", S08° 27' 47", and was about 1 NM (1.87 km) to the northwest of the aerodrome. The elevation of the accident site was 477 m (1,565 ft) above mean sea level (AMSL). That was 50 m (164 ft) below the published runway 14 threshold elevation that was depicted on the Jeppesen Sanderson Inc. (Jeppesen) Baucau runway 14 non-precision instrument approach and aerodrome charts. The location of the accident site is depicted at Figures 1 and 2.

FIGURE 1:
Accident location

Source: Department of Public Information, Cartographic Section, United Nations

The Lao Peoples Democratic Republic (Lao PDR) registered IL-76TD departed Macau International Airport, Macau 5 hours 29 minutes earlier, at 0052. The aircraft was on an international non-scheduled cargo flight to Baucau, carrying about 31 tonnes of telecommunications equipment.[6] The aircraft occupants comprised the pilot in command, copilot, flight engineer, flight navigator and two loadmasters.[7]

6 Baucau was the planned destination for the flight, because the runway at Dili Comoro aerodrome was considered unsuitable for that particular operation.

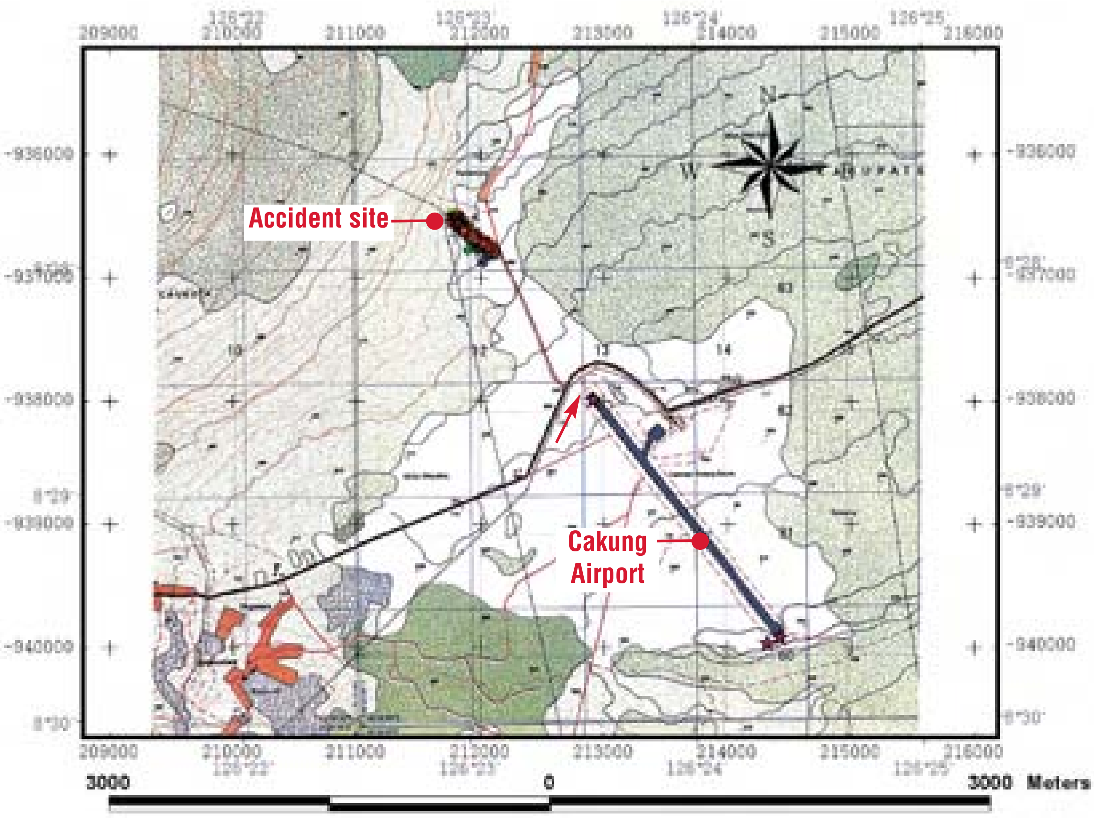
7 The term 'flight crew' in this report refers to the operating crew, which comprised the pilot in command, the copilot, the flight engineer, and the flight navigator. The two loadmasters did not form part of the operating crew, and are classified as passengers for the purposes of this report.

The aircraft departed Macau about 9 hours late because of restrictions on the departure of Stage II aircraft from Macau.[8] The flight crew rested in a hotel during the stopover in Macau, while the two loadmasters remained on board the aircraft to supervise the loading of the cargo.

The planned flight included a 5-hour turnaround at Baucau to unload the cargo, after which the flight crew were to ferry the aircraft to Rayong-Utapao International Airport, Rayong, Thailand, with an intermediate stop at Hasanuddin International Airport, Makassar, Indonesia. The planned flight time from Baucau to Makassar was 1 hour 15 minutes. A 1 hour 35 minute turnaround was planned at Makassar, and the planned flight from Makassar to Rayong was 4 hours 15 minutes. The flight crew nominated El Tari aerodrome at Kupang, West Timor, as the alternate for the flight from Macau to Baucau.

The aircraft was not provided ATS at Baucau. A notice to airmen (NOTAM), valid at the time of the occurrence, stated that ATS was only available for aircraft conducting United Nations troop rotations at Baucau. At 0540, ATS at Baucau received advice from ATS at Brisbane, Australia, that the aircraft's revised arrival time was 0610. At 0553, the flight crew contacted Baucau ATS. A controller, who was present at Baucau aerodrome at the time but not on operational duty, advised the flight crew that ATS was not available and that landing would be at the discretion of the flight crew, which they acknowledged. The pilot in command was the handling pilot during the descent, overflight, and landing approaches at Baucau.

FIGURE 2:
Accident site in relation to Cakung Airport, Baucau



8 Stage II aircraft: Term used to classify an aircraft based on aircraft noise level. A stage II aircraft has a noise level greater than 95 decibels.

According to the cockpit voice recorder (CVR) data, the flight crew set the aircraft barometric altimeter subscales to 714 mm of mercury (Hg) as the aircraft was descending through 2,400 m (7,784 ft) as it approached Baucau. That subscale setting equalled 952.8 hectopascals (hPa). The flight navigator provided the pilot in command with navigation data to position the aircraft to overfly runway 14, but when the flight navigator finally saw the runway as the aircraft overflew the aerodrome, it was not where he had expected it to be.

The pilot in command then climbed the aircraft to a height of 500 m (1,640 ft) above the elevation of the aerodrome and positioned it on a left downwind leg for runway 14. The runway was not visible to the flight crew during the downwind leg, but they discussed passing 4 to 5 km (2.1 NM to 2.7 NM) laterally abeam the runway. The flight navigator provided the pilot in command with navigation data to position the aircraft for an approach to runway 14. However, the aircraft again overflew the runway before the flight crew expected to do so, and a landing was not possible from that approach.

The pilot in command again climbed the aircraft to 500 m (1,640 ft) above the elevation of the aerodrome. The flight navigator provided the pilot in command with navigation data to position the aircraft for a second landing approach to runway 14, based on his revised estimate of where he thought the runway was located. During that landing approach, the flight navigator told the pilot in command that the aircraft was high on the approach, and the pilot in command increased the aircraft's rate of descent. Shortly after, when the aircraft was about 2 km (1 NM) from the aerodrome, the flight crew suddenly realised that the aircraft was too low on the landing approach profile, and shortly after the aircraft impacted terrain.

Three residents from Caicido village witnessed the aircraft emerge from low cloud, close to the ground, just before it impacted terrain. One of the residents was standing near trees that were struck by the aircraft shortly after it first contacted the ground. Another of the residents was blown to the ground by jet blast from the aircraft as it flew past that resident just before the impact.

Witnesses at the aerodrome at the time of the occurrence estimated that the cloud base was about 1,000 ft (305 m) above ground level (AGL), and that the visibility was about 1,500 m (0.8 NM). Witnesses photographed the aircraft as it overflew the aerodrome. They reported seeing the aircraft overfly the aerodrome twice before its impact with terrain, and that:

- the aircraft landing gear was not extended as it overflew the aerodrome on the first occasion (see Figure 3)
- the aircraft landing gear was extended during the first landing approach (see Figure 4), but the aircraft appeared too high to be able to land, and discontinued the landing approach
- the weather at the time was overcast with a low cloud base
- a few minutes after the discontinued first landing approach, they heard an explosion to the northwest of the aerodrome, and saw flames and smoke in that vicinity (see Figure 5).

FIGURE 3:
The first overflight of the aerodrome

FIGURE 4:
The second overflight of the aerodrome

FIGURE 5:
Smoke seen to the northwest of the aerodrome

Rescue and firefighting services from the aerodrome were immediately notified, and were reported to be at the accident site within about 5 minutes. The weather conditions at the accident site were described as low misty cloud with light rain, with a visibility of between 200 to 300 m. At 0740 UTC, several fires were reported to have still been burning within the wreckage, one of which was described as being a '…major fire that was flaming bright white…'.

1.1.1 Chronology of events

A chronology of the events leading up to the accident was constructed from the flight data recovered from the flight data recorder (FDR) and from the recorded flight crew conversations obtained from the CVR. The times referred to in the chronology of events are elapsed times as recorded flight and voice data events occurred. They are expressed in hours, minutes and seconds format (hh:mm:ss). The relevant flight data for the descent into Baucau is depicted at Figure A.8 at Appendix A.

1.1.1.1 The descent to Baucau

At 05:26:17, while the aircraft was still cruising at about flight level (FL) 280, the CVR data revealed that the pilot in command briefed the flight crew for the intended approach to runway 14 at Baucau. The briefing included the statement 'At Baucau we'll land with heading 135 degrees NDB approach…'.[9]

[9] The inbound track for the runway 14 NDB approach at Baucau was 146 degrees, and not 135 degrees, which was the published heading for runway 14 at Baucau, as depicted on the Jeppesen Sanderson, Inc. (Jeppesen) Baucau Aerodrome chart. Instrument approach charts are discussed at subsection 1.8.4.

The pilot in command briefed the flight crew that he would fly the aircraft at 250 km/h (135 kts) '…on glidepath…'. He also briefed them on the missed approach procedure, and referred to the missed approach altitudes in feet AMSL, as published on the Baucau instrument approach charts. The pilot in command did not, however, brief the flight crew on whether he intended to descend to the published minimum descent altitude (MDA) in terms of altitude AMSL, or to the published minimum descent height (MDH) in terms of height above the aerodrome. Nor did he brief the flight crew on whether he intended to do a straight-in landing from the approach to runway 14, or whether he intended to conduct a circle-to-land from the published minimum descent altitude/height (MDA(H)) for the approach.

Although the briefing included information on the relevant heights for the missed approach procedure expressed in feet, none of the other crewmembers commented on those heights in their metric equivalents. The CVR data revealed that the pilot in command did not refer to the source of data that he used for the briefing on the intended NDB approach at Baucau. The pilot in command's briefing also contained no information or discussion on:

- the planned altimeter subscale settings for the descent to Baucau
- the applicable minimum sector altitude (MSA) within 10 NM (18 km) of the Baucau NDB; the MSA was 9,300 ft (2,834 m) AMSL
- the commencement altitude for the runway 14 NDB approach at Baucau, which was 5,500 ft (1,676 m) AMSL
- the LSALT for the last route sector into Baucau, which was 4,500 ft (1,372 m) AMSL
- the applicable MDA(H) for the approach[10]
- the expected weather at Baucau
- the Baucau NOTAMs.[11]

The CVR data revealed that none of the other crewmembers commented on the omission of this critical information.

The pilot in command then called for the checklist. The flight navigator called the checklist items, and in response to the 'altimeter' callout, the pilot in command responded 'ON', and the copilot responded 'ON on the right 750'. The response by both pilots indicated they had both turned their respective radio altimeters on. The copilot's reference to '…750…' was likely to have been in response to him turning his radio altimeter on, and setting the decision height bug to 750 m. That was in accordance with the IL-76TD Flight Manual procedures.

At 05:28:38, in response to a call to set the landing heading, the pilot in command responded that a heading of 135 (degrees) had been set, and that the NDB was set.[12] At 05:28:51 the pilot in command commented again that the NDB was set, and at 05:28:54 the flight navigator remarked 'Good too'.

At 05:30:31, when the aircraft was about 300 km from Baucau, the pilot in command directed the copilot to contact Baucau ATS to get information about the weather and the runway in use

10 The relevant MDA(H) for the intended approach is discussed at sub-section 1.8.4.

11 The relevant NOTAMs for instrument approaches at Baucau are discussed at sub-section 1.8.2.

12 The CVR data provided no evidence to confirm that any of the crew positively identified the morse code identifier of the Baucau NDB, or that they tested the radio compass to establish that it was functioning correctly.

at Baucau.[13] Between 05:31:22 and 05:35:49, the copilot called Baucau Tower five times, but received no response to any of those calls.

At 05:39:06, the flight navigator directed the pilot in command to descend to FL250. The pilot in command sought clarification of that instruction, and the flight navigator responded 'FL250, 7600'.[14] The FDR altitude plot revealed that the aircraft started descent at about 05:39:15.

Between 05:39:19 and 05:40:20, the copilot called Baucau Tower another three times, but received no response to any of those calls.

At 05:40:36, the flight navigator made a radio call to the Ujung Pandung flight information region (FIR) en route ATS controller, and reported '…(call sign), approaching FL250, having contact with Baucau'. The controller sought confirmation that the aircraft was in contact with Baucau, and the flight navigator responded in the affirmative. The controller then advised the flight crew '(call sign), follow contact with Baucau for landing'. The CVR data revealed that the flight crew did not establish contact with Baucau Tower until 05:53:54, about 13 minutes after the flight navigator told the controller that the aircraft was in contact with Baucau.

The FDR altitude plot revealed that the aircraft descended through 7,500 m (24,606 ft) into Timor-Leste airspace at about 05:41:45. Between 05:41:45 and 05:47:50, the copilot called Baucau Tower another 13 times, but received no response to those calls. The CVR data revealed that the flight crew set both VHF transmitters to the Baucau Tower frequency of 120.2 MHz after the aircraft left the Ujung Pandung FIR. There was no evidence that the flight crew was monitoring the Timor Common High frequency of 123.45 MHz during the period that the aircraft was above 3,048 m (10,000 ft) in Timor Leste airspace.

The FDR autopilot pitch and roll data plots revealed that the autopilot was disengaged at about 05:46:45. There was no evidence from the CVR data that the pilot in command announced to the copilot his intent to disengage the autopilot, and nor did the copilot acknowledge he was aware that the autopilot had been disconnected.

At 05:48:10, the flight navigator suggested to the pilot in command '…to make [the] first approach as control and to land on the second'. The pilot in command agreed with that suggestion and stated 'We'll flight with heading 135 left' (05:48:15). The flight navigator responded 'Yes, we'll turn to left and I'll give you data for landing, will be no problems' (time 05:48:17). The CVR data revealed that the copilot was not involved in the decision to divert from the Ambon – Baucau track before reaching the Baucau NDB, or to overfly the aerodrome.

The FDR altitude plot revealed that the aircraft descended through 3,000 m (9,842 ft) at about 05:49:40. The CVR data revealed that the flight crew continued to monitor the Baucau Tower frequency of 120.2 MHz. However, there was no evidence that the flight crew was monitoring the Timor Common Low frequency of 127.1 MHz below 3,048 m (10,000 ft).

At 05:48:56, when the aircraft was about 60 km (32 NM) from Baucau and descending through about 3,500 m (11,480 ft), the pilot in command asked the flight navigator for the altimeter subscale setting. The flight navigator directed the pilot in command to set the subscale to 760 (mm Hg). That subscale setting equalled a standard sea level atmospheric pressure setting of 1,013.2 hPa.

13 The Baucau NOTAMs at the time of the occurrence included information that Baucau ATS was only available on UN troop rotation days.

14 The flight navigator's reference to '…7600…' was the metric equivalent of FL250, expressed in metres.

The flight navigator then directed the pilot in command to set the altimeter subscale to 717 mm Hg (955.8 hPa), and then almost immediately amended that setting by stating 'Sorry, 714, I had not seen there, 714' (time 05:49:38). A setting of 714 mm Hg equalled 952 hPa, which was standard atmospheric pressure 1,013.2 hPa, minus 61.2 hPa. The runway elevation, as published on the Jeppesen NDB charts was 62 hPa. The altimeter setting of 714 mm Hg would have provided the pilot in command with information referenced to the aircraft's height above the aerodrome, and not its height AMSL.

At about 05:50:00, the aircraft passed through 2,834 m (9,300 ft) AMSL on descent, which was the 10 NM MSA for the runway 14 NDB non-precision approach at Baucau. The CVR data revealed that none of the flight crew commented on the fact that the aircraft had descended through the MSA.

Between 05:50:55 and 05:52:26, the copilot called Baucau Tower another four times, but received no response to any of those calls.

At about 05:52:30, the aircraft passed through 1,676 m (5,500 ft) AMSL on descent, which was the commencement altitude for the runway 14 NDB non-precision approach at Baucau. The CVR data revealed that none of the flight crew commented on the fact that the aircraft had descended through the commencement altitude.

At about 05:52:55, the aircraft passed through 1,372 m (4,500 ft) AMSL, which was LSALT for the track from Ambon to Baucau. The CVR data revealed that none of the flight crew commented on the fact that the aircraft had descended through the LSALT.

As the aircraft approached Baucau and the extended centreline of runway 14, the flight navigator continued to provide the pilot in command with navigation data for the aircraft's distance from Baucau, and the lateral offset distance of the aircraft from the extended centreline. The non-directional signals broadcast from an NDB provide no data to flight crews on distance to run to the NDB. The CVR data revealed that the flight navigator was getting the distance and lateral offset navigation data from the self-contained aircraft onboard navigation equipment.

At 05:51:12, the pilot in command announced to the flight crew that the aircraft was maintaining 400 m.

1.1.1.2 In the circuit area at Baucau

The FDR and CVR data from time 05:53:00 has been consolidated into a series of flight path plots that are depicted at Figures. A.2 to A.6 at Appendix A.

A plot of the aircraft flight path during the approaches at Baucau is depicted at Figure A.1. The position of the runway at Baucau, as estimated by the flight crew, is depicted as a light blue/grey line. The actual position of the runway is depicted as an olive green line. The aircraft was not on the direct Ambon - Baucau track as it approached Baucau, and was not tracking directly to the Baucau NDB.

The first overflight is depicted at Figure A.2. As discussed previously, the flight crew decided to overfly Baucau on the first approach with the aircraft not configured for landing.

At 05:53:16 the flight navigator stated '…we'll check how we will path over the runway using my data', and at 05:52.22 he stated 'We'll take into consideration (illegible) on GPS'.

The flight navigator called Baucau Tower at 05:53:49. ATS was not provided at Baucau at that time, however, a controller who was present at the aerodrome at the time but not on operational duty responded at 05:53:54 '(call sign), Baucau traffic services at your discretion for landing'.

The flight navigator reported to the controller that the aircraft would be descended in the Baucau area at the discretion of the flight crew.[15] He made no attempt, however, to ask the controller about the current weather conditions at Baucau.

As the aircraft approached the extended centreline of runway 14, the flight navigator directed the pilot in command to turn the aircraft left on to a magnetic heading of 135 degrees. The pilot in command was slow to start the turn, and the aircraft flew through the extended centreline. At 05:54:40, the flight navigator directed the pilot in command to continue the left turn on to a magnetic heading of 105 degrees to position the aircraft overhead where the flight crew expected the runway to be. The runway was not where the flight crew expected it to be. The flight navigator provided the pilot in command with navigation data to position the aircraft for the next approach, which the flight crew intended to be the landing approach.[16,17,18] At 05:57:10, as the aircraft was on the downwind leg for the first landing approach, the flight navigator asked the pilot in command if he could see the runway out to the left of the aircraft, and the pilot in command replied 'No' (time 05:57:12).

The flight crew configured the aircraft for landing during the downwind leg after the first overflight. The navigator provided the pilot in command with navigation data for the lateral distance offset from the runway centreline and the distance to run to position the aircraft onto final approach to runway 14 for the (first) landing approach. The first landing approach and subsequent go around is depicted at Figure A.3, and commences at time 05:59.00. At 05:59:50, as the aircraft was approaching the aerodrome, the copilot stated 'Threshold'. Two seconds later the pilot in command also stated 'Threshold', and then at 05:59:53 'We already passed runway'. [19] The approach was discontinued, and the flight navigator stated 'That means the data was not right…'(time 05:59:55), and at 05:59:58 he advised the pilot in command that 'I took 4 km correction'. As the aircraft was turning onto the crosswind leg, the pilot in command stated 'We approached a little bit actively', and the flight navigator replied 'So, I understood to minus 3 km [1.6 NM], approximately, even 4 [2.1 NM], we'll descend by stepped (time 06:01:26). The pilot in command then positioned the aircraft onto the downwind leg for the second landing approach.

The flight navigator again provided the pilot in command with navigation data for the lateral distance offset from the runway centreline and the distance to run to position the aircraft onto final approach to where he had re-estimated the runway to be. The second landing approach is depicted at Figure A.5, and commences at time 06:04:00.

At 06:04:33, the flight navigator stated 'Lateral 600 m, distance is 5'. At 06:04:42 the flight navigator instructed the pilot in command to turn onto the landing heading, and at 06:04:46 he stated 'Now we are crossing landing heading, distance…a…is 4 km'. At 06:04:54, the flight navigator stated 'On the right 200m, distance is 3'.

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15 There was no recorded evidence that the flight navigator attempted to obtain updated weather information or the current sea level atmospheric pressure (QNH) from the Baucau controller. Meteorological information is discussed at subsection 1.7.

16 The CVR data provided no evidence that any of the crew checked that the barometric altimeter readings corresponded with the radio altimeter absolute altitude readings during the overflight of Baucau.

17 The CVR data provided no evidence that any of the crew was monitoring the ADF relative bearings to confirm 'station passage' of the Baucau NDB during the overflight.

18 The CVR data provided no evidence that the flight navigator used the onboard self-contained aircraft navigation equipment to check the prevailing wind speed and direction during the overflight.

19 The CVR data provided no evidence that any of the crew was monitoring the ADF relative bearings to confirm 'station passage' of the Baucau NDB during the second approach.

At 06:04:54, the FDR data revealed that a minimum fuel left cockpit warning was triggered, signifying that 2 tonnes of fuel was remaining for each of the aircraft engines. The FDR pitch plot revealed that minimum fuel warning was coincident with a sudden nose-down pitch of the aircraft.[20]

At 06:04:59 the flight navigator instructed the pilot in command 'Have this heading, distance is 3.5', and the pilot in command responded 'OK'. The aircraft heading, which was at that stage about 136 degrees magnetic, was maintained to the point of impact. At 06:05:07, when the aircraft had been established on final approach, the flight navigator informed the pilot 'On radio altimeter 300 we have, continue descending".[21] At 06:05:10 the flight navigator stated 'Distance now is 3', and at 06:05:16 he stated 'Distance is 2 km'.

At 06:05:17, when the aircraft was at an altitude of about 200 m (656 ft) above field elevation, the flight navigator stated 'We are flying above again'. The pilot in command responded by increasing the rate of descent of the aircraft, and at 06:05:19 he stated 'Increased'. The rate of descent of the aircraft increased to about 18 m/sec (3,543 fpm). At the same time, the FDR thrust lever angle (TLA), exhaust gas temperature (EGT), and engine rotation speed (N2) plots revealed that engine thrust was increased, and at time 05:05:21 the flight engineer called 'Increased'. At time 06:05:23 the pilot in command called 'No, I increased vertical speed', and engine power was reduced. At about the same time, the aircraft descended through 162 m, which was the published minimum descent height for the runway 14 NDB approach.[22]

At 06:05:27 the flight navigator stated 'Descending, distance is about 2'.

At 06:05:31.8, about 2.7 seconds before impact, the copilot called 'Ach, increase altitude!'. The flight data recorder FDR elevator position plots and pitch angle plot revealed that back elevator was suddenly applied, and aircraft pitch attitude increased. However, the FDR thrust lever angle (TLA), engine exhaust gas temperature (EGT) and engine high-pressure compressor RPM (N2) plots remained unchanged.

The impact sound was recorded on the CVR at 06:34:05.5, and the recorder ceased functioning at 06:34:06. The FDR barometric altitude data revealed that the aircraft barometric altitude with reference to the 760 mm Hg (1,013.2 hPa) pressure datum was 609 m (1,998 ft). The impact point was 1,877 m to the northwest of the threshold of runway 14, on the extended centreline of the runway, and was 495 m (1625 ft) AMSL.

The vertical flightpath profile for the final descent to the impact point is depicted in Appendix A at Figure A.6. The relevant FDR data plots for the final approach are depicted at Figure A.7.

1.2 Injuries to persons

Injuries	*Flight crew*	*Passengers*	*Others*	*Total*
Fatal	4	2	-	6
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

20 The minimum fuel warning is examined further in the analysis section of this report.

21 The navigator's reference to the radio altimeter is examined further in the analysis section of this report.

22 The CVR data provided no evidence that any of the flight crew was aware that the aircraft had descended below the published minimum descent height.

1.3 Damage to aircraft

The aircraft was destroyed by impact forces and the post-impact fire.

1.4 Other damage

During the impact sequence, the right wingtip of the aircraft struck a partially constructed house to the left of the centreline of the wreckage trail, about 190 m from the first impact point (see Figure 6). The house, which was occupied at the time by its owner, was severely damaged. The owner of the house was physically uninjured by the impact.

Crops near the wreckage trail were also damaged from a combination of turbine fuel, which sprayed from the aircraft fuel tanks as they ruptured during the impact sequence, and from the post-impact fire.

FIGURE 6:
Partially constructed house struck by the aircraft during the impact sequence

1.5 Personnel information

1.5.1 General information

The investigation was unable to determine the individual total levels of experience on the IL-76 TD aircraft type for the pilot in command, copilot, flight engineer or flight navigator. An IL-76 TD type rating was entered in each of those flight crew member's Russian flight crew licences, and all had held those type ratings for at least 10 years.

1.5.2 Pilot in command

Type of licence	Lao PDR Commercial Pilot Licence 046
Medical certificate	Valid to 12 March 2003
Type rating	Command IL-76
Instrument rating	Nil
Flying experience (total hours)	14,500
Hours on the type	Unable to be determined
Hours flown in the last 24 hours	6 hours (estimated)
Hours flown in the last 7 days	6 hours (estimated)
Hours flown in the last 90 days	37 hours (estimated)

The pilot in command also held a valid Airline Pilot Licence First Class, issued by the Federal Aviation Authority of Russia. The medical certificate associated with that licence was current. The licence included command and instructor type-ratings on IL-76 TD aeroplanes, and an instrument rating. The pilot in command's Russian licence contained no authorisation issued by the Department of Civil Aviation, Lao PDR (Lao DCA) that rendered the licence valid as an alternative to the issue of a Lao PDR airline transport pilot licence. The investigation was unable to determine the pilot in command's experience in conducting non-precision instrument approaches with reference to ground-based radio navigation aids.

1.5.3 Copilot

Type of licence	Lao PDR Commercial Pilot Licence 047
Medical certificate	Valid to 14 February 2003
Type rating	Copilot IL-76
Instrument rating	Nil
Flying experience (total hours)	6,800
Hours on the type	Unable to be determined
Hours flown in the last 24 hours	6 (estimated)
Hours flown in the last 7 days	6 (estimated)
Hours flown in the last 90 days	37 (estimated)

The copilot also held a valid Airline Pilot Licence, issued by the Federal Aviation Authority of Russia. The medical certificate associated with that licence was not current. The licence included a copilot type rating on IL-76 TD aeroplanes, but contained no information that the copilot held an instrument rating (or was required to hold that rating). The investigation was unable to determine the copilot's experience in conducting non-precision instrument approaches with reference to ground-based radio navigation aids.

1.5.4 Flight Engineer

Type of licence	Lao PDR Flight Engineer Licence 016
Medical certificate	Valid to 10 September 2003
Type rating	AN-12, IL-76
Flying experience (total hours)	5,100
Hours on the type	Unable to be determined
Hours flown in the last 24 hours	6 (estimated)
Hours flown in the last 7 days	6 (estimated)
Hours flown in the last 90 days	37 (estimated)

The flight engineer also held a valid Flight Engineer Licence, issued by the Federal Aviation Authority of Russia. The medical certificate associated with that licence was current. The licence included a flight engineer (overland) type rating on IL-76 TD aeroplanes.

1.5.5 Flight Navigator

Type of licence	Lao PDR Flight Navigator Licence 012
Medical certificate	Valid to 11 November 2003
Type rating	YAK-42, AN-74, IL-76
Flying experience (total hours)	9,300
Hours on the type	Unable to be determined
Hours flown in the last 24 hours	6 (estimated)
Hours flown in the last 7 days	6 (estimated)
Hours flown in the last 90 days	37 (estimated)

The flight navigator also held a valid Flight Navigator Licence, issued by the Federal Aviation Authority of Russia. The medical certificate associated with that licence was current. The licence included a flight navigator instructor type rating on IL-76 TD aeroplanes.

1.6 Aircraft information

1.6.1 General information

Manufacturer:	Tashkent Aviation Plant, Uzbekistan.
Model:	IL-76 TD
Manufacture number:	0053465941
Registration:	RDPL-34141
Year of manufacture:	1986
Certificate of airworthiness:	Lao PDR 024/AT&FSD/DCA,
Issue date:	13 December 2002
Certificate of registration:	Lao PDR 024/AT&FSD/DCA
Issue date	13 December 2002
Total airframe hours/landings:	2,349/1,400
Allowable take-off weight:	190,000 kg
Actual take-off weight:	Greater than 190,000 kg (estimated)
Weight at occurrence:	Less than 142,000 kg (estimated)
Allowable centre of gravity limits:	Unable to be determined[23]
Centre of gravity at occurrence:	Unable to be determined

1.6.2 Aircraft history

The aircraft was manufactured as an IL-76 MD variant in 1986, and was originally operated in the Ukraine. It was converted to an IL-76 TD variant in 2001.

The aircraft's owners, who were based at Sharjah in the United Arab Emirates (UAE), purchased the aircraft in July 2001 from a Ukraine-based air cargo operator. The owners withdrew the aircraft from the Ukraine State register on 21 Aug 2001. Later that month, the regulatory authority in the Islamic Republic of Iran issued the aircraft with certificates of airworthiness and registration, and in September 2001, it was leased to an Iranian company operating from Teheran.

23 The Australian Accredited Representative requested the State of Registry (Lao PDR) to provide details of the aircraft weight and balance to the Australian investigation team. No response to that request was received prior to publishing this report.

The lease with the Iranian operator continued until December 2001. The owners then leased the aircraft to another Iranian operator that also operated from Teheran. The new lease expired in October 2002, after which the aircraft was relocated to the UAE and the Iranian registration was cancelled.

On 1 November 2002, the UAE owners leased the aircraft for one year to a company based in the Lao PDR. The operation of the aircraft is further examined at subsection 1.17.1.

The aircraft's technical log was recovered from the aircraft wreckage. It contained records of refuelling and engineering pre-flight inspections, and the pre-flight inspection record at Macau was annotated '…no defects recorded…'.

On 18 November 2002, the aircraft underwent an "A" check at Sharjah, UAE, at 2,312 airframe hours.

1.6.3 Aircraft engines

The aircraft was fitted with four D-30KP turbofan engines, which also underwent periodic inspection on 18 November 2002. At that date, the engine data was as follows:

- Engine number-1 D30-KP Serial number 0305303302041
  2,687 hours total time and 1,608 cycles since new, with 1,396 hours in service and 666 cycles since last overhaul
- Engine number-2 D30-KP Serial number 03053028602046
  3,160 hours total time and 1,452 cycles since new, with 0 hours in service since last overhaul
- Engine number-3 D30-KP Serial number 0305301202046
  2,624 hours total time and 1,290 cycles since new, with 1,205 hours in service and 484 cycles since last overhaul
- Engine number-4 D30-KP Serial number 0304402911657
  4,876 hours total time and 2,404 cycles since new, with 972 hours in service and 316 cycles since last overhaul.

1.6.4 Aircraft load

The aircraft manufacturer's IL-76 TD Flight Manual contained information on the mass limitations of the aircraft, which are depicted in Table 1.

TABLE 1:
Aircraft mass limitations

Maximum takeoff weight	190,000 kg
Maximum payload	50,000 kg
Maximum fuel capacity	90,000 kg
Maximum landing weight	151,500 kg
Maximum zero fuel weight	138,000 kg

Based on those figures, the maximum empty weight of the aircraft was therefore 88 tonnes.

During the descent approach briefing, the pilot in command briefed the flight crew that the estimated landing weight at Baucau would be 144 tonnes, and that there would be 25 tonnes of fuel on board. The aircraft documentation recovered from the wreckage showed that the aircraft was refuelled to 75 tonnes of fuel at Macau. The planned fuel burn between Macau and Baucau was therefore 50 tonnes. Based on the aircraft mass limitations, the cargo manifest information, and the fuel load and fuel burn, the estimated take-off weight of the aircraft at departure from Macau, and the estimated landing weight at Baucau are depicted at Table 2.

TABLE 2:
Estimated take-off and landing weights for the occurrence flight

Aircraft empty weight at impact	88,000 kg
Add cargo weight per manifest	30,600 kg
Add estimated weight of aircraft occupants	600 kg
Add estimated fuel on board at impact	25,000 kg
Add estimated burn-off Macau – Baucau	50,000 kg
ESTIMATED TAKEOFF WEIGHT	**194,200 kg**
Less burn-off Macau to Baucau	50,000 kg
ESTIMATED LANDING WEIGHT	**144,200 kg**

1.6.5 Aircraft limitations

The aircraft manufacturer's IL-76 TD Flight Manual stated that the landing minimum for an NDB approach was 250 m (820 ft) decision height, with a visibility of 4000 m (2.16 NM). For visual approaches, the landing minimum was 180 m (590 ft), with a visibility of 3000 m (1.62 NM).

1.6.6 Aircraft systems which may have had a bearing on the accident

The aircraft was fitted with a separate radio altimeter system that provided radio altitude readings to the pilots and to the flight navigator. It also provided absolute altitude data to the automatic flight control system, the ground proximity warning system (GPWS), and the air-data recording system.[24]

The pilot in command was provided with a 150 m-scale (492 ft) radio altimeter (PB-150), and the copilot was provided with a 750 m-scale (2,460 ft) radio altimeter (PB-750). The flight navigator was provided with a 1,000 m-scale radio altimeter. A PB-750 radio altimeter indicator is depicted at Figure 7.

[24] Absolute altitude is the term used to describe height above terrain.

FIGURE 7:
A PB-750 radio altimeter indicator

Limit altitudes, such as decision heights for instrument approaches, could be pre-set on the individual radio altimeter indicators by rotating a knob on the flange of that indicator to drive a reference bug to the desired altitude. Descent below the pre-set altitude would illuminate a light bulb located behind the amber lens inscribed with the delta (Δ) symbol mounted at the end of the reference bug adjustment knob. It would also illuminate the 'DECISION HEIGHT' annunciators mounted on both pilots' instrument panels, and sound a 'BELOW PRESELECTED ALTITUDE' aural voice warning in the pilots' and flight navigator's earphones. The pilot in command's radio altimeter system activated the voice-warning signal.

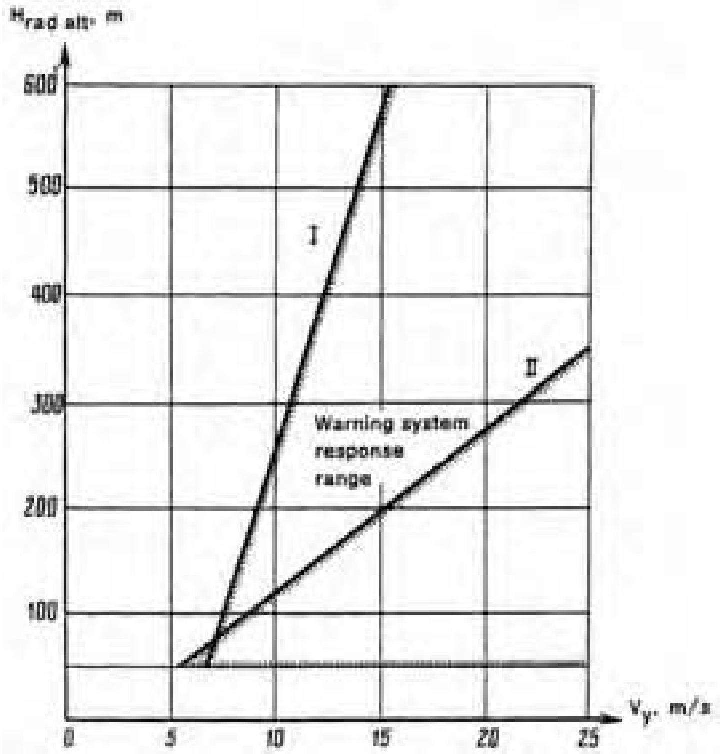
Red warning lamps located on the flanges of the radio altimeter indicators of the pilot in command, copilot and flight engineer illuminated if the radio altimeter systems became inoperative when the aircraft was below an absolute altitude of 750 m (2,460 ft).

The Interstate Aviation Committee, Air Transport Accident Investigation Commission, Moscow, Russia, (IAC) advised that the reference bug on the pilot in command's PB-150 radio altimeter indicator was normally set to 60 m (197 ft), or to the decision height if it was less than 60 m, before commencement of descent. At the same time, the reference bug on the copilot's PB-750 radio altimeter indicator was set to the relevant holding altitude, or to 750 m (2,460 ft) if the holding altitude was greater than 750 m.

The IL-76 TD Flight Manual stated that the flight crew were required to switch the radio altimeters off as the aircraft passed through 2,500 m (8,200 ft) on climb, and to switch them on before commencing descent. Radio altimeters are further examined at subsection 1.12.2 of this report.

The aircraft was fitted with GPWS, in accordance with the requirements specified in ICAO Annex 6, Part 1 (Eighth Edition July 2001), Chapter 6, paragraph 6.15. The GPWS was designed to warn the flight crew of potential terrain conflicts. The system generated warnings based on data from the radio altimeter system, static pressure vent (barometric pressure), linear acceleration, landing gear position indicator, and the angle of attack and acceleration warning unit. The warning response graph for the GPWS fitted to the occurrence aircraft is depicted at Figure 8.

FIGURE 8:
GPWS warning response graph



The following parameters were depicted on the GPWS warning response graph:

- $H_{rad\ alt}$ m – radio altitude (metres)
- V_y – rate of descent (m/s)
- I – rate of descent measured by static vent
- II – rate of descent measured by radio altimeter

GPWS warnings illuminated a 'GROUND PROXIMITY' annunciator mounted on each of the pilot in command and copilot instrument panels, and also activated a warning horn to provide the flight crew with an audible warning.

The IL-76 TD Flight Manual stated that with the landing gear extended, warnings of excessive terrain closure rate were generated in the following circumstances:

- excessive descent rate - if the barometric rate of descent exceeded certain thresholds whenever the aircraft was between 600 m (1,968 ft) and 50 m (164 ft) AGL. The barometric rate of descent trigger threshold reduced at a linear rate from about 15.3 m/sec (3,011 fpm) at 600 m radio height to about 6.7 m/sec (1,319 fpm) at 50 m radio height.

- excessive terrain closure rate - if radio altimeter rate of descent or terrain closure exceeded certain thresholds whenever the aircraft was between 400 m (1,312 ft) and 50 m (164 ft) AGL. The radio altimeter rate of descent or terrain closure trigger threshold reduced at a linear rate of about 25 m/sec at 350 m radio height to about 5.3 m/sec at 50 m radio height.

Rate of descent in excess of the linear trigger threshold illuminated a 'DANGER GROUND' annunciator on both pilots' instrument panels. It also triggered an audible warning, and resulted in a 'dangerous speed of ground approach' being registered by the FDR.

The GPWS required a valid radio altimeter signal to compute the aircraft trajectory with respect to the warning trigger thresholds.[25]

1.6.7 Other aircraft technical information

Refer to Appendix B.

1.7 Meteorological information

The area forecast for Timor-Leste and surrounding waters, issued by the Australian Bureau of Meteorology (BoM), and valid at the time of the occurrence, contained information that isolated thunderstorms were expected about the ranges and northern slopes during the afternoon and evening. Broken stratus cloud was forecast between 800 ft (244 m) and 2,000 ft (610 m) AMSL, with scattered cumulus and stratocumulus cloud between 2,000 (610m) and 20,000 ft (6,096 m). Aerodrome forecasts were not issued for Baucau.

Before the aircraft's departure from Macau, the flight crew was provided with NOTAM and weather forecast information for the planned flight. The weather information provided to the flight crew included information that there would be up to 7 OKTAS of cloud coverage below the LSALT on the last route segment.[26] It did not include a terminal aerodrome forecast (TAF) or an aviation routine weather report (METAR) for Baucau, because those weather forecasts were not produced for Baucau.

BoM provided the investigation with an analysis of the prevailing weather around Baucau at the time of the accident, based on interpretation of satellite imagery. Their analysis reported that there was a north-westerly low-level monsoon flow over the Arafura Sea, with wind speeds of between 10 - 20 kts (18 – 37 km/h), and widespread areas of middle-level cloud. Showers and storms developed along the ranges of Timor-Leste during the afternoon. The showers and storms which developed southeast of Baucau tracked toward the aerodrome, but the central areas of convection associated with those showers and storms were several miles distant from the aerodrome at the time of the accident. BoM reported that there may have been some light rain around the aerodrome at the time of the accident, and that that the rain was likely to have been accompanied by low-level cloud.

The moist onshore monsoon winds being lifted up the steeply sloping coastal terrain would have also produced low cloud. The base of that cloud was likely to have been about 1500-1700 ft (457 – 518 m) AMSL, which would have appeared as fog, or perhaps mist, to any ground-based observer near the top of that sloping terrain. Under the prevailing conditions, BoM considered it unlikely that the steeply sloping terrain would have produced any significant turbulence.

The BoM data for Dili (Comoro) aerodrome at 0800 indicated that the sea level atmospheric pressure (QNH) at Comoro was 1,008.9 hPa (756.8 mm Hg). BoM reported that there were no significant meteorological features that would have resulted in any significant change in the synoptic conditions between Dili and Baucau, and the pressure variation between 0630 and 0800 UTC would have been small. BoM reported that its records for Baucau indicated the QNH at Baucau was typically 2 hPa (1.5 mm Hg) higher than Dili. On that basis, BoM estimated the QNH at Baucau at the time of the accident was about 1,011 hPa (758.3 mm Hg).

25 ICAO Annex 6, Part 1, Chapter 6, sub-section 6.15 contains the standard relating to the fitment and operational capability of GPWS equipment.

26 The amount of cloud covering the sky is expressed in eights (OKTAS) - 0 OKTAS means the sky is clear, 8 means it is completely covered.

1.8 Aids to navigation

1.8.1 Equipment on board the aircraft

The aircraft was equipped with analogue flight instruments that were not integrated into single flight instrument displays or navigation displays for each of the pilots and the flight navigator.

The aircraft's navigation equipment included two automatic direction-finder (ADF) sets, a Bendix/King KLN-90B GPS, a KOUPOL-76 integrated flight and navigation system, an ДИСС-013-С2М Doppler navigation system, and an И-11-76 inertial navigation system. The aircraft was also fitted with a radio altimeter system, and a ground proximity warning system (GPWS). The IL-76 TD Flight Manual contained information about the integrated flight and navigation system, the Doppler navigation system, and the inertial navigation system, but contained no information about the GPS.

There were two types of altimeters on each of the pilots' instrument panels. The first type was a УВ75-15 series repeater that presented altitude data from the air-data computer system. The second type was a mechanical ВМФ series altimeter, and its barometric subscale setting could be adjusted by rotating a knob on the flange of the instrument.

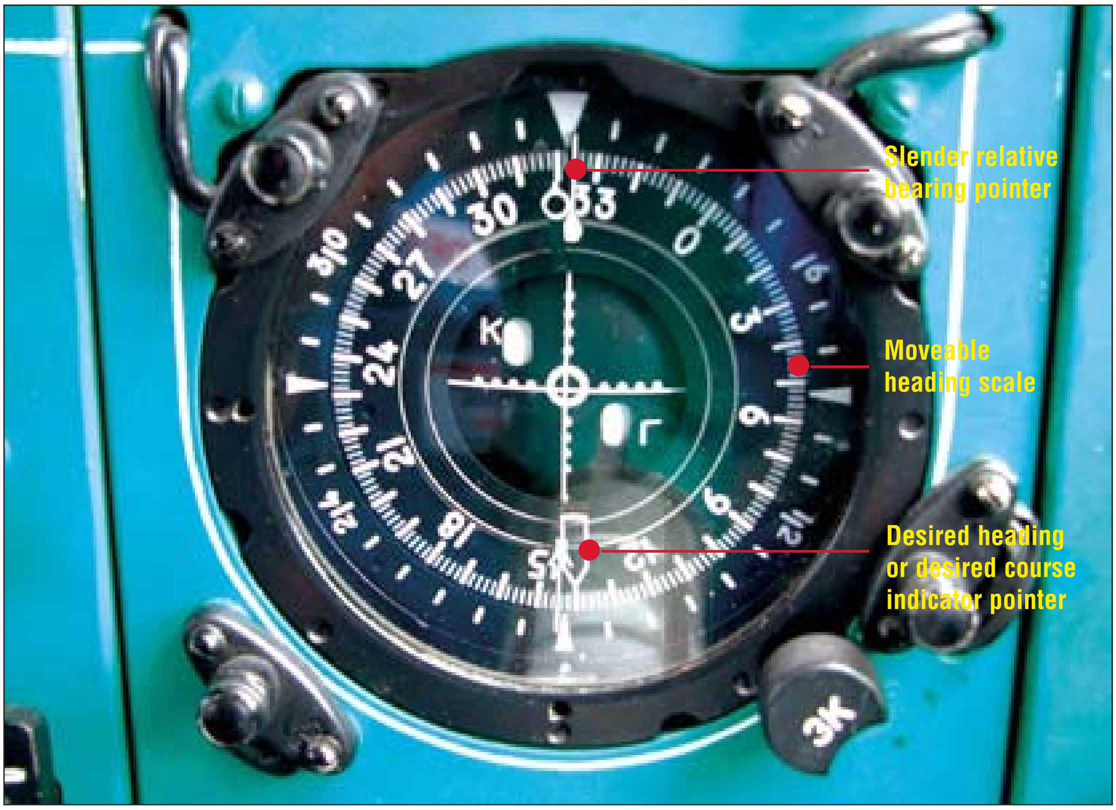
Two variants of the ВМФ series altimeter were available. The ВМФ-15 variant presented altitude data in metres, and its subscale setting was calibrated in mm Hg. The ВМФ-50 variant presented altitude data in feet, and its subscale setting was calibrated in hPa.

The IL-76 TD flight manual stated that aircraft operating to foreign countries were fitted with ВМФ-50 mechanical altimeters on the pilot in command's and navigator's instrument panels. Due to the destruction of the aircraft, it could not be determined what variant of altimeter was fitted to the pilot in command's and navigator's respective instrument panels.

The aircraft's ADFs displayed the relative bearings of NDBs, from which signals were being received in relation to the aircraft heading. Each ADF set was provided with two control panels. A control panel for each of the two ADF sets was mounted in the central overhead panel in the cockpit and also on the flight navigator's instrument panel. The ADF control panels were fitted with frequency selectors and audio controls to allow the flight crew to monitor the morse-code identifier of a selected NDB through their headsets.

A narrow pointer on the radio magnetic indicators on each of the pilots' and the flight navigator's instrument panels displayed the NDB relative bearings from the first ADF set. A wide pointer on each of the radio magnetic indicators displayed the NDB relative bearings from the second ADF set. Information from the first ADF set was also displayed to each of the pilots on-course indicators (CIs) mounted on either side of the cockpit instrument panel. The CIs presented great circle course or gyro-stabilised aircraft heading information to the pilots. A CI similar to those fitted to the occurrence aircraft is depicted at Figure 9.

FIGURE 9:
Course indicator similar to those fitted in the occurrence aircraft



By rotating the 3K knob, the desired heading or desired course could be set. With the automatic flight control system disengaged, the slender relative bearing needle on the CIs provided the pilots with information on the relative bearing of a selected NDB from the aircraft's nose or tail.

The Bendix/King KLN 90B GPS unit was approved for the conduct of non-precision GPS approaches to aerodromes where those procedures were promulgated. The KLN 90B provided navigation distance information in feet and nautical miles. There was no provision for that information to be displayed in metres or kilometres. It also provided the flight crew with information about wind direction and speed, based on the aircraft heading and true airspeed.

The GPS was mounted at the flight navigator station under the cockpit, and was equipped with a receiver autonomous integrity monitoring (RAIM) function to detect erroneous GPS satellite signals. It was also equipped with a course deviation indicator (CDI) to provide information about the aircraft's lateral offset from a desired or planned lateral navigation track. During en route segments, the RAIM protected area was 2 NM (3.7 km). It would normally transition to 1 NM (1.85 km) within 30 NM (56 km) of a destination, then 0.3 NM (556 m) within 2 NM (3.7 km) of the final approach fix during a GPS approach that was derived from approach data stored within the onboard GPS unit's database.[27] The investigation was unable to determine the validity of the database.

On a GPS unit that is approved for non-precision approach (NPA) procedures, the sensitivity of the CDI automatically transitions from 5 NM (9.2 km) full-scale sensitivity to 1 NM (1.85 km) full-scale sensitivity, then 0.3 NM (556 m) full-scale sensitivity during the conduct of an NPA. CDI sensitivity can normally be changed from en route full-scale sensitivity to approach full-

27 GPS approaches are discussed in sub-section 1.18.8.

scale sensitivity at times other than during the conduct of an approved GPS approach. However, changing the CDI sensitivity in that manner does not change the GPS RAIM calculation tolerances, and will remain in the 2NM (3.7 km) en route mode.

The Pilot's Guide for the KLN 90B GPS contained the following information regarding the conduct of non-precision approaches:

> WARNING: It is not approved to conduct the final portion of the approach unless the KLN 90B is in the approach active mode (ACTV on external annunciator).

The KOUPOL-76 integrated flight and navigation system provided navigation capability to selected navigation waypoints that had been manually entered into the system on a keyboard at the flight navigator's station. The ДИСС-013-С2М Doppler navigation system constantly measured aircraft ground speed and drift angle, and provided that data to the KOUPOL-76 integrated flight and navigation system. The И-11-76 inertial navigation system also provided navigation capability to selected navigation waypoints that had been manually entered into the system on a keyboard at the flight navigator's station, and was used in conjunction with the KOUPOL-76 integrated flight and navigation system. The inertial navigation system could also provide flight crew with information about wind direction and speed. The integrated flight and navigation system, the Doppler navigation system, and the inertial navigation system each provided navigation distance information in km.

1.8.2 Baucau non-directional beacon

Cakung Airport was served by the Baucau NDB, which broadcast on frequency 315 kHz. A 2-letter morse code identifier "BC" was broadcast seven times every 30 seconds on the carrier frequency to provide confirmation that the correct frequency of the NDB had been selected and that the beacon was functioning normally.[28]

The NOTAMs for Baucau included NOTAM GO111/02, which stated:

> …INST APP PROC DATED 1 APRIL 2001 FOR RWYS 14/32 AVBL FM CIVIL AVIATION DIV EAST TIMOR UPON REQUEST VIA FAX TO +61 (8) 89463900 EXT 6151…

On 1 January 2003, the Baucau NDB was affected by a lightning strike. On 2 January, the contractor operating aerodrome inspected the NDB for damage. On 24 January, the contractor reported that both NDB transmitters were serviceable, however, repairs had been needed to rectify minor damage to the NDB circuitry because of lightning damage. The contractor reported that the aviation technician who effected the repairs on the NDB recommended that extra components were needed to ensure the future serviceability of the NDB. Those components had not been ordered at the time of the occurrence.

The Baucau NDB was intended to operate continuously. A monitor in the aerodrome control tower could be used to check its operational status, but the control tower was not staffed at the time of the occurrence. Two days before the occurrence, when the tower was staffed for a UN troop rotation flight, the NDB was noted to be operating normally. When the NDB monitor in the control tower was checked during the evening after the occurrence, it indicated that the NDB was not operating. The operational status of the NDB at the time of the occurrence could not be determined.

[28] ICAO Annex 10 - Aeronautical Telecommunications recommends that the morse code identification signal of an NDB should be transmitted at least three times each 30 seconds, spaced equally within that time period. The identification signal for the Baucau NDB was 2.2 seconds for transmission of the morse code "BC", followed by 2 seconds of silence.

1.8.3 Baucau aerodrome visual ground aids

Aerodrome visual ground aids and their serviceability were not a factor in this occurrence.

1.8.4 Baucau runway 14 instrument approach procedure

Instrument approach and landing procedures were available for runways 14 and 32 at Baucau, using the NDB. The aircraft was fitted with suitable navigation equipment to allow the flight crew to conduct those non-precision instrument approach procedures. The approved approach charts for those procedures were available on request from the Civil Aviation Division (CAD), Timor-Leste.

Jeppesen also published approach charts for the runway 14 and 32 Baucau NDB procedures. The Jeppesen Baucau runway 14 NDB instrument approach and aerodrome charts are depicted at Figures 10 and 11 respectively.

The runway 14 non-precision instrument approach procedure on the CAD and Jeppesen charts were identical in terms of tracking requirements and limit altitudes/heights. Both the CAD and Jeppesen runway 14 NDB charts depicted the inbound track of the procedure as being 146 degrees magnetic. The charts included information on the minimum descent altitude/heights for straight-in landings at the completion of the approach procedure, and minimum descent altitude/heights for circle-to-land procedures. The MDA(H) was the minimum altitude/height below which descent was not to be made without the required visual reference to the ground.

The MDA for a straight-in landing on runway 14 was 2,260 ft (689 m) AMSL. That was equivalent to an MDH of 531 ft (162 m) above the elevation of the threshold of runway 14. The published visibility minimum for a straight-in landing was 3,000 m (1.62 NM) on the Jeppesen runway 14 NDB chart. Based on the pilot in command's statement during the descent approach briefing that he would fly the aircraft at 250 km/h (135 kts) '…on glidepath…', MDA for a circle-to-land on runway 14 was 2,300 ft (701 m) AMSL. That was equivalent to an MDH of 500 ft (152 m) above the elevation of the aerodrome. The published visibility minimum for a circle-to-land was 2,900 m (1.56 NM) on the Jeppesen runway 14 NDB chart.

The published runway 14 threshold elevation on the Jeppesen and CAD charts was 527m (1,729 ft) AMSL.

The Jeppesen aerodrome chart depicted the threshold of runway 14 as being about 0.9 NM (1,700 m) southeast of the NDB. The Jeppesen runway 14 and 32 NDB approach charts also depicted the runway in that position, relative to the NDB. During the investigation the actual threshold of runway 14 was found to be about 1.35 NM (2,500 m) northwest of where it was depicted on those charts. The runway heading for runway 14 at Baucau was depicted as 135 degrees magnetic on the Jeppesen aerodrome chart. CAD did not publish an aerodrome chart for Baucau, and the runway heading was not included on CAD Baucau NDB approach charts. Following the occurrence, runway 14 was surveyed and the actual runway heading was determined to be 139 degrees magnetic.

Jeppesen charts and maps were found scattered throughout the cockpit wreckage area. They were also located in the adjacent areas of the wreckage. Most of the charts and maps were found in a fragmented and water-damaged condition. Many of the charts and maps were not located, and had probably been consumed by the post-impact fire. The Baucau runways 14 and 32 NDB non-precision instrument approach charts and aerodrome chart were not among those that were located. The revision sheet for the Jeppesen charts was located. It was in the name of a Cambodian-based operator, and not the Lao PDR-based operator, in whose name the aircraft was registered.

The track from Ambon to Baucau was 198 degrees magnetic. To conduct a runway 14 NDB approach, the flight crew of an aircraft arriving at Baucau on the Ambon – Baucau track would maintain that track to the Baucau NDB. On reaching the NDB, the flight crew would then turn the aircraft left onto a magnetic heading of 170 degrees to fly parallel to the inbound leg of the holding pattern. After 1 minute on that heading the flight crew would then turn the aircraft left onto the holding side of the holding pattern. They would then intercept the inbound leg of the holding pattern (350 degrees magnetic) to reposition the aircraft overhead the NDB. Once overhead the NDB, the flight crew could then conduct the non-precision approach, as depicted at Figure 10.

Because the commencement altitude for the runway 14 NDB was 5,500 ft (1,676 m) AMSL, and the LSALT on the Ambon – Baucau track was 4,500 ft (1,372 m) AMSL, there were three alternatives regarding the minimum altitude to be maintained until overhead the Baucau NDB. Those were:

- to maintain LSALT until overhead the NDB, then climb the aircraft to the commencement altitude upon entering the holding pattern
- to descend to LSALT then climb back to the commencement altitude before overflying the NDB and entering the holding pattern
- to descend no lower than the commencement altitude before overflying the NDB and entering the holding pattern.

On 10 February 2003, CAD notified Jeppesen about the location of the runway in relation to the NDB and that the aerodrome reference point (ARP) was incorrectly depicted on the Jeppesen charts, and asked Jeppesen to withdraw the charts.

Jeppesen subsequently researched the origin of the runway end coordinates for runway 14/32 at Baucau in its database, but it could find no documentation about how the coordinates were calculated. Jeppesen assumed that the coordinates had probably been calculated based on the Baucau ARP data published in an old version of the Indonesian Aeronautical Information Publication. On 28 February 2003, Jeppesen issued Airway Manual Services Revision Letter number 5-03 which provided details of revisions to material in the Pacific Basin edition of the manual, and included instructions that the Baucau 16-1 and 16-2 charts were to be destroyed.

FIGURE 10:
The Jeppesen August 30, 2002 Baucau runway 14 NDB approach chart

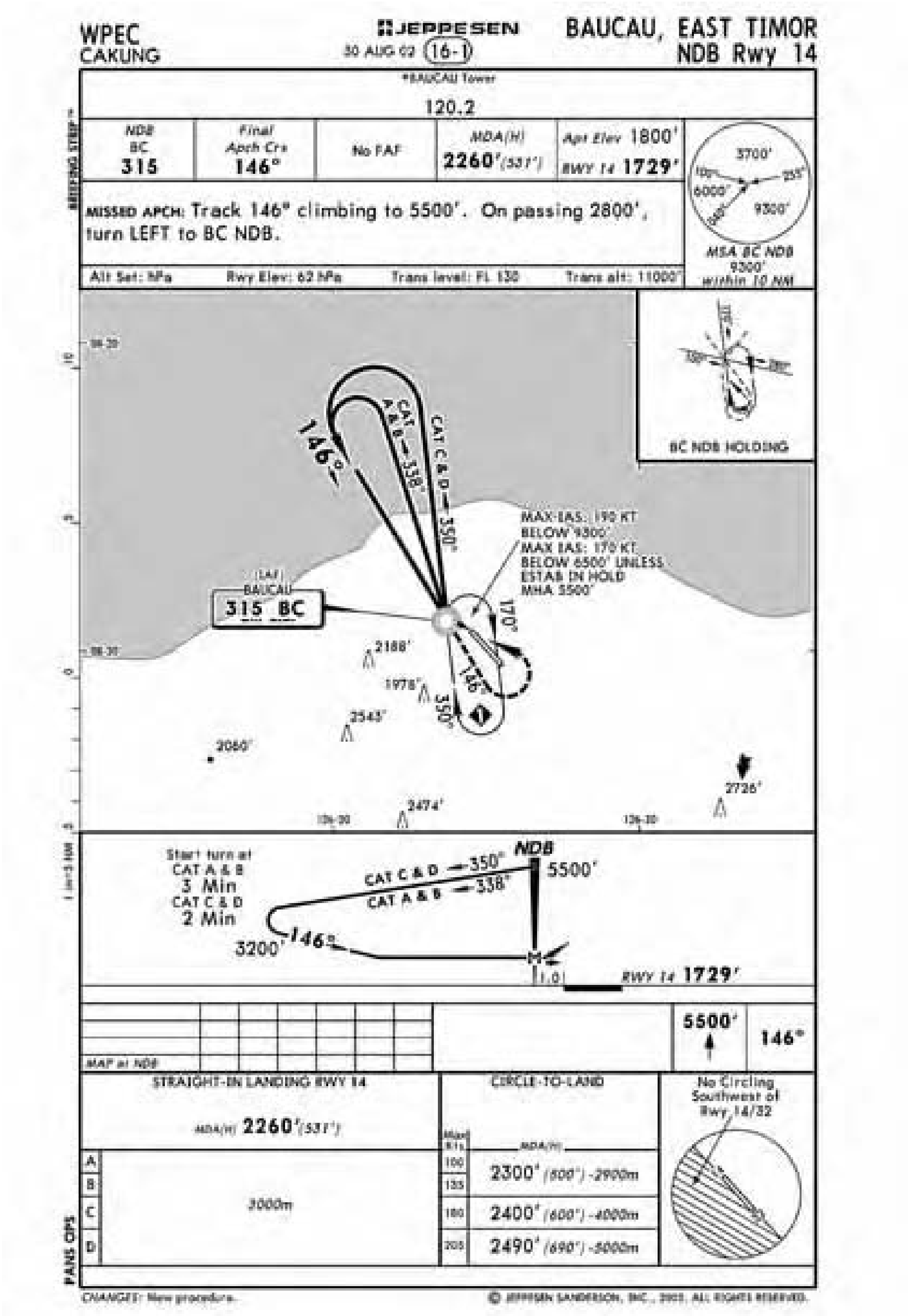


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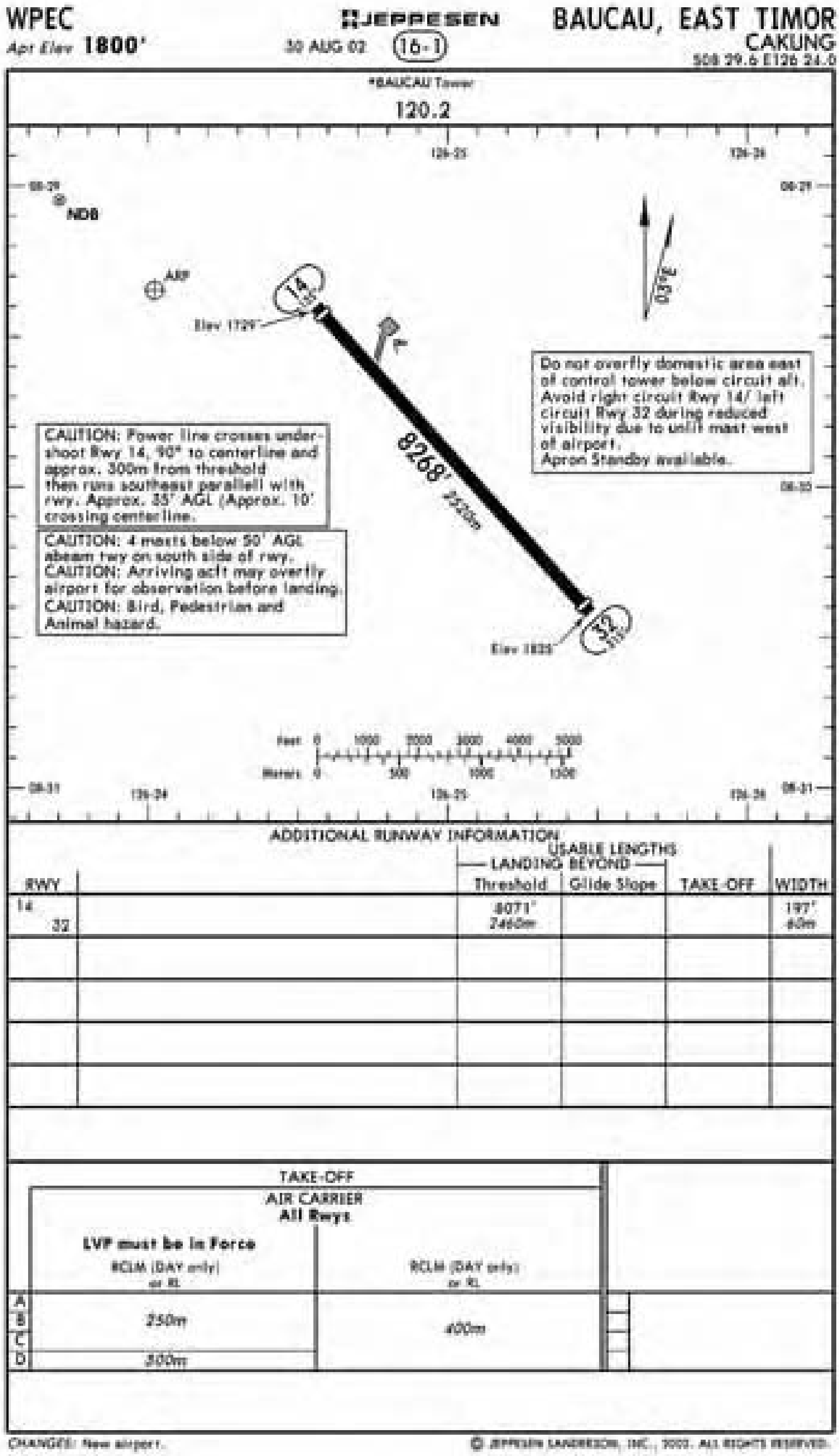
FIGURE 11:
The Jeppesen August 30, 2002 Baucau aerodrome chart



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1.9 Communications

There was no requirement for ground based automatic voice recording equipment at Baucau. Apart from the CVR data, there was no other record of communications between ATS at Baucau and the flight crew of the occurrence aircraft. The automatic voice recording equipment in the Comoro control tower at Dili revealed that the flight crew had not contacted either Comoro Approach or Comoro Tower at any stage before the accident. The CVR also contained no evidence that the flight crew tried to broadcast their intentions and traffic information on the Timor Common Low frequency of 127.1 kHz, as required in NOTAM GO113/02.

1.10 Aerodrome information

1.10.1 Timor-Leste airspace arrangements

Timor-Leste airspace extended from surface level to 24,500 ft (7,468 m), and was below the Bali and Ujung Pandung flight information regions. Most of the Timor-Leste airspace was uncontrolled, and CAD did not provide aircraft operating within Timor-Leste airspace with a flight following service. The investigation was unable to determine if the flight crew had arranged flight following for the purposes of search and rescue for the occurrence flight.

Aircraft operating within Timor-Leste airspace were required to make traffic information broadcasts to help in reducing the risk of collisions. Those broadcasts were required on 123.45 MHz above 10,000 ft (3,048 m), and on 127.1 MHz below 10,000 ft, and ATS did not monitor those frequencies, nor was there a requirement for it to do so. The NOTAMs for Baucau included NOTAM GO113/02, which stated:

> ALL ACFT OPR TO/FROM BAUCAU OUTSIDE AD OPR HR ARE TO BCST INTENTIONS AND TFC INFO ON THE FLW FREQ: WITHIN 5NM OF AD - BAUCAU TWR 120.2. BEYOND 5NM - TIMOR COMMON LOW 127.1

The CVR revealed that the flight crew did not monitor 123.45 MHz during the descent in Timor-Leste airspace while the aircraft was above 10,000 ft. Nor did they monitor 127.1 MHz below 10,000 ft or broadcast their intentions and traffic information on that frequency.

Controlled airspace within Timor-Leste airspace was established at Dili and Suai airports. Controlled airspace was also established at Baucau, but ATS at Baucau was only available for UN aircraft on UN troop rotation days. The NOTAMs for Baucau included NOTAM GO114/02, which stated:

> …ATS ONLY AVBL ON UNITED NATIONS TROOP ROTATION DAYS IN ACCORDANCE WITH UN ROTATION SCHEDULE…

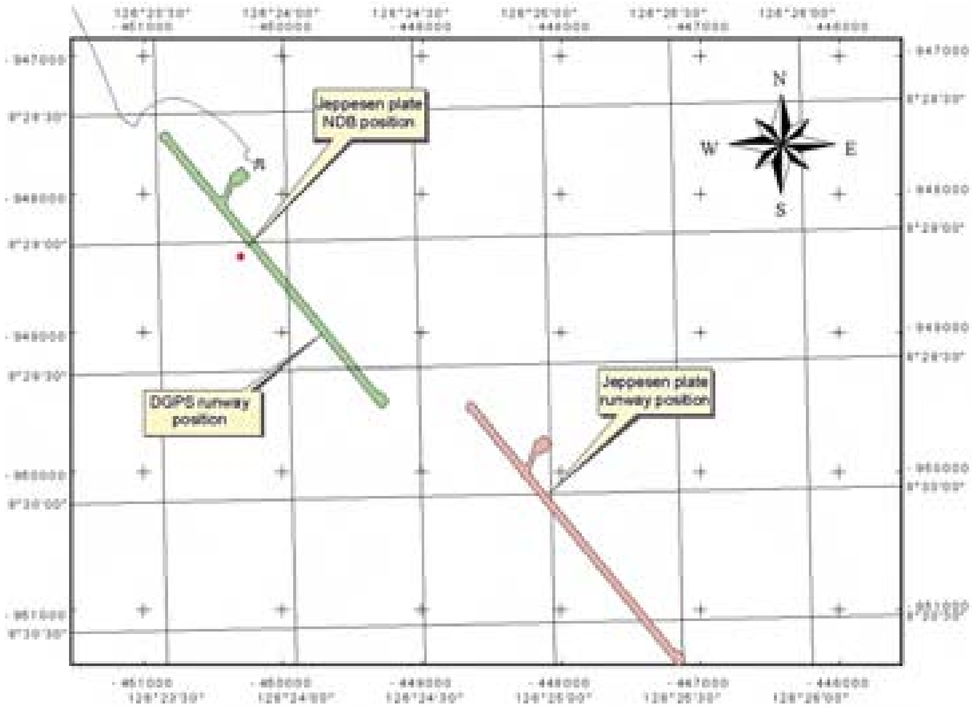
The occurrence aircraft was not engaged in UN troop rotation operations, and 31 January 2003 was not a UN troop rotation day.

1.10.2 Baucau aerodrome survey coordinates and elevations

The 1993 Indonesian 1:25000 topographical map of Baucau depicted the elevation of the threshold of runway 14 as 524 m (1,719 ft) AMSL. In February 2001, another survey was conducted of the aerodrome, and the survey report included information that the threshold elevation of runway 14 was 527 m (1,729 ft) AMSL.

During the investigation, personnel from the Australian Defence Science Technology Organisation (DSTO), acting as advisers to the Australian accredited representative, used differentially-corrected GPS (DGPS) wreckage mapping and analysis equipment to establish the geographic coordinates of the runway at Baucau. The aerodrome runway coordinates were measured and compared with the coordinates depicted on the Jeppesen Baucau aerodrome chart. The comparison revealed that the position of the runway depicted on the Jeppesen chart was displaced from the actual position of the runway by about 2.38 km (1.28 NM), as depicted at Figure 12, and also at Figures A1 to A5 in Appendix A.. The location of the ARP and NDB in relation to the actual runway position and the runway position as depicted on the Jeppesen charts are also depicted at Figures A.1 to A.5.

FIGURE 12:
Actual vs. depicted runway position



The Australian accredited representative and his team were unable to locate the aerodrome reference point (ARP) in the position where it was depicted on any of the Jeppesen aerodrome chart. Using the DSTO GPS, the threshold elevation of runway 14 was determined to be 519 m (1,703 ft) AMSL. Subsequent to the accident, the UN commissioned another survey of Baucau, which revealed that the threshold elevation of runway 14 was 516 m (1,694 ft) AMSL.

1.10.3 Altimeter setting procedures for Baucau

The UN controlled the operation of Cakung Airport, and was responsible for the serviceability of the facilities at the airport. Until 24 January 2003, the NOTAM information for Baucau included advice that QNH data for Baucau was unreliable. Flight crews of aircraft operating into Baucau were required to use the Dili Comoro aerodrome QNH, and to add 320 ft (97.5 m) to the published minimum descent altitudes of the Baucau instrument approach procedures. The NOTAM resulted from the inaccuracy of the QNH derived from the Baucau automated weather observing system (AWOS). The reference elevation for the AWOS was adjusted, and the Air Operations Division of United Nations Mission of Support in East Timor (UNMISET) then requested CAD to withdraw the NOTAM, which it did on 24 January 2003.

At the time of the occurrence, there was no method in place to provide the Baucau QNH to aircraft operating into Baucau if they were not conducting UN troop rotations. Subsequent to the occurrence, a NOTAM was issued which stated that QNH for Baucau was only available to aircraft operated by, and on behalf of UNMISET, during periods that ATS was available for aircraft engaged in UN troop rotations.

1.11 Flight recorders

The aircraft was fitted with an MSRP-64 FDR, two MS-61B CVRs, and a quick access recorder (QAR). The FDR and CVRs were recovered from the rear fuselage section in the wreckage during the early stages of the on-site investigation. The QAR was also recovered from the cockpit wreckage area. The impact forces extensively damaged the QAR, and no flight data could be recovered from it.

On advice from the Australian Accredited Representative, CAD forwarded the FDR and CVRs to the IAC for readout and analysis.

The casing of the FDR storage unit was sooted from the post-impact fire, but revealed no evidence of heat or structural damage (see Figure 13). Examination of the recorded data revealed that the FDR had operated normally until impact.

FIGURE 13:
Flight data recorder before recovery from the aircraft wreckage

The parameters recorded by the MSRP-64 FDR normally included:

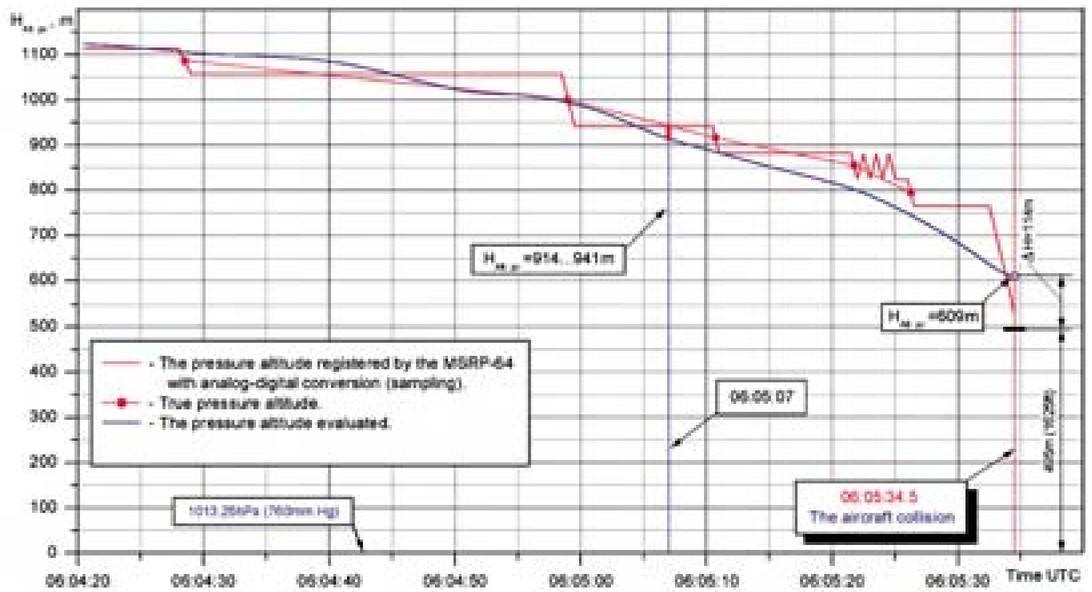
- lateral acceleration
- vertical acceleration ('g')
- rudder position
- elevator position
- magnetic heading

- roll
- stabiliser position in degrees
- pitch angle in degrees
- angle of attack in degrees
- barometric altitude in metres, with reference to a standard sea level pressure datum of 760 mm Hg (1,013.2 hPa)
- radio altitude in metres
- GPWS activation
- indicated airspeed in km/hour
- thrust lever angles for each engine
- N_2 for each engine
- EGT for each engine
- wing slat extension
- landing gear activation
- autopilot pitch engagement
- autopilot roll engagement.

Plots of the recorded flight data are depicted at Appendix A in Figures A.7 to A.9.

The IAC reported that the FDR recorded barometric altitude in 60 m increments, and that it was possible there could be as much as a 120 m error in the barometric altitude plot. The IAC 'smoothed' the recorded barometric altitude data to take into account the variable quality of the recorded data and to derive true pressure altitude. It then applied recorded vertical acceleration ('g') to the derived true pressure altitude data to provide an evaluation of the actual aircraft barometric altitude (see Figure 14).

FIGURE 14:
Evaluated aircraft barometric altitude



The evaluated pressure altitude varied slightly from the 'smoothed' true pressure altitude derived from the variable recorded barometric altitude data. The impact point was 495 m (1,625 ft) above the 760 mm Hg (1,013.2 hPa) datum. The evaluated pressure altitude at impact was 609 m (1,998 ft), indicating a discrepancy of 114 m (374 ft) between the recorded barometric data and the evaluated pressure data.

The FDR did not record vertical velocity (rate of climb or descent). The vertical velocity derived from the barometric altitude data indicated that the average vertical velocity of the aircraft was about 120 m/sec (393 ft/sec, or 23,622 ft/min) during the last 2 seconds of the flight. The IAC concluded that that figure was inaccurate, and was due to disturbance of the airflow around the barometric pressure source when elevator was suddenly applied to increase the aircraft pitch angle shortly before the impact, as depicted at Appendix A in Figures A.6 and A.9. The IAC calculated the vertical velocity of the aircraft during the final stages of the flight, using the evaluated barometric altitude, as referred to above.

No roll information was recorded from the left and right attitude indicators. Additionally, no information was recorded from the radio altimeter system. The IAC reported that when it examined the FDR, a note was found affixed to the tape cassette within the unit which stated '…no altitude from RALT…'. The IAC reported that the note would have been the result of previous maintenance testing of the unit, and that the lack of those recorded parameters was probably the result of a malfunction in the flight data acquisition unit of the aircraft's FDR system. Examination of the flight data for the five flights preceding the occurrence flight revealed that no radio altitude had been recorded on those flights. The IAC reported that failure of the radio altitude registration channel on the FDR would not necessarily indicate a failure of the radio altimeter system. The IAC also reported that examination of the CVR data for the flight prior to the occurrence flight revealed that the flight navigator had provided radio altimeter information to the pilots during the landing approach, commencing at 100 m (328 ft) absolute altitude. However, the FDR had not recorded radio altimeter data during that flight.

The cases of both CVRs were also sooted from the post-impact fire, but they revealed no evidence of structural damage (see Figure 15).

FIGURE 15:
Cockpit voice recorders during recovery from the aircraft wreckage

The interior of both CVRs showed no evidence of interior heat or impact damage. The wire-recording medium in one of the CVRs was dislodged from the recorder spools in that unit, and provided no useful data. The other cockpit voice recorder provided good quality audio information for the descent and approaches to Baucau.

The MS-61B was a single-channel recorder, and combined all onboard audio channels into one recorded channel. It operated in an automatic 'auto-start' mode, and the recording media only moved and recorded acoustical and time data if the flight crew operated the intercom or the radio transmitter keys. The system incorporated disengaging delay of about 15 seconds (+/- 5 seconds) between when the intercom or the radio transmitter keys were released, and when the recording media stopped.

The aircraft was not fitted with a 'hot mic' system that provided acoustical data to the CVR.[29] Additionally, the CVR was not equipped with a cockpit area microphone (CAM). Both 'hot mic' and CAM systems provide a CVR with the capacity to capture flight crew communications and acoustical signals relating to the operation of the aircraft. Those signals improve the ability to analyse the activities of a flight crew and the operation of the aircraft in the period leading up to an occurrence. Both 'hot mic' and CAM are most effective when the CVR is continuously recording acoustical data. Without a CAM, the CVR on the occurrence aircraft was not able to record the flight deck aural environment as required under the standard described in 2.1.1.b) of Attachment B to Annex 6 Part I to the *Chicago Convention*.

A readout of recorded flight crew conversations was obtained for the final 40 minutes of the flight. The CVR transcript was prepared by the IAC, and was a translation from the Russian language to the English language. From the CVR, it was evident that the pilot in command was the handling pilot for the flight. Relevant aspects of the flight crew conversations in the circuit area at Baucau are depicted at Figures A.2 to A.6 at Appendix A.

The IAC reported that because the time intervals between the flight crew conversations recorded on the CVR during the second landing approach were less than 10 seconds, any audible warnings generated by the radio altimeter system and the GPWS would have been recorded on the CVR. However, none were evident.

1.12 Wreckage and impact information

1.12.1 General description

The wreckage distribution map is depicted at Appendix C in Figure C.1.

The wreckage trail was aligned on a track of about 130 degrees magnetic. The aircraft began to break up immediately after impact. It also slewed about 5 degrees to the left during the break-up sequence, as is evident in Figure 19 at subsection 1.12.2. Despite the destruction of the aircraft during the break-up sequence, all extremities of the airframe were located. The four engine cores were also located. They were relatively intact, and each revealed damage consistent with engine rotation while delivering power.

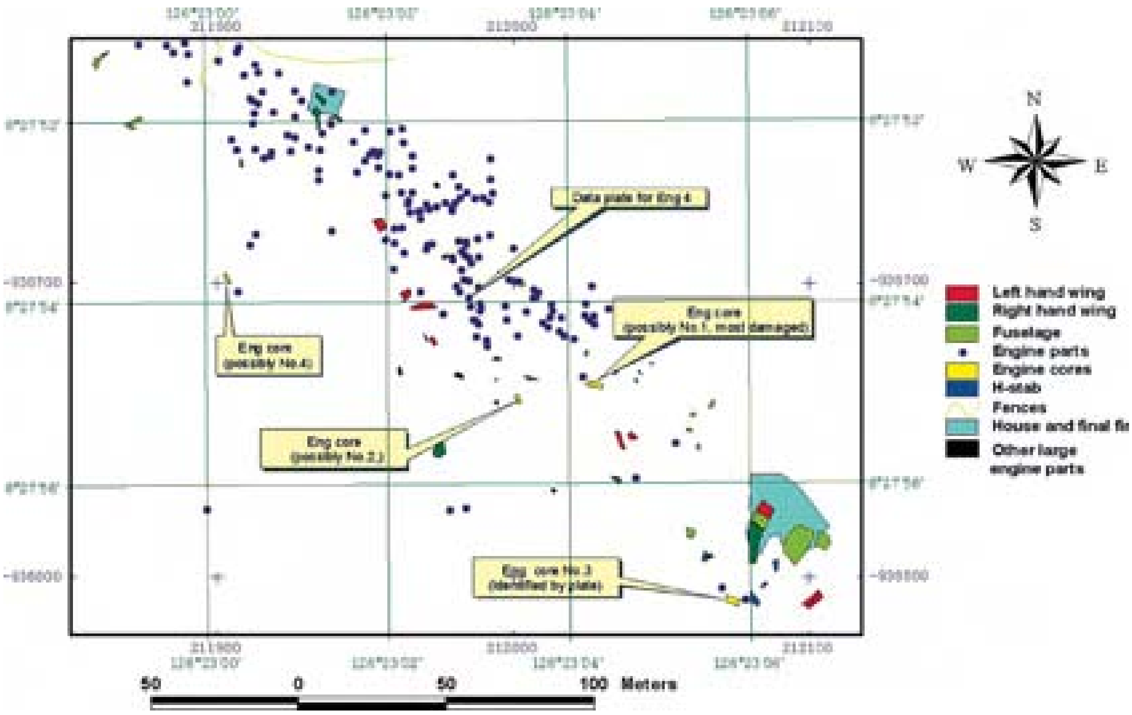
The post-occurrence technical examination of airframe and engine parts revealed no evidence of inflight break-up or mechanical failure. There was also no evidence of any pre-impact explosion or fire. All meltage within the wreckage displayed evidence of a vertical flow in relation to the ground, which suggested that the individual metallic structures were in a static

29 A 'hot mic' system refers to the microphone operated at any crew member position presenting signals to the CVR for recording at all times when electrical power is applied, irrespective of the keying of the intercom or radio transmitters.

state when they were exposed to the heat source that resulted in the melting process. While there was evidence of sooting and ash on the wreckage, there was no evidence of slipstream effect to indicate that fire had occurred before impact.

The engine cores and accessories were mostly intact, however each engine fan assembly had separated from its respective engine, and fan blades were spread throughout the accident site (see Figure 16).

FIGURE 16:
Location of engines



The post-occurrence technical examination of the engine fan blades found in the wreckage did not display any evidence of bird strike or blending repairs.[30] It was not possible to determine whether the engines had sustained any foreign object damage before impact because of the significant damage resulting during from the impact sequence. The FDR EGT and N2 plots are depicted at Figures A.8 and A.9 in Appendix A. The plots revealed no apparent aircraft engine anomalies during the descent into Baucau or during the approach sequences. The extent of the typical resultant engine damage is depicted at Figures 17 and 18.

The slat and flap assemblies that had remained attached to primary wing structure were in the extended position. The flap tracks were lubricated, and displayed no evidence of significant wear. The screw jack and actuator positions were consistent with the wing high lift devices having been extended at the time of impact. The FDR slats extended, heading and pitch plots are depicted at Figures A.8 and A.9. They revealed no slat or flap abnormalities during the approach sequences.

All landing gear assemblies were found in the extended position. The FDR landing gear actuator plot is depicted at Figures A.8 and A.9. It revealed no landing gear abnormalities during the approach sequences.

There was no apparent evidence of electromagnetic interference with the on-board navigation equipment.

30 Blending is the maintenance process to repair minor fan blade damage.

FIGURE 17:
Typical engine damage

FIGURE 18:
Another damaged engine

1.12.2 Impact sequence and distribution of the wreckage

The aircraft impacted terrain about 1 NM (2 km) to the north-northwest of Baucau aerodrome. The accident site is depicted at Figures 19 and 20.

FIGURE 19:
Accident site in relation to Baucau runway 14

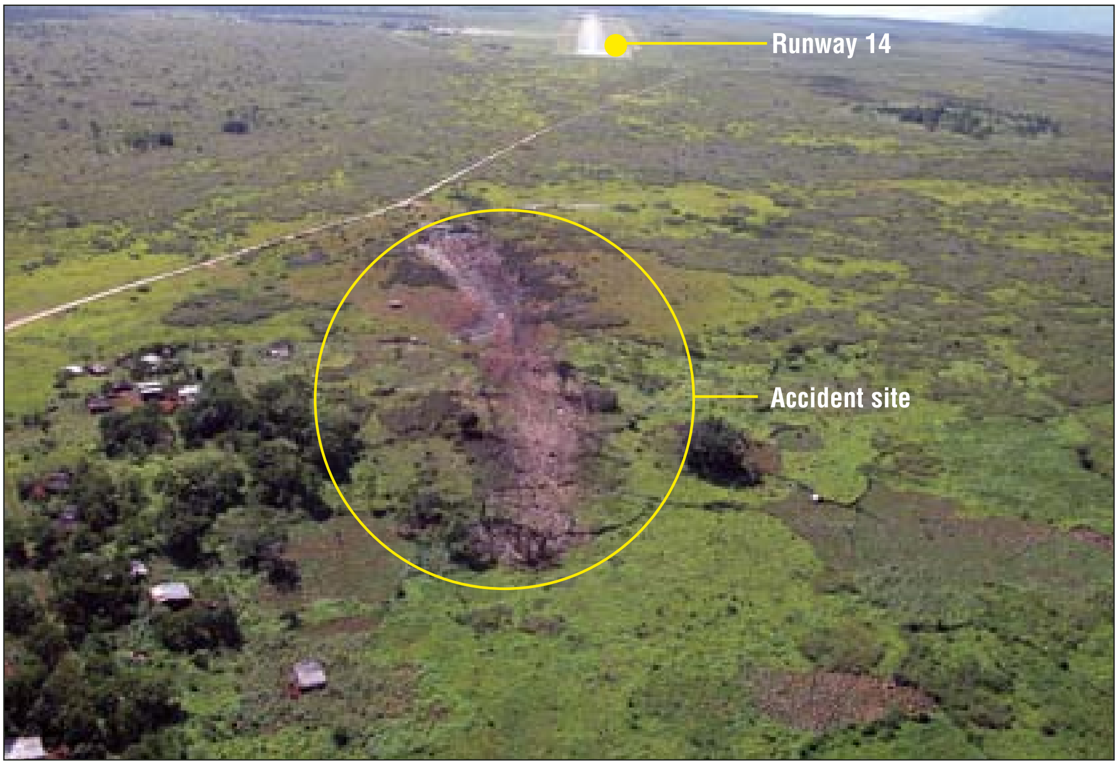


FIGURE 20:
Accident site viewed from the south looking north

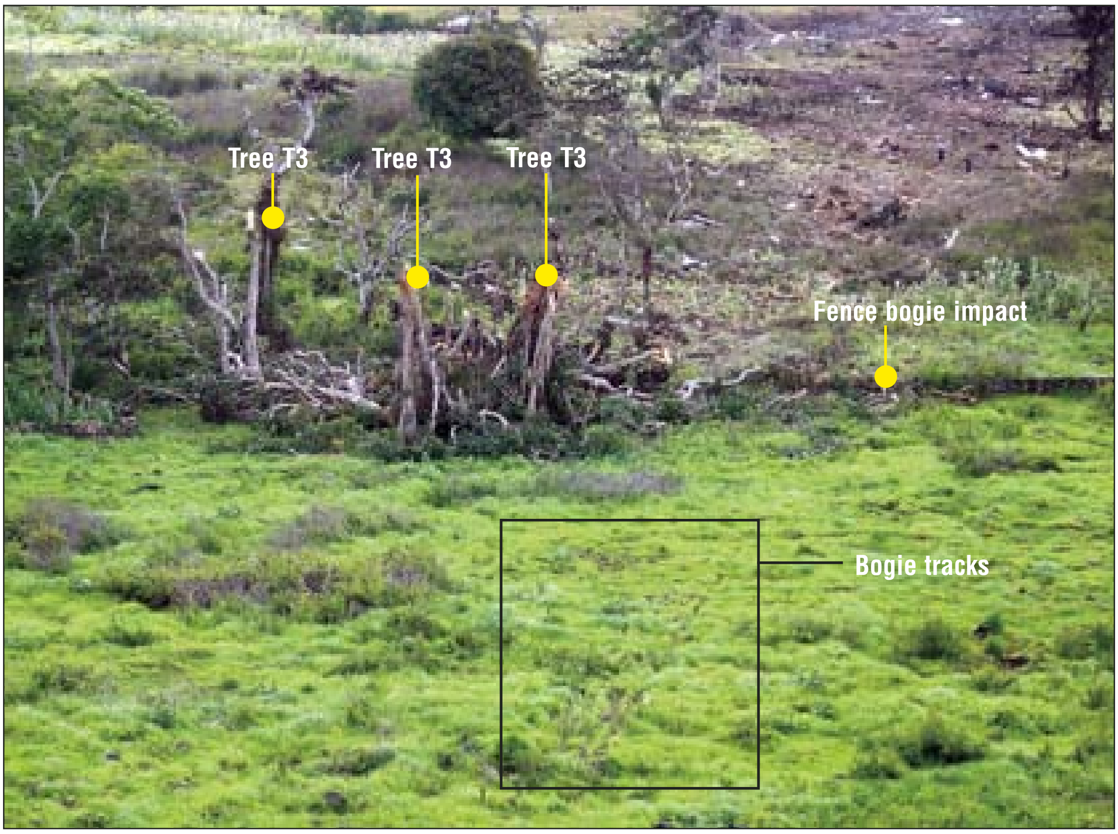
The first marks in the wreckage path were a single set of ground marks on slightly rising ground, consistent with ground contact of one of the main landing gear bogies. Those marks ran for about 39 m (128 ft) on a track of about 130 degrees magnetic. A single main landing gear bogie had impacted a 1.2 m (3.9 ft) high stone fence about 1m above the ground, nearly in line with, and 41 m (135 ft) from where the initial ground marks ended. Pieces of the lower cockpit windows and a windshield wiper blade were located not far down track from the fence that had been struck by the main landing gear bogie.

The aircraft then impacted the group of large trees depicted in Figure 21. The trees were located about 1 NM (2 km) to the north-northwest of the threshold of runway 14. They were situated about 11 m to the left of the track between the ground marks and the fence bogie impact marks. The nearest tree (T1) had been impacted about 6m (19.7 ft) above the ground, while the furthest tree with impact damage (T3) was 22m (72 ft) from the track.

The trees were estimated to have been about 17 m (55.8 ft) high before they were damaged by the impact. The angle of the cuts in the trees as a result of the impact was between 1.5 and 4 degrees up, when viewed from the tree closest to the wheel track towards the furthest tree with obvious impact damage. Several wing parts and engine fan parts were found beyond the trees.

The distance between the fence that was struck by the main landing gear bogie and the resting-place of the wing centre section near the end of the wreckage trail was 385m (1,263 ft). The centre line of the debris trail was a few degrees to the left of the direction of the initial ground impact markings.

FIGURE 21:
The group of trees at the initial impact area



The inverted right wing tip was found beside a partially constructed house about 190 m (623 ft) beyond the impacted trees. The house was severely damaged by the impact. Fragments of the left wing tip light were found some 206 m (676 ft) from the trees. The fragments were located along the centreline of the wreckage trail about 23 m (75.5 ft) to the right of an imaginary line extending in the direction of travel of the wreckage trail from where the right wing tip was located.

A serrated area of rising ground consisting of coral outcrops up to a metre (3.3 ft) high was located just past the partially constructed house that was struck by the aircraft during the impact sequence. The area was difficult to traverse on foot, and the Australian investigation team likened it to an 'enormous cheese-grater' (see Figure 22).

FIGURE 22:
Terrain within the wreckage area

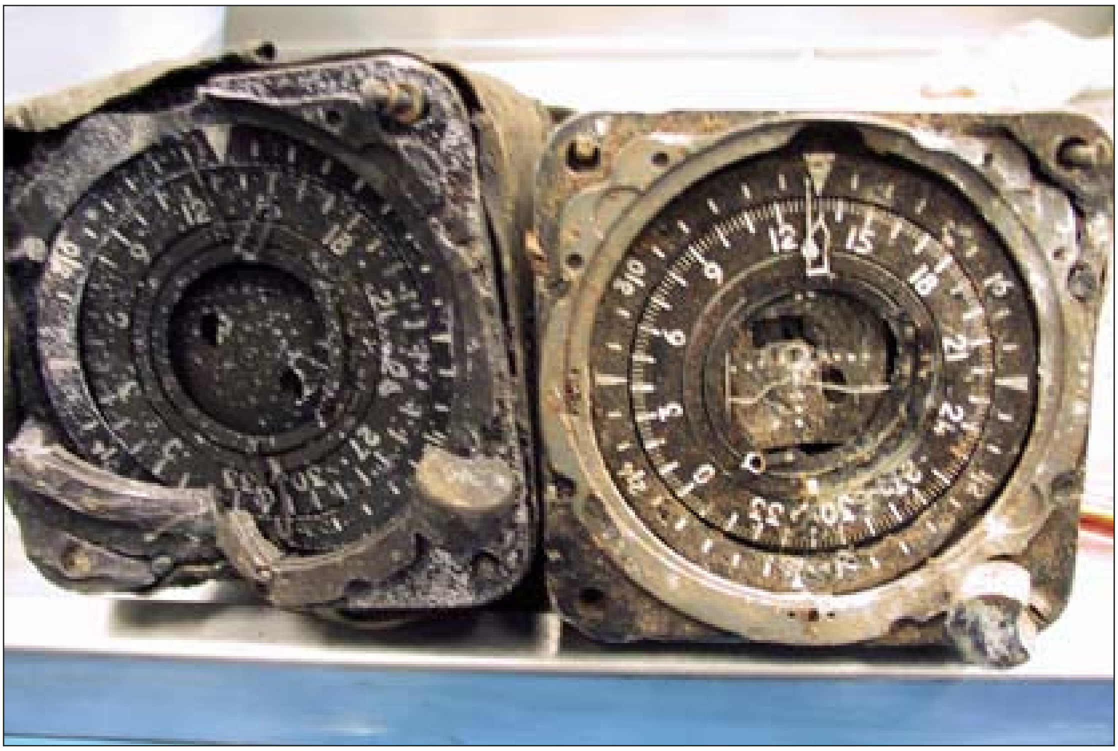
Many small parts of the forward fuselage section, wing sections, and engine fan blades were found to the left of the wreckage trail, starting from the beginning of that serrated portion of ground. Several of the cockpit instruments, controls, the quick access recorder, the remains of most of the occupants, and large sections of the cockpit windows where also found to the left of and beyond that area (see Figure 23). The area also displayed evidence of an intense short-duration fire.

As discussed in subsection 1.8.4., Jeppesen charts and maps were found scattered throughout the cockpit wreckage area and in the adjacent areas of the wreckage. One torn and water-damaged page of meteorological terminal forecasts was found within the wreckage, but the flight plan and NOTAMs relevant to the flight were not. That page of meteorological information contained no information that related to Baucau. No other weather-related documentation was found.

Two CIs were recovered from the wreckage (see Figure 24).

FIGURE 23:
Commencement of the cockpit wreckage area

FIGURE 24:
Course Indicators recovered from the wreckage



The ADF control panels, the radio magnetic indicators, the GPS unit, and the GPWS warning displays were not found in the wreckage because of the level of destruction of the aircraft.

The impact forces had substantially damaged both the CIs. One was badly sooted from exposure to the post-impact fire around where it lay after being dislodged from the instrument panel. The 3K desired heading pointer on the less-damaged CI was aligned to a magnetic heading of about 134 degrees. The 3K desired heading pointer of the more-damaged CI had been bent during the impact sequence.

Examination of the correlation between the desired heading pointers on both CIs revealed that both had been aligned on a heading of about 135 degrees before being damaged.

The head of the slender relative bearing pointer on the less-damaged CI was offset about 3 degrees to the right of the aircraft nose. The slender relative bearing pointer on the more-damaged CI was badly damaged. Although the head of the pointer was bent, the tail was intact. The position of the tail was consistent with the head of that pointer having also been offset by about 3 degrees to the right of the aircraft nose before it was damaged.

Two radio altimeter indicators were also found in the cockpit wreckage area. Both indicators were designed to provide readings of aircraft height above terrain in metres, and had been substantially damaged by the impact forces; one more so than the other. The less-damaged radio altimeter indicator was a PB-150 unit (see Figure 25).

FIGURE 25:
The PB-150 radio altimeter indicator located in the aircraft wreckage

The reference bug on the indicator was not set to a positive altitude setting, but was parked in a position that was slightly less than the zero altitude reading.

The small light bulb located behind the amber lens inscribed with the delta (Δ) symbol was later removed from the PB-150 indicator and examined to determine whether it was illuminated at the time of impact. The result of that examination is discussed at subsection 1.16.

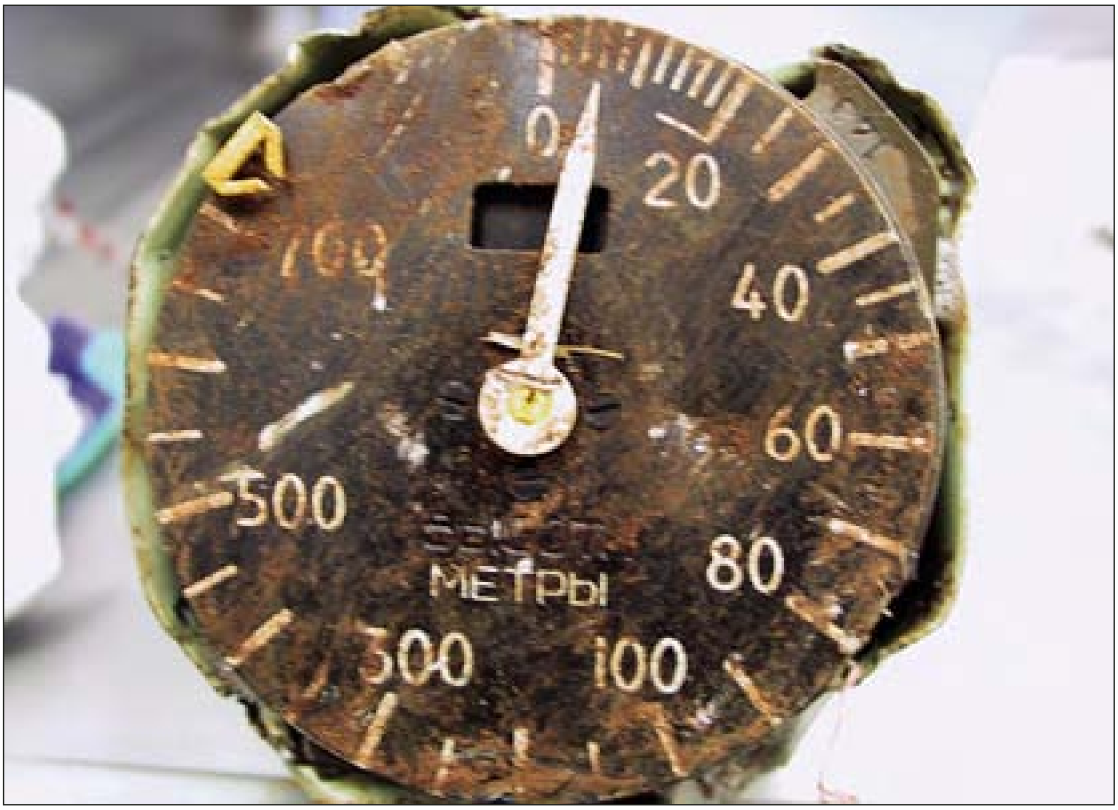
The more-damaged indicator was a PB-750 m scale unit (see Figure 26). The reference bug on that indicator was set to 750 m.

The two damaged radio altimeter units were the only components of the radio altimeter system that were identified and located in the aircraft wreckage. It was therefore not possible to conduct a technical investigation of all the elements comprising the radio altimeter system to determine its serviceability prior to impact.

None of the components of the GPWS system were identified within the aircraft wreckage. It was therefore also not possible to conduct a technical investigation of all the elements comprising the GPWS to determine its serviceability status prior to impact.

A number of other instruments were also found in the cockpit wreckage area. The casings of many of those instruments were badly distorted from impact forces, and some of the instruments were damaged to such an extent that they provided no reliable information.

FIGURE 26:
The PB-750 radio altimeter indicator located in the aircraft wreckage



The main part of the right and left wings and the wing carry-through structure were found in the correct context but in an inverted position about 190 m (623 ft) beyond the left wing tip light fragments (see Figure 27).

FIGURE 27:
Main wreckage area

The aft part of the fuselage and the tail were a further 15 m (49 ft) along the wreckage trail, with most of the cargo scattered beyond this region.

A high intensity fire had engulfed much of the relatively large pieces of the inverted main part of the right and left wings and the wing carry-through structure, and the aft section of the cargo compartment that contained the rear pressure bulkhead (see Figure 28).

FIGURE 28:
Fire damage in main wreckage area

The post-impact fires had not damaged the vertical and horizontal tail sections of the aircraft. The damage to the vertical fin was confined to leading edge impact damage and sooting from fire. The left section of the horizontal stabiliser had been dislodged during the impact sequence, but the right section was intact.

Three of the four main landing gear bogies were located in the main wreckage area. The remaining main landing gear bogie was found about 30 m (98.4 ft) to the right of the wing centre section. The nose wheel was found 40 m (131.2 ft) to the left of, and about 23 m (75.4 ft) behind the wing centre section.

1.13 Medical information

The UNMISET Forensic and Crime Scene Serious Crimes Unit in Dili performed autopsies on the aircraft occupants. They reported that it had been impossible to positively identify all of the occupants because of the severity of the injuries sustained. Similarly, toxicological examinations could not be performed on all of the occupants. The investigation was therefore unable to determine whether any physiological factors may have adversely affected the performance of any of the flight crew.

The post-mortem reports also contained details of the clothing worn by each of the aircraft occupants at the time of the accident. The variety and different nature of the remains of the outer garments was not consistent with any of the occupants having been in uniform for the conduct of the flight, as they were required to be.[31]

31 Refer subsection 1.17.4.1.

1.14 Fire

Fuel spillage and misting occurred from the damaged and ruptured left wing following the impact with the trees at the beginning of the wreckage trail. The chemical damage from fuel spillage and misting resulted in the browning of much of the vegetation in and around the north-western and central areas of the wreckage trail (see Figure 29).

The post-impact ground fires were contained within the wreckage trail, commencing prior to where the partially constructed house had been struck by the right wing of the aircraft. The intensity of the fire increased beyond the house because of significant spillage of fuel from the disruption of the right wing following its impact with the house.

The initial ignition source of the fire could not be positively identified. It is likely however, that misted fuel from the ruptured left wing was ignited by a combination of hot engine parts and/or from friction sparking of various metallic aircraft pieces as they traversed the ground.

The intense short-duration fire in and around the cockpit wreckage was fed by fuel spilling from the ruptured wings as they passed adjacent to the cockpit wreckage area. The high-intensity fire that engulfed much of the wreckage within the main wreckage area was fed by fuel remaining in the parts of the wings when they came to rest.

The intensity of the fuel-fed fires was such that most of the aluminium alloy components and structures within the wreckage were consumed or melted.

FIGURE 29:
Chemical damage from fuel spillage

1.15 Survival aspects

The emergency crash response vehicles from Baucau arrived at the accident site within five minutes of the accident and attempted to contain the fires. The uneven terrain prevented vehicular access into some areas of the accident site. First aid and ambulance points were established near the main wreckage area, and a search was commenced for the occupants of the aircraft.

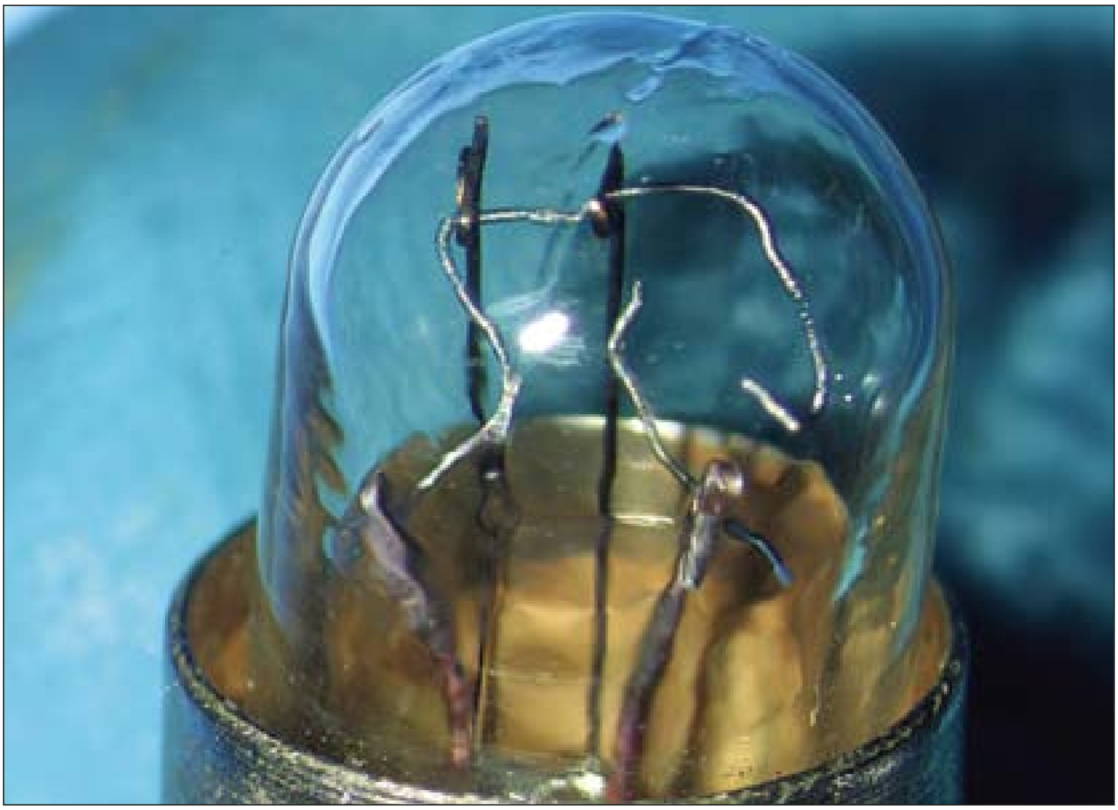
The remains of the six occupants were located within and beyond the cockpit wreckage area. The almost total destruction of the aircraft from the combined effect of the impact forces and post-impact fires rendered the accident non-survivable.

1.16 Tests and research

The PB-150 radio altimeter indicator, which had been dislodged from the instrument panel during the post-impact break-up sequence, was examined to determine if it was operating at the time of impact.

The glass face of the indicator was undamaged, however the rear part of the instrument casing had been damaged, and the gear train assembly within the instrument was not intact. The reference bug adjustment knob was jammed due to damage, and could not be rotated to move the bug. The small light bulb located behind the amber lens inscribed with the delta (Δ) symbol on the reference bug adjustment knob was removed and examined to determine whether it was illuminated at the time of impact (see Figure 30).

FIGURE 30:
Damaged light bulb filament from the PB-150 radio altimeter indicator



The globe envelope was unbroken, and displayed no signs of discolouration. The bulb filament was not severely stretched, and was fractured in one location. The coils had remained mostly symmetrical, and showed little evidence of gross stretch or distortion. The filament was also only slightly elongated.

The condition of the filament was consistent with the high loading forces of the post-impact break-up sequence. The investigation concluded that it was unlikely the bulb was illuminated at the time of impact.

1.17 Organisational information

1.17.1 Operation of the aircraft

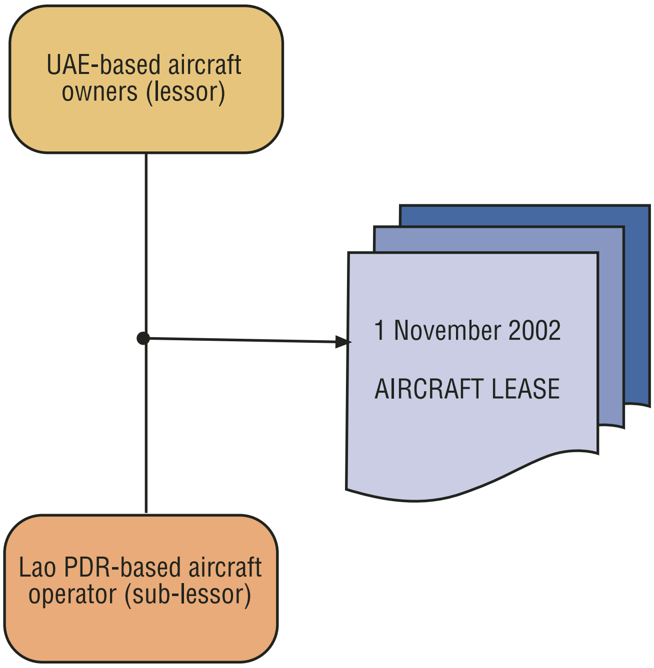
The aircraft owners were based in Sharjah, UAE. On 1 November 2002, the owners leased the aircraft to a Lao PDR-based company for one year (see Figure 31). Under the terms of the lease, which was signed by both parties, the lessor was required to provide the flight crew and the loadmasters.

The lease specified that the pilot in command was fully responsible for the flight safety of the aircraft. The lease also specified that the flight crew was required to comply with the legislation of the Lao PDR, and that the lease agreement was subject to the approval of the Lao PDR Department of Civil Aviation (DCA).

The lessor was required to provide the flight crew with all required flight documentation, including a complete set of Jeppesen en-route navigation charts.

The lease specified that the lessee would not be entitled to sublease the aircraft to a third party without the prior written consent of the lessor.

FIGURE 31:
Aircraft lease arrangement – 1 November 2002



On 9 November 2002, the Lao DCA issued Air Operator Certificate (AOC) AOC-002/02 to the lessee. The AOC included information that the Lao-based company had met operator certification requirements specified in the Civil Airworthiness requirements of the Lao DCA, and was authorised to conduct commercial air transport operations.[32]

The operations specifications relating to the AOC included information that the aircraft (RDPL-34141) was to be used by the lessee company on non-scheduled cargo services. The operations specifications also included information that the aircraft was to be operated in accordance with the Standards for Commercial Air Operations Part 1 'AEROPLANES ABOVE 5700 Kg MTOW' approved by the DCA as the Tentative Civil Aviation Regulations of the Lao PDR.[33]

On 18 November 2002, the Lao PDR-based company entered into an arrangement to sublease the aircraft to another company based in Cambodia (see Figure 32). Under the terms of the proposed sublease, which was signed by both parties, the lessor would provide the aircraft flight crew to the lessee.

The proposed sublease specified that the aircraft was to remain registered by the Lao PDR, and that supervision over the flight, technical and commercial operation was the lessor's '…competent authority…'. The proposed sublease also specified that the lessee was to act as the lessor's agent for the provision of necessary waybills and cargo documentation in accordance with the laws of the countries to, through, or over which the aircraft was to be flown. The lessee was also required to supervise the provision of that documentation through its representatives.

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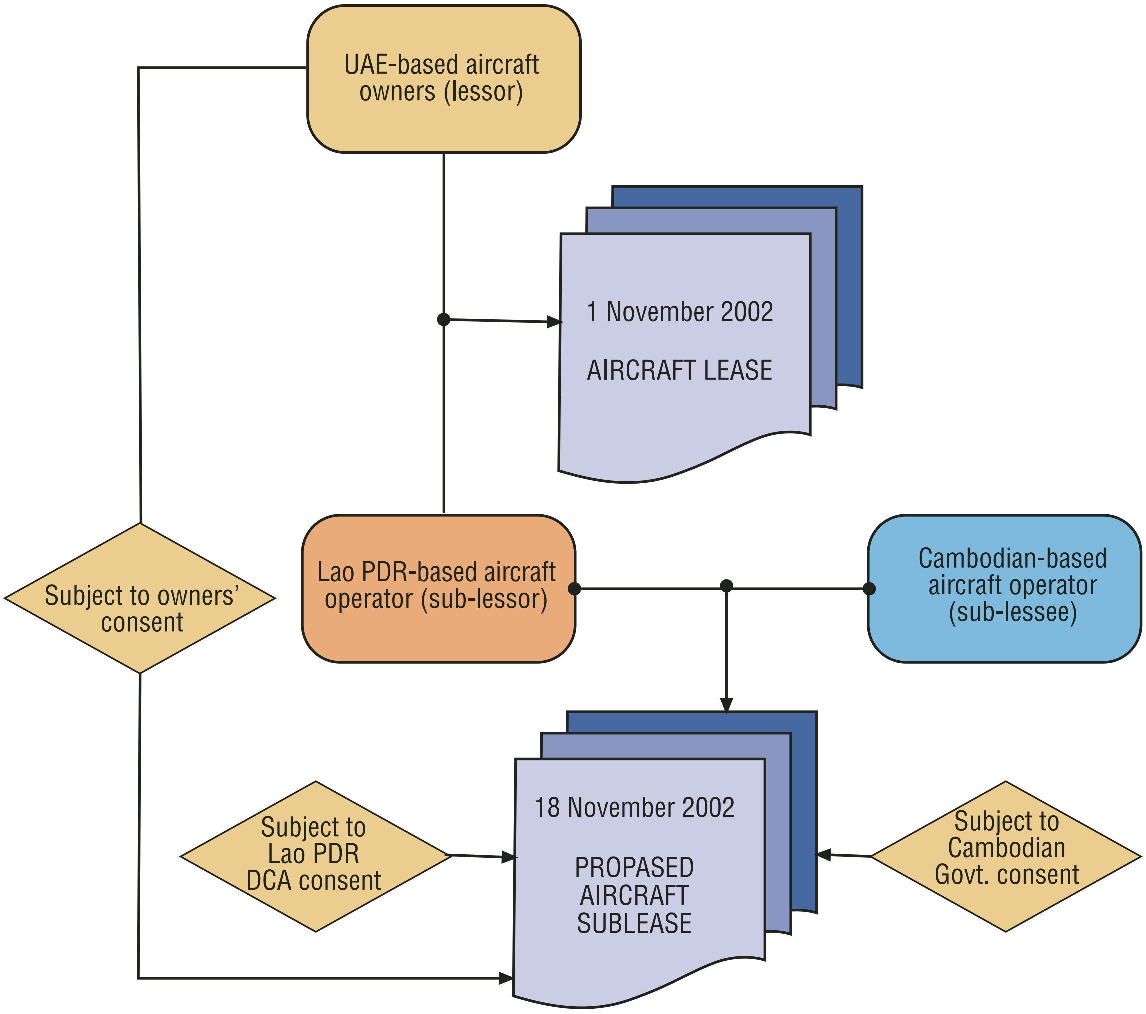
32 A commercial air transport operation is defined in ICAO Annex 6 as 'An aircraft operation involving the transport of passengers, cargo or mail for remuneration or hire'.

33 MTOW maximum take off weight

FIGURE 32:
Proposed aircraft sublease arrangement – 18 November 2002



On 30 December 2002, the Lao DCA issued a letter of clarification concerning the original lease agreement, dated 1 November 2002, and the proposed sublease, dated 18 November 2002. The Lao DCA concluded the letter with the statement that the Cambodian-based operator was an operator of the aircraft owned by the Sharjah, UAE-based company.

On 20 January 2003, the Cambodian-based company executed a Cargo Transportation Agreement with a Singapore-based company for a flight from Macau to Baucau on 30 January 2003 to carry 32 tonnes of cargo. The Cambodian-based company was listed on the agreement as the "Carrier", and the Singapore-based company was listed as the "Client". The cargo manifest, however, listed the Lao-based company against the aircraft type and registration details.

On 28 January 2003, a request was sent to the UN in Timor-Leste for landing permission for the aircraft's intended arrival at Baucau on 30 January 2003. CAD approved the request for landing permission. The approval document issued by CAD included a note that '…Baucau ATS [was] only available on UN troop rotation days'. It did not specify on which days troop rotations would take place.

On 28 January 2003, the Singapore-based company contacted a freight-forwarding company in Dili and requested that the freight-forwarder arrange for payment of landing fees and the provision of ATS at Baucau for the occurrence flight. The freight-forwarder contacted UN Air

Operations, and was given a quote for the provision of administration and security, rescue and fire fighting services, and ATS. UN Air Operations subsequently reported that freight-forwarder indicated that the only service needed at Baucau would be help with unloading the cargo. The freight-forwarder subsequently reported that it made no payments for the services needed, because '…we never received an invoice from the UN'. UNMISET subsequently reported that no one associated with the operator ever advised UNMISET of a request or a need for the provision of ATS for the aircraft at Baucau.

On 7 February 2003, the General Director of the Lao-based company reported that the request for landing permission, dated 28 January 2003, and sent under the letterhead of his company, had been sent without his authorisation. On 20 March 2003, the Chairman of the Cambodian-based company advised that although the proposed sublease document had been signed by both parties, the Lao-based company had not received consent from the aircraft owners in the UAE to enter into the sublease. The Chairman advised that under the circumstances, the inferred sublease had not taken effect, and the Cambodian-based company had therefore acted as an intermediary between the Singapore-based company and the Lao-based company for the occurrence flight.

On 20 March 2003, the aircraft owners also advised that neither the Lao-based company nor the Cambodian-based company had sought their consent for the proposed sublease, and therefore the inferred sublease had not been finalised.

On 3 July 2003, the Lao-based company advised the Australian investigation team in writing that they had not been granted, nor had they sought, consent of the aircraft owners in the UAE to sublease the aircraft to the Cambodian-based company.

On 21 July 2003, the Cambodian-based company advised the Australian investigation team in writing that the formalities for the proposed sublease had not been finalised at the time of the occurrence.

1.17.2 International Civil Aviation Organization

1.17.2.1 Standards and Recommended Practices

ICAO promulgates standards and recommended practices (SARPS) relating to aircraft, personnel, airways and auxiliary services. Those standards and recommended practices are contained in the Annexes to the *Chicago Convention*.

The Lao PDR is a contracting State to the *Chicago Convention*. It is obliged under Article 37 of the convention to conform to standards and to endeavour to conform to recommended practices. Article 38 of the convention requires a contracting State to notify ICAO of a difference if it is unable to comply with any standard.

ICAO defines standards as:

> Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognised as necessary for the safety or regularity of international air navigation and to which Contracting States will conform in accordance with the Convention.

ICAO defines recommended practices as:

> Any specification for physical characteristics, configuration, matériel, performance, personnel or procedure, the uniform application of which is recognised as desirable in the interest of safety, regularity or efficiency of international air navigation, and to which Contracting States will endeavour to conform in accordance with the Convention.

1.17.2.2 ICAO Annex 6, *Operation of Aircraft, Part I, International Commercial Air Transport — Aeroplanes*

Annex 6, Part I (Eighth Edition), dated July 2001, contained the SARPS applicable to international commercial air transport operations, which include scheduled and non-scheduled operations.

The supplement to Annex 6, dated September 2002, contained information that the Lao PDR had not notified ICAO of differences between its national regulations and the corresponding SARPS contained in Annex 6, Part I.

Appendix 2 to Annex 6 Part 1 stated that the contents of an operations manual shall include information regarding, but not limited to:

- standard operating procedures for each phase of flight
- instructions on the maintenance of altitude awareness and the use of automated or flight crew altitude call-out
- departure and approach briefings
- route and destination familiarisation
- stabilised approach procedure
- limitation on high rates of descent near the surface
- conditions required to commence or to continue an instrument approach
- allocation of flight crew duties and procedures for the management of flight crew workload during night and IMC instrument approach and landing operations
- instructions and training requirements for the avoidance of controlled flight into terrain (CFIT) and the use of GPWS.

Attachment F to Annex 6 Part 1 contained supplementary information regarding air operator certificates, and included advice that ongoing regulatory surveillance was:

> … an essential part of the State's responsibility to ensure that the required standards of operations are maintained in order to provide a safe and reliable commercial air transportation service to the public.

1.17.2.3 ICAO Annex 8, *Airworthiness of Aircraft*

Annex 8 (Eighth Edition) dated July 1988, contained the SARPS for general airworthiness procedures applicable to aircraft, and the minimum airworthiness characteristics for aeroplanes provided, or to be provided, with certificates of airworthiness.

The supplement to Annex 8, dated January 1999 contained information that the Lao PDR had not notified ICAO of differences between its national regulations and the corresponding SARPS contained in Annex 8.

Paragraph 3.2 of Part II of Annex 8 contained the following information in part:

> When an aircraft possessing a valid Certificate of Airworthiness issued by a Contracting State is entered on the register of another Contracting State, the new State of Registry, when issuing another Certificate of Airworthiness or rendering the original certificate valid, may consider prior issuance of the Certificate of Airworthiness by a Contracting State as satisfactory evidence, in whole or in part, that the aircraft is airworthy…

1.17.2.4 Procedures for operations inspection, certification and continued surveillance

ICAO has published a manual of procedures for operations inspection, certification and continued surveillance.[34] The manual provided States and operators with detailed guidance concerning the establishment and maintenance of safe, regular and efficient international commercial air transport operations in accordance with the *Chicago Convention* and its associated Annexes, in particular Annex 6.

The manual contained guidance on the content of an operations manual, and detailed the specific factors that should be covered, including flight deck procedures. It stated that those flight deck procedures for descent, approach and landing should include:

- preparation for the approach and the approach briefing
- the approach procedure
- stabilised approach procedure
- standard flight crew call-outs
- circling approach procedure
- landing procedure
- missed approach procedure.

The manual also contained guidance material on the need for a State to establish a system for both the initial inspection and certification and the continued surveillance of an operator to ensure that the required standards of operation were maintained. Paragraph 1.2.4 contained advice that if a State adopted a passive role towards inspection and surveillance, then it:

> … would not be in a position to assess the adherence of the operator to the regulations other than by knowledge acquired fortuitously or in the course of an accident or incident investigation.

1.17.3 Department of Civil Aviation – Lao People's Democratic Republic

In April 1999, an ICAO safety oversight team audited the Lao DCA under Assembly Resolution A32-11, and under the ICAO Universal Safety Oversight Audit Programme. The objective of the audit was to ascertain the safety oversight capability of the Lao DCA, and to ensure it conformed with the ICAO standards and recommended practices that are contained in Annexes 1, 6 and 8 to the *Chicago Convention*.

ICAO conducted a follow-up audit of the Lao DCA in March 2002. The objective of the follow-up audit was to confirm that corrective action identified during the April 1999 audit had been implemented, and to discover the status of progress made on the State's safety oversight system as a result of those actions.

The follow-up audit revealed that a viable system for compliance and enforcement had not yet been implemented. It also revealed that there were still no qualified staff in the Lao DCA to conduct flight tests or to supervise designated flight test examiners. Moreover, it found that only one individual, who was not a pilot, staffed the Flight Operations and Inspection Section.

[34] ICAO Doc 8335-AN/879, Manual of Procedures for Operations Inspection, Certification and Continued Surveillance, Fourth Edition 1995

1.17.3.1 Air operator certificate

On 9 November 2002, the Lao DCA issued Air Operator Certificate (AOC) AOC-002/02 to the lessee, as discussed at subsection 1.17.1 of this report.

1.17.3.2 Aircraft certificates of airworthiness and registration

On 11 December 2002, the Lao DCA inspected the aircraft, and on 13 December 2002 it issued airworthiness, registration and aircraft noise certificates for the aircraft.

1.17.3.3 Flight crew licensing

In December 2002, the Lao DCA issued commercial pilot licences (aeroplane) to the pilot in command and the copilot. Those licences included information that they had been issued in accordance with the SARPS of Annex 1 to the *Chicago Convention*.

The supplement to Eighth Edition of Annex 1 contained information that the Lao PDR had not notified ICAO of differences between its national regulations and the corresponding SARPS contained in Annex 1. The supplement was dated June 2000. The Ninth Edition of Annex 1, dated July 2001 incorporated all amendments adopted by the Council prior to 20 February 2001. On 1 November 2001 the Ninth Edition became effective and superseded all previous editions of Annex 1. The amendments incorporated in Annex 1 included human factors knowledge requirements, visual and colour perception requirements, and the language used in personnel licences. The amendments did not relate to the circumstances in which an instrument rating was required, the privileges of the holder of a commercial pilot licence (aeroplane), or the privileges of the holder of a airline transport pilot licence (aeroplane). At the time of publication of this report, ICAO had not published a supplement to Ninth Edition of Annex 1. The pilot in command's Lao licence included a command type-rating and an instructor rating for IL-76 aeroplanes. The copilot's Lao licence included a copilot type-rating for IL-76 aeroplanes. Both licences contained no entries to signify whether either crewmember was the holder of an instrument rating that entitled either of them to pilot aeroplanes under instrument flight rules (IFR).

Paragraph 2.1.7 of the Ninth Edition of Annex 1 detailed the circumstances in which an instrument rating was required. It stated that:

> A Contracting State, having issued a pilot licence, shall not permit the holder thereof to act either as pilot-in-command or as copilot of an aircraft under instrument flight rules (IFR) unless such holder has received proper authorization from such Contracting State. Proper authorization shall comprise an instrument rating appropriate to the aircraft category.
>
> *Note:— The instrument rating is included in the airline transport pilot licence — aeroplane, and the provisions of 2.1.7 do not preclude the issue of a licence having the instrument rating as an integral part thereof*

Paragraph 2.4.2.1 of the Ninth Edition of Annex 1 provided information that the privileges of the holder of a commercial pilot licence (aeroplane) were:

a) to exercise all the privileges of the holder of a private pilot licence - aeroplane;

b) to act as pilot-in-command in any aeroplane engaged in operations other than commercial air transportation;

c) to act as pilot-in-command in commercial air transportation in any aeroplane certificated for single-pilot operation; and

d) to act as co-pilot in commercial air transportation in aeroplanes required to be operated with a co-pilot.

Paragraph 2.5.2. of the Ninth Edition of Annex 1 provided information that the privileges of the holder of a airline transport pilot licence (aeroplane) were:

a) to exercise all the privileges of the holder of a private and commercial pilot licence - aeroplane and of an instrument rating - aeroplane; and

b) to act as pilot-in-command and co-pilot in aeroplanes in air transportation.

Under Annex 6, the occurrence flight was a commercial air transport operation. The pilot in command was therefore required to hold an airline transport pilot licence issued by the State of Registry of the aircraft (Lao PDR). Alternatively, the pilot in command could have held an authorisation issued by the Lao DCA to validate his Russian airline transport pilot licence, as detailed in paragraph 1.2.2.1. in the Ninth Edition of Annex 1. The pilot in command held neither.

1.17.3.4 Supervision of the operator

During the period 28 December 2002 to 2 January 2003, the aircraft was operated on a series of flights between Bangkok and Bombay on behalf of the Cambodian-based company. On 2 January 2003, the aircraft flew from Bombay to Taipei. The investigation was unable to establish if the aircraft operated any flights during the period 3 January 2003 to 29 January 2003, or if it remained in Taipei throughout that period. On 30 January 2003, the aircraft flew from Taipei to Macau, and on arrival at Macau it was loaded with cargo for the flight to Baucau on 31 January 2003.

The investigation was unable to determine whether the Lao DCA had established a system for the continued surveillance of the Lao-based operator during the period between the issue of the AOC and the occurrence.

1.17.4 The operator

1.17.4.1 Operations manual

The operator provided the investigation with extracts from its operations manual that contained information on the conduct of flights, including flight crew duties and responsibilities. That information contained no detailed instructions concerning:

- standard operating procedures for each phase of flight
- instructions on the maintenance of altitude awareness and the use of automated or flight crew altitude call-out
- departure and approach briefings
- route and destination familiarisation
- stabilised approach procedure
- limitation on high rates of descent near the surface
- conditions required to commence or to continue an instrument approach
- allocation of flight crew duties and procedures for the management of flight crew workload during night and IMC instrument approach and landing operations
- instructions and training requirements for the avoidance of CFIT and the use of GPWS.

Chapter 8 of part A of the manual contained information on the operator's standard operating procedures. Paragraph 8.1 contained instructions relating to pre-flight preparation. It stated that the flight crew were to be in uniform for the conduct of the flight. It also stated that the pilot in command was responsible to ensure that all crewmembers complied with that requirement.

Paragraph 8.1.1. stated that the flight crew was forbidden to operate flights below specified minimum altitudes except during the landing stage of an approach.

Paragraph 8.1.5. stated that landing minima were those published or advised by ATS. It also stated that in the absence of a published minima, the minimum height for a non-precision approach was 60 m on the aircraft barometric altimeter with the altimeter subscale set to the atmospheric pressure at aerodrome elevation so that the altimeter indicated height above aerodrome (QFE). The paragraph also contained advice that minima for landing at a foreign aerodrome was set according to the requirements of the State in which that aerodrome was located.

Paragraph 8.1.5. also stated that before each landing approach, the pilot in command was to announce to the flight crew the minimum for the approach.

Paragraph 8.1.6. stated that during the pre-flight preparation, the flight crew was obliged to analyse the meteorological conditions at the destination.

Paragraph 8.3.3. stated that the barometric altimeter subscale settings were to be set to 760 mm Hg (1,013.2 hPa) on passing the transition level during climb. On descent, the altimeter subscale settings were to be set to QFE. The QFE setting was to be derived from local sea QNH.

Chapter 14 of the manual contained information on CFIT and measures for its prevention. The manual referred to a document published by the Federal Aviation Administration of Russia, which had included information that the prevention of CFIT relied on the compliance with established rules of flight and standard operational procedures.

Chapter 14 also contained inflight procedures for CFIT avoidance. Those included requirements for flight crews to:

- constantly analyse the height of flight trajectory in relation to the ground
- observe the safe heights of any landing approach
- verify the height of the landing approach at transition level
- verify heights ("call-outs") and altimeter pressure settings on non-precision approaches
- comply with stabilised approach procedures.

1.17.4.2 Flight preparation

CAD approved the planned flight from Macau to Baucau on 29 January 2003, and sent a flight approval to the Singapore-based agent. The flight approval included a note that NOTAMs for Timor-Leste were available for download from the Airservices Australia website, and provided the uniform resource locator (URL) for that site. The flight approval also included a note that information on airports, air traffic management, flight planning requirements, flight approval procedures, facilitation and aeronautical fees were posted on the Timor-Leste government website, and included the URL for that site.

During the investigation, it was reported that it was standard procedure for the ground-handling agent at Macau International Airport to provide aircraft flight crews with NOTAMs and weather information. According to the airport service log, the flight crew of the occurrence aircraft were provided with NOTAMs and weather information for the planned flight to Baucau. However, the weather information did not include TAF & METAR for Baucau, because those weather forecasts were not produced for Baucau.

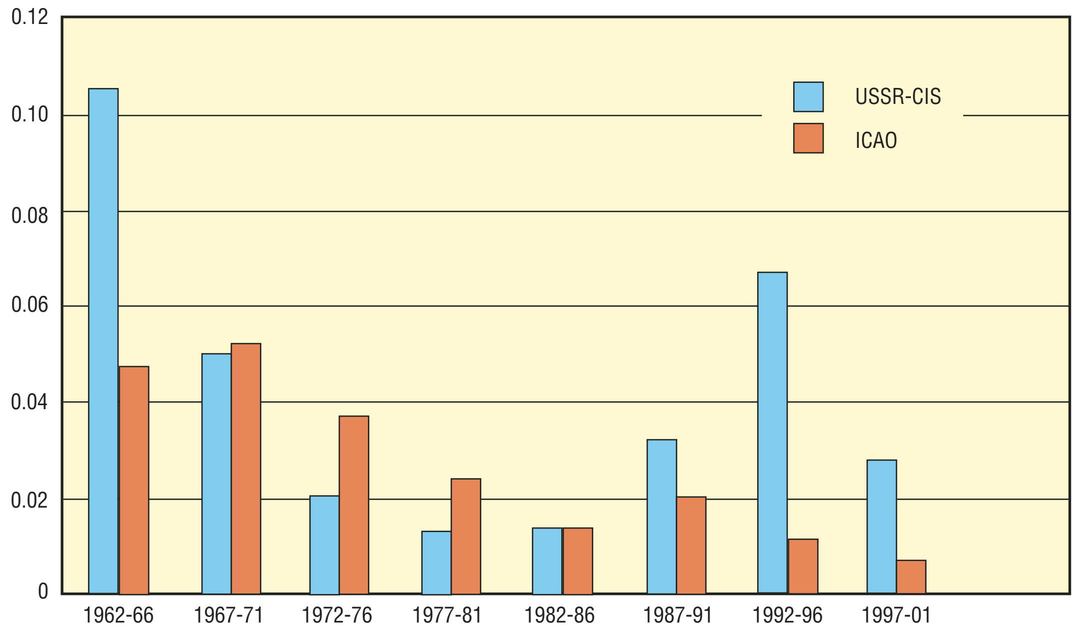
Following the accident, the Singapore-based agent confirmed that it forwarded the relevant CAD-issued Baucau charts to the aircraft operator before the aircraft's departure from Macau.

1.18 Other information

1.18.1 Aircraft accident statistics

At the Flight Safety Foundation (FSF) 55th International Air Safety Seminar in Dublin, Ireland in 2002, representatives from the IAC presented information on flight safety in commercial aviation in the Confederation of Independent States (CIS). The information included statistics on aircraft fatal accidents as a result of CFIT involving Union of Soviet Socialist Republics (USSR)/CIS-manufactured aircraft of greater then 10 tonnes MTOW between 1962 – 2001 (see Figure 33).

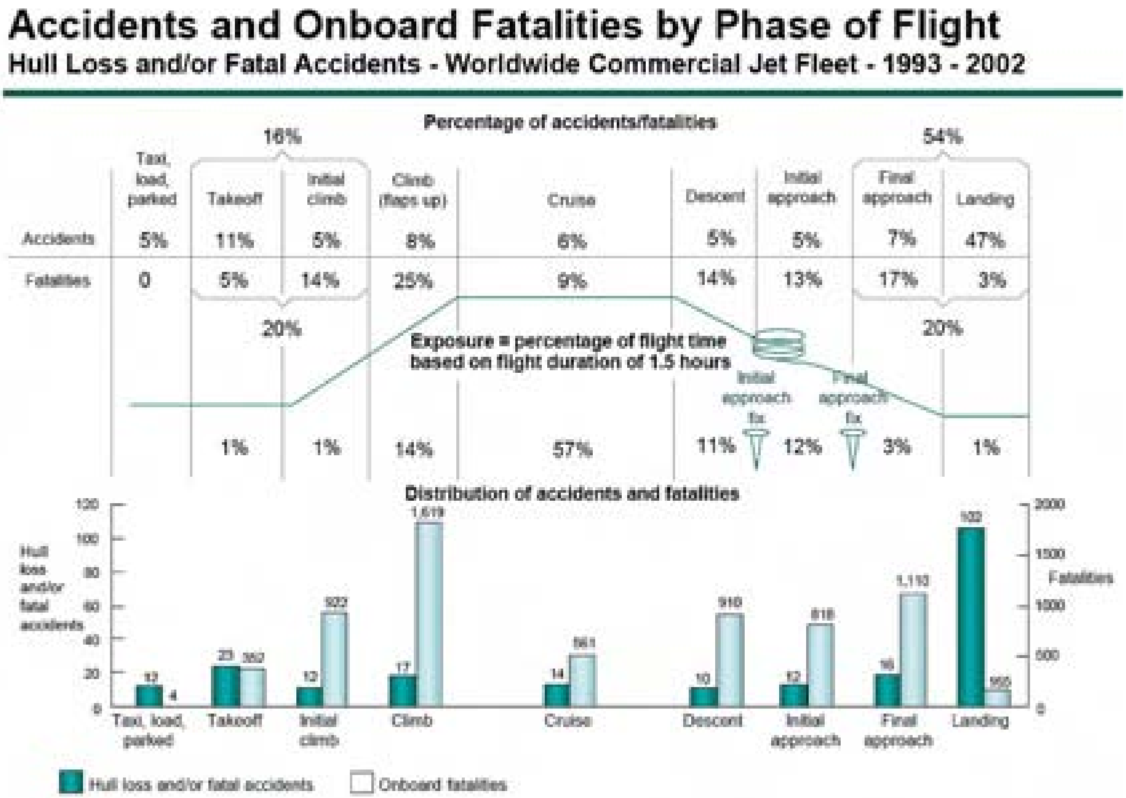
FIGURE 33:
USSR/CIS-manufactured aircraft - fatal accidents per 100,000 flight hours due to CFIT (take-off weight over 10 tons)



The IAC presentation included information that CFIT resulted from the most dangerous flight crew 'errors', and concluded that 'the recent years show conspicuous worsening (of the CFIT phenomenon)'.

The Boeing Commercial Airplane Group (BCAG) has produced statistical data for what it describes as the worldwide commercial jet aircraft fleet hull loss and/or fatal accidents by phase of flight for the period 1993 to 2002 (see Figure 34). However, the data does not include data for CIS-manufactured aircraft, and is therefore not representative of the worldwide commercial jet aircraft fleet. The BCAG data reveals that while the final approach and landing phases of flight account for 4 per cent of flight time (based on a flight duration of 1.5 hours, 54 per cent of accidents occurs during those phases.

FIGURE 34:
Accidents and onboard fatalities by phase of flight for the period 1993 – 2002



Source: Boeing Commercial Airplane group Statistical Summary of Commercial jet Airplane Accidents (Worldwide Operations 1959–2002) published May 2003.

1.18.2 Prevention of approach-and-landing accidents

In the early 1990s, FSF commenced efforts to reduce CFIT and approach-and-landing accidents accidents. The FSF Approach-and-Landing Accident Reduction (ALAR) Task Force concluded, amongst other things, that:

- establishing and adhering to adequate standard operating procedures and flight crew decision-making processes improve approach-and-landing safety
- failure to recognise the need for a missed approach and to execute a missed approach is a major cause of approach-and-landing accidents
- unstablised approaches cause approach-and-landing accidents
- the risk of approach-and-landing accidents increases in operations conducted in low light and poor visibility
- effective use of radio altimeters will help to prevent approach-and-landing accidents
- global sharing of aviation information decreases the risk of approach-and-landing accidents.

A number of recommendations were developed from those conclusions, and they provided a framework for a series of 34 briefing notes to help prevent approach and landing accidents, including those which involve CFIT.[35] The briefing notes provided guidance for the

[35] FSF ALAR Tool Kit briefing notes were based on data-driven recommendations and conclusions developed by the FSF ALAR Task Force, as well as on data from the US Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JAST) and the European Joint Aviation Authorities Joint Safety Strategy Initiative (JSSI).

development of operational practices and procedures that were aimed at increasing the safety of flight. The briefing notes included, but were not limited to:

- standard operating procedures
- standard calls
- normal checklists
- approach (arrival) briefings[36]
- crew resource management
- interruptions/distractions
- barometric and radio altimeters
- descent and approach profile management
- terrain
- stabilised approaches
- constant angle non-precision approach.

The international CFIT Task Force comprised representatives of aircraft manufacturers, aviation training organisations, aircraft equipment manufacturers, airlines, pilot groups and government and regulatory agencies. The Task Force developed a CFIT education and training aid. ICAO has recommended that those in positions of responsibility in civil aviation should apply the recommendations of the CFIT Task Force, and '…make the best use of the education and training aid'.

1.18.3 Controlled flight into terrain

CFIT refers to an unintended inflight collision with terrain, water, or obstacle without any indication of the loss of control of an aircraft. The factors leading to CFIT events are varied. They can include loss of flight crew situational awareness, loss of terrain awareness, non-adherence to standard operating procedures, conduct of improvised (user-defined) approach procedures in IMC and operations in areas of low cloud base and/or poor visibility.

CFIT continues to be the main reason for accidents involving aeroplane hull losses and fatalities. In global terms, since the advent of commercial jet operations, 9,000 fatalities have been attributed to CFIT events.

In 1993, the FSF organised an international CFIT Task Force that was dedicated to reducing CFIT events. Five teams were formed to study the causes and factors of CFIT events, and to make recommendations to prevent these accidents.

In 1996, the FSF also published a report produced by the Netherlands National Aerospace Laboratory (NLR) on factors associated with CFIT events involving commercial aircraft operators.[37] The report focused on 156 CFIT events that occurred between 1988 and 1994, and

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36 Subsequent to but not as a direct result of the occurrence, the US Federal Aviation Administration published Advisory Circular (AC) 120-74A (dated 26 September 2003), Flightcrew Procedures During Taxi Operations. The AC contained information regarding aerodrome arrival briefings, and stated that:

> …an effective arrival briefing can increase crew performance by highlighting those potential areas that need special attention and consideration.

37 Flight Safety Digest, Vol. 15 No. 4/5 April–May 1996

found that the descent and approach phases of landing accounted for about 70 per cent of the accident sample.

1.18.4 Hazard and risk

A hazard is a source of potential harm or a situation with a potential to cause loss. CFIT is therefore a hazard, because it has the potential to cause fatal or life threatening injury to human life and damage to property and/or the environment. Hazard is not necessarily synonymous with risk, however it is a determinant of risk.

Risk is related to the likelihood of an event occurring that will have an impact upon objectives. It is measured in terms of consequences and likelihood. Likelihood, or probability, in the context of risk is not determined by, or dependant on, mere chance. Rather, it is expressed in either qualitative or quantitative terms. The level of risk of the event depends on its likelihood and consequences, as depicted in Table 3.

TABLE 3:
Qualitative risk analysis matrix

LIKELIHOOD	CONSEQUENCE				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	High	High	Extreme	Extreme	Extreme
Likely	Moderate	High	High	Extreme	Extreme
Moderate	Low	Moderate	High	Extreme	Extreme
Unlikely	Low	Low	Moderate	High	Extreme
Rare	Low	Low	Moderate	High	High

Source: Standards Australia AS/NZS 4360:1999

Because CFIT has the potential to cause fatal or life threatening injury to human life and damage to property and/or the environment, its consequences are likely to be major to catastrophic. Therefore, if the likelihood of CFIT is moderate or greater, the risk of the event will be extreme.

Standards Australia has published AS/NZS 4360:1999 to provide a generic framework for qualitatively identifying, analysing, assessing, treating and monitoring risk. The standard defines risk management as:

> …a logical and systematic method of establishing the context, identifying, analyzing, evaluating, treating, monitoring and communicating risks associated with any activity, function or process in a way that will enable organizations to minimize losses and maximize opportunities.

Risk management is therefore a systematic method of examining potentially hazardous activities to establish safe and effective procedures that provide defences against the undesirable outcomes of those activities. Transport Canada has published a simple method of conducting a risk analysis that involves the evaluation of the severity (S) of a occurrence which may arise from a hazardous activity, the probability (P) of the occurrence, and the exposure (E) to the hazard. From the evaluation of S, P and E, a quantitative level of risk can be established.[38] Refer to Appendix E for further information on the Transport Canada simple method of risk analysis.

38 Transport Canada, Risk Management & Decision Making in Civil Aviation, Type 2A, Short Process, TP 13905, March 2001

Risk management encompasses the identification, analysis and assessment of risks and the design and implementation of risk treatments in a structured process. In general, it involves the following elements:

- define the objectives and operational context of an intended activity and consider the impact of external environment on those objectives
- identify risk events that could affect achievement of the defined objectives
- analyse the consequences of each identified risk event becoming a reality, in terms of its severity and probability against established criteria
- evaluate risks events to determine their significance based on a combination of consequence and likelihood. Risks are then ranked in priority order based on significance, and assessed to determine whether risk is acceptable based on an established acceptability criteria
- treat risks – assess existing or available controls and treatments to determine whether they are suitable to treat unacceptable risks. However, if risks remain unacceptable, then an alternative risk treatment strategy must be developed and implemented.

Once treated, risks must continue to be monitored to review the effectiveness of the risk treatment process.

Risks rarely remain static, and changes in an operational context can result in changed risks or changed level of risks. Thus, when an operational context is changed, for whatever reason(s), the risk events that can affect achievement of the changed objectives must be identified, analysed, evaluated and treated.

Communication and consultation are required at each step of the risk management process between decision-makers and those affected by the decisions. Effective two-way communication is an essential part of the process to ensure that no misunderstanding exists concerning the basis on which decisions are made, and why particular actions are necessary. Perceptions of risk may also vary, and the varying perceptions must be identified and dealt with during the risk management process.

1.18.5 CFIT risk

The reduction of consequences and likelihood of risks is termed risk management. A CFIT event involving a transport-category aircraft is almost certain to result in major to catastrophic consequences, and the risk of the event will almost certainly be high to extreme. The risk should therefore be assessed, and if identified, it must be managed.

The FSF have designed and published a checklist to evaluate CFIT risk, as part of its international program to reduce CFIT events that present risk to aircraft, flight crews, and passengers. The checklist is currently published in Arabic, Chinese, English, French, Russian and Spanish.

The FSF intended that the checklist be used to evaluate specific flight operations and to enhance pilot awareness of the CFIT risk. The checklist is divided into three parts, and in each part, numerical values are assigned to a variety of factors that the pilot/operator uses to score his/her own situation and to calculate a numerical total for the particular part.

In *Part I: CFIT Risk Assessment*, the level of CFIT risk is calculated for each flight, sector, or leg. In *Part II: CFIT Risk-reduction Factors*, Company Culture, Flight Standards, Hazard Awareness and Training, and Aircraft Equipment are evaluated for their individual contribution as risk-reduction factors. In *Part III: Your CFIT Risk*, the totals of the four sections in *Part II* are combined into a single value (a positive number) and compared with the total (a negative number) in *Part I* to determine the total CFIT Risk Score for the particular flight, sector, or leg.

Appendix F contains further information on the FSF risk assessment safety tool, and its relevance in assessing the CFIT risk score for the occurrence flight.

1.18.6 Stabilised approaches

A stabilised approach requires that an aeroplane be established in the landing configuration with the appropriate (and steady) airspeed and power set when it descends through 500 ft (152.4 m). In any instrument approach procedure, that requires the approach to be stabilised from the commencement of the final descent. During a non-precision approach, the approach will no longer be stabilised if it requires a change to a segment of level flight at the minima.

Constant angle instrument landing approaches are normally constructed using a 3-degree approach profile, which provides for a descent of 300 ft/NM (50 m/km).

Unstabilised approaches have been found to be a significant factor in 66 per cent of 76 approach and landing accidents and serious incidents that occurred worldwide between 1984 and 1997.[39]

According to the FSF Approach-and-Landing Accident Reduction (ALAR) Task Force, an approach will be stabilised if the following criteria are met:

- the aircraft is on the correct flight path
- only small changes in heading/pitch are required to maintain the correct flight path
- the aircraft speed is not more than the landing reference speed (V_{REF}) +20 kts (37 km/h) indicated airspeed and not less than V_{REF}
- the aircraft is in the correct landing configuration
- the sink rate is no greater than 1,000 ft/min (305 m/min, or alternatively, 5 m/sec); if an approach requires a sink rate greater than 1,000 ft/min, a special briefing should be conducted
- the power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined in the aircraft operating manual
- all briefings and checklists have been conducted.

Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilised approach require a special briefing.

Industry best-practice requires that an approach should be stabilised by no lower than 1,000 ft (305 m) AGL in IMC. If the approach is not stabilised by that point, or if it becomes unstable below the minimum stabilisation height, the approach should be discontinued and a go-around executed.

1.18.7 GPS navigation

Airborne supplemental navigation equipment using GPS is equipped with a RAIM function to detect erroneous GPS satellite signals. An IFR-certified GPS receiver must continuously perform a RAIM function to assure position integrity.

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[39] FSF Approach-and-Landing Accident Reduction (ALAR) Task Force.

If there are insufficient satellites in view to assure position integrity, the GPS provides a warning to the flight crew. With five satellites in view, RAIM is able to detect the failure of a satellite, and with six satellites in view RAIM is able to continue to provide integrity monitoring following the detection of a faulty satellite if fault detection and exclusion capability is incorporated into the GPS receiver.

In certain locations, there are insufficient satellites in view to provide RAIM integrity monitoring. Those gaps in coverage are referred to as RAIM holes. There were 11 satellites in view at Baucau at the time of the occurrence (see Figure 35). Green signifies a satellite's elevation of greater than 5 degrees above the horizon and yellow signifies a satellite's elevation of between 0 degrees and 5 degrees above the horizon.

Dilution of precision may also affect the integrity of navigation data provided by a GPS, and its extent is dependent on the number of satellites in view to a GPS, and also the geometry of those satellites relative to the user. Under ideal conditions, the calculated position of a GPS will be at the point where two satellite range rings intersect. However, in reality the calculated position will be in an area of uncertainty, because of errors in the satellite ranges, and the area of uncertainty will become greater as the two satellites get closer to each other. Dilution of precision occurs in both vertical (VDOP) and horizontal senses (HDOP), with HDOP being more critical in terms of the integrity of lateral navigation solutions. The calculated HDOP at Baucau at the time of the occurrence was less than 1, and would have resulted in little effect on the integrity of lateral navigation data that was being provided by the aircraft's GPS (see Figure 36).

FIGURE 35:
GPS satellite coverage at Baucau

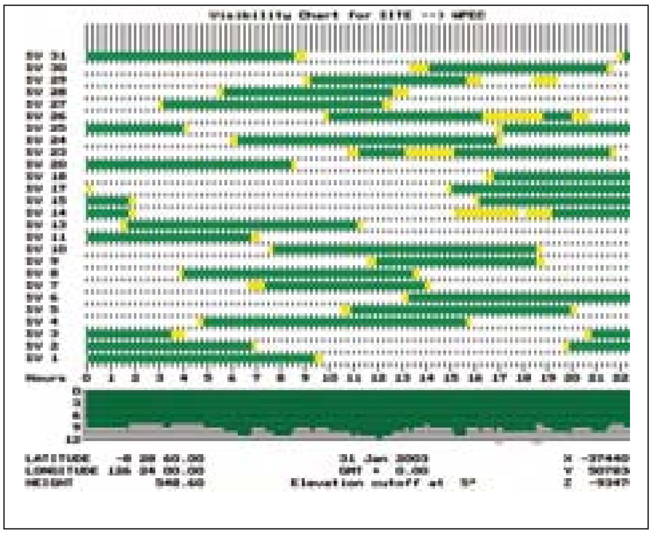
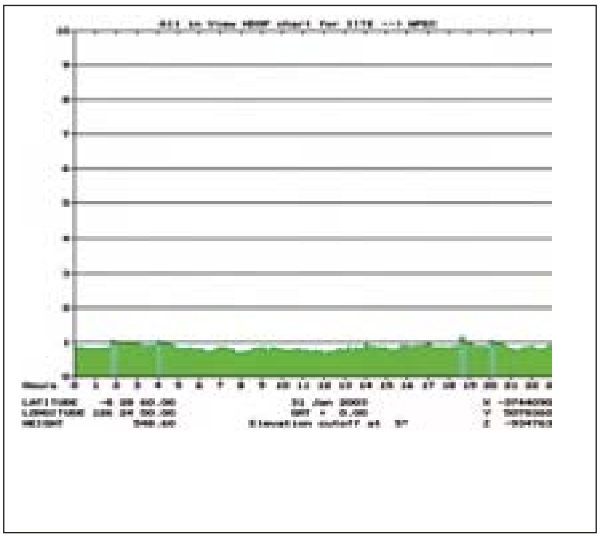


FIGURE 36:
Satellite HDOP at Baucau



1.18.8 GPS arrivals and instrument approach procedures

An approved GPS may be used to conduct an en route IFR descent below the LSALT/MSA in accordance with approved procedures. A GPS arrival procedure requires that azimuth guidance be available from an NDB or VHF omni directional radio range (VOR) located at the destination. There were no published GPS arrival procedures at Baucau at the time of the occurrence.

An approved GPS may also be used for stand-alone aerodrome instrument approaches, or as an aid in conducting NDB or VOR approaches, with or without the assistance of distance measuring equipment (DME). There were no published GPS instrument approach procedures at Baucau at the time of the occurrence.

1.18.9 User-defined non-precision approach procedures

The CVR data provided evidence that the flight navigator was using the onboard navigation equipment to provide the pilot in command with navigation data during the approach sequences at Baucau. On 12 August 1999, a Beech 1900D aircraft was involved in a CFIT event during the conduct of a user-defined GPS approach at Sept-Îles, Quebec, Canada. In subsection 2.2 of its report into the accident, the Transportation Safety Board (TSB) of Canada commented on the inherent dangers of user-defined GPS approaches, and that the:

> …selection of a user-defined waypoint as a reference to conduct an ad hoc GPS approach bypassed all the safety criteria considered in the design of stand-alone or overlay GPS approaches.[40]

The TSB report included information that with increasing confidence in the use of GPS, its relative ease of use, and its accuracy, flight crews have come to appreciate that GPS generally provides a more accurate and flexible means of navigation than traditional ground-based navigation aids, such as NDBs or VORs. That confidence has resulted in some flight crews developing their own user-defined approach procedures, utilising a combination of specific headings to fly to the coordinates of individual runway thresholds. Those user-defined approaches are not approved procedures, but are flown in favour of published approaches, and often to lower levels than those prescribed in approved procedures. Furthermore, they often ignore the specific obstacle clearance tolerances that have been inbuilt into approved procedures, and therefore are a hazardous practice.

User-defined non-precision approach procedures are based on the selection of user-defined waypoints, and as such bypass the safety standards inbuilt into the design criteria of approved approach procedures.

Additionally, if a user-defined approach is flown using a GPS, the GPS remains in the en route navigation mode, and while the sensitivity of the GPS CDI can be forced into the approach value (0.3 NM), the RAIM protection will not alter to the approach value.

1.18.10 Altimeter subscale settings – units of measurement

In aviation operations, three different units can be used for altimeter subscale settings to compensate for variations in atmospheric pressure. Those units are inches, hectopascals, and millimetres. While hectopascals are used throughout most of the world, inches of mercury are used in North America, and millimetres of mercury are commonly used in China and the CIS.

1.18.11 Q-code altimeter pressure settings

Three Q-code altimeter pressure settings can be used.[41] Their selection depends on whether the display of height above the Standard Pressure 1,013 hPa datum, altitude above local sea level

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40 Transportation Safety Board of Canada Report Number A99Q0151

41 The Q-code was instituted at the Radiotelegraph Convention held in London, 1912. The meanings of the aeronautical code signals were assigned by ICAO, and the three Q-codes referred to in sub-section 1.18.11. are the standard altimetry references used in aeronautical code signals.

atmospheric pressure, or height above ground level is required. The Q-code altimeter settings are as follows:

- QNE – International Standard Atmosphere standard pressure altimeter setting of 1,013.25 hPa, which is required to be set for flight above a transition altitude
- QNH – altimeter sub-scale setting to obtain elevation when on the ground (the pressure setting to indicate elevation above mean sea level). Area QNH is a forecast value for an area that is valid for 3 hours, and is within +/- 5 hPa of actual value at any low-level point (below 1,000 ft AMSL) in the area during the validity period of the forecast. Local QNH is for a particular location, and can be provided by ATS, automatic weather stations, or published terminal aerodrome forecasts. An altimeter with QNH set on the subscale will display elevation above mean sea level
- QFE – atmospheric pressure at aerodrome elevation or at runway threshold (the pressure setting to indicate height above aerodrome). For example, an aircraft on the ground at Baucau (published aerodrome elevation above sea level 1,800 ft), the aircraft altimeter would read zero if set to QFE. The QFE subscale setting in this instance would be 62 hPa less than the local QNH subscale setting. In the air, with QFE set on the subscale, the altimeter would display height above ground level. QFE is set by adjusting the subscale so that the altimeter reads zero when the aircraft is on the ground at a particular location. QFE is used mainly in China and the CIS for establishing height above the ground when operating in the circuit area of an aerodrome.

1.18.12 Standard operating procedures

Standard operating procedures provide a structured framework by which flight crews are intended to operate aircraft, and provide step-by-step guidance to ensure that operations are conducted in a predictable, uniform and safe manner. They are one of the most important factors in assuring flight safety during normal and abnormal operations.

In 1997, Degani and Weiner published information on procedures in complex human-machine systems.[42] The authors noted that:

> The function of a well-designed procedure is to aid flight crews by dictating and specifying a progression of sub-tasks and actions to ensure that the primary task at hand will be carried out in a manner that is logical, efficient, and also error resistant.

The authors reported that a study conducted in 1987 found that pilot deviation from basic operational procedures was the leading ‘crew-caused factor’ in 93 hull-loss accidents that occurred in the period 1977-1984.[43] They also reported that a study of 37 airline accidents conducted by the National Transportation Safety Board (NTSB) determined that procedural error accounted for 24 per cent of all flight crew errors, and was by far the most dominant factor.[44]

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42 Degani, A., and Wiener, E. L. (1997), Procedures in complex systems: The airline cockpit, IEEE Transactions on Systems, Man, and Cybernetics, 27(3), 302-312.

43 Lautman, L., and Gallimore, P. L. (1987), *Control of the crew caused accident: Results of a 12-operator survey*, Boeing Airliner, April-June, 1-6.

44 National Transportation Safety Board (1994), *A review of flightcrew-involved major accidents of U.S. air carriers, 1978 through 1990* (Safety study, NTSB/SS-94/01). Washington, DC: Author.

Degani and Weiner noted that similar statistics could also be found in the nuclear and maritime industries to demonstrate procedural deviation was the highest ranking category in crew or operator caused accidents.[45,46]

1.18.13 Flight crew coordination

The operation of an aircraft, which requires more than one crewmember on the flight deck for its safe operation, is dependent upon the coordinated efforts of all crewmembers working together as an integrated team. However, aircraft accidents continue to occur in which the failure of flight crew coordination is identified as a significant factor.

A lack of assertiveness by copilots has contributed to a breakdown of flight crew coordination in a number of prominent aircraft accidents. In its report into the aircraft accident involving an Allegheny Airlines Convair CV-580 at New Haven, Connecticut, USA on 7 June 1971, the NTSB stated:

> The concept of command authority and its inviolate nature, except in the case of incapacitation, has become a tenet without exception. This had resulted in second-in- command pilots reacting diffidently in circumstances where they should perhaps be more affirmative. Rather than submitting passively to this concept, second-in-command pilots should be encouraged under certain circumstances to assume a duty and responsibility to affirmatively advise the pilot-in-command that the flight is being conducted in a careless and dangerous manner. Such affirmative advice could very well result in the pilot-in-command's reassessing his procedures.
>
> The regulations prescribe that the pilot-in-command, during flight time, is in command of the aircraft and is responsible for the safety of the passengers, crewmembers, cargo and airplane. In this regard, he has full control and authority in the operation of the aircraft.
>
> The second-in-command is an integral part of the operational control system in-flight, a fail-safe factor, and as such has a share of the duty and responsibility to assure that the flight is operated safely. Therefore, the second-in-command should not passively condone an operation of the aircraft which in his opinion is dangerous, or which might compromise safety. He should affirmatively.advise the captain whenever in his judgement the safety of the flight is in jeopardy.

On 9 July 1978, an Allegheny Airlines BAC 1-11 aircraft overran the end of runway 28 at Rochester, New York, USA after landing. The NTSB reported that the probable cause of the accident was that the pilot in command had a 'complete lack of awareness' of the aircraft's airspeed, vertical speed and performance throughout the landing approach, and that:

> Contributing to the accident was the first officer's failure to provide required callouts which might have alerted the captain to the airspeed and sink rate deviations. The Safety Board was unable to determine the reason for the captain's lack of awareness or the first officer's failure to provide required callouts.

The NTSB also reported:

> While the ultimate responsibility for decisions affecting the safety of the passengers, the crew, the cargo, and the aircraft rests with the pilot-in-command, the crew concept dictates that the pilot not flying assist the flying pilot in the performance of the latter's duties to insure that the cockpit workload remains at an acceptable level throughout an approach and landing.
>
> The Board believes that the captain may have controlled his approach more successfully had the first officer performed the duties required by the company for the pilot not flying. Specifically,

45 Trager, E. A. (1988), Special study report: Significant events involving procedures, (Office for Analysis and Evaluation of Operational Data AOED/S801). Washington DC: Nuclear Regulatory Commission.

46 Perrow, C. (1984), Normal accidents, New York: Basic Books.

the CVR disclosed that the first officer did not make any of the required altitude, descent rate, or airspeed callouts during the approach. His failure placed added workload on the captain during the most critical period of the flight, the approach and landing. This accident again illustrates the importance of disciplined crew coordination and emphasizes the need for flightcrew members to continue to make required, as well as meaningful, callouts, including excessive descent rates and airspeeds.

On 23 August 2000, a Gulf Air Airbus A320-212 crashed into the sea about 3 NM north-east of Bahrain International Airport. In its report into the accident, the Accident Investigation Board (AIB) of the Kingdom of Bahrain commented that the copilot played 'little effective part in flight deck management and decision making', and that:

> At no stage did he raise any issues with, or question the captain's decisions, even though the captain performed non-standard procedures and manoeuvres.

The AIB 'very strongly emphasised' that at no point in the approach and final phases of the flight did the pilot in command consult the copilot or include him in the decision making process, and that:

> The first officer was a valuable operational resource available to the captain, which he did not use effectively.

In its analysis of the performance of the flight crew performance as a team, the AIB noted that:

> …the captain did not effectively use the first officer, a valuable operational resource available to him. In addition, the first officer did not effectively discharge his responsibilities, in the management of aircraft flight operations, of alerting the captain about the deviations from the standard flight parameters, and to respond to hard GPWS warnings. To all intents and purposes, the captain appeared to conduct this part of the flight effectively as a single pilot. The first officer did not participate in the role of decision making, but rather assumed a subordinate role, being primarily responsible for communications, calling out checks and conducting checklist procedures under the directions of the captain.

The AIB also noted that:

> The first officer performed routine procedural functions, and made little significant contribution to the conduct of the last critical phases of the flight. His lack of comments throughout this period shows that, whatever he might have thought internally, he deferred to all of the captain's decisions and actions, even though they involved the violation of SOPs.[47]

1.18.14 Flight crew communication

As a part of their duties, flight crews spend much time communicating with each other, and that communication, if effective, enhances flight crew coordination and situational awareness. Ineffective communication, on the other hand, results in misunderstanding, mistakes, disruptions and loss of situational awareness, and may lead to major or catastrophic consequences.

External and/or internal barriers to communication may disrupt effective communication. External barriers include workload, noise, light, temperature, policies and procedures, cockpit layout, and location of resources. Internal barriers included perceptions, bias, attitude, assumptions, complacency, self-sufficient attitude, unwillingness to communicate, and 'wishful hearing'. Wishful hearing is the tendency a crewmember to hear what he/she expects to hear, and consequently reach a preconceived conclusion on the basis of limited information. The

47 SOPs standard operating procedures.

crewmember assumes that the conclusion is correct without giving consideration to, or ignoring, other relevant information.

Each crewmember has a responsibility to raise concerns that he/she may have with the other members of the flight crew. Those concerns may be advocated by assertive communication, and can contribute to the overall level of situational awareness by the flight crew as a whole. Inquiry, on the other hand, is a request from a crewmember for information or suggestions from the other members of the flight crew to increase situational awareness.

1.18.15 The nature of flight crew error

Data obtained by the University of Texas Line Operational Safety Audit (LOSA) collaborative has revealed that flight crew error can involve:

- intentional non-compliance - violations
- procedural - following procedures but executing them incorrectly
- communication - missing information or misinterpretation
- decision(s) that unnecessarily increase risk.

During the first 6 years of the LOSA program, 18 major airlines were audited in a process that involved LOSA auditors observing flight crews on more than 4,200 flights. The audit data revealed that flight crew errors were observed on 90 per cent of those flights.

The LOSA methodology defines threats as events or errors that originate outside the influence of flight crews in the environmental and airline contexts in which they operate. Nevertheless, flight crews must be aware of, and manage, those threats to maintain adequate safety margins. Environmental threats include adverse weather, air traffic control events/errors, terrain, traffic, and airport conditions. Airline threats include operational time pressure, cabin events/ errors, maintenance events/errors, and aircraft malfunctions/minimum equipment lists.

The archive data from the final 10 audits of the initial phase of the LOSA collaborative revealed that 7,576 threats were identified during the1,835 flights involved, and that one or more threats occurred on 98 per cent of those flights. The threats comprised 2/3 environmental threats and 1/3 airline threats. Forty four per cent of the environmental threats occurred during the descent/approach/landing phases of flight, and 72 per cent of airline threats occurred pre-departure. The most prevalent threats were adverse weather (26 per cent), and air traffic control errors/challenging clearances/late changes (21 per cent).

The data revealed that there were 960 mismanaged threats during the1,835 flights, that is, there was an average of one mismanaged threat every two flights. The data also revealed that 5,172 errors were observed during the flights, that is, there was an average of nearly three errors every flight, and 32 per cent of those errors were classified as intentional non-compliance (violations). The most often mismanaged errors were:

- aircraft handling – hand flying, speed and vertical deviations
- decision errors – mostly during the descent/approach/landing phases
- automation – incorrect entries.

Half of the errors went undetected by the flight crews. At times, additional errors occurred as a consequence of the initial error. Decision errors and procedural errors were the most common form of consequential errors. The consequential errors sometimes led to additional errors, and at times, an undesired aircraft state.

The LOSA collaborative determined that flight crews who committed at least one intentional non-compliance error were twice as likely to commit unintentional errors (procedural, decision etc.), and to have a mismanaged error. The most frequent intentional non-compliance errors were:

- checklist – performing from memory
- automation cross-verification
- non-standard or omitted callouts and briefings.

A total of 28 per cent of flights in the LOSA archive had an undesired aircraft state. The most frequently mismanaged undesired aircraft states were unstable approaches, and speed deviations during the descent/approach/landing phases of flight. Most threats and errors identified by the LOSA collaborative occurred during the descent/approach/landing phases.

The collaborative examined archive data from what it defined as the 'blue box' phase of flight. The 'blue box' phase comprises all phases of flight from just prior to descent until a stabilised landing approach is established. The data revealed that more automation and decision errors occurred in the 'blue box' phase. It also revealed that only 20 per cent of the errors were effectively managed, and that 28 per cent of the errors led to undesired aircraft states such as incorrect aircraft configuration, vertical deviations, and speed excursions.

In summary, the LOSA audit data revealed that in terms of errors, the descent/approach/land phase was the highest risk phase of flight (44 per cent), and in terms of threats, the second highest risk phase (33 per cent) after pre-departure/taxiing phase (40 per cent). In other words, the descent/approach/landing phase involved the most errors, the most variability in flight crew performance, and the most consequential errors.

1.19 Useful or effective investigation techniques

The Australian investigation team, which conducted the onsite investigation phase of the investigation for and on behalf of CAD, consisted of the Australian Accredited Representative, three investigators from the Directorate of Flying Safety - Australian Defence Force, and two scientists from the Australian DSTO.

The Australian investigation team made extensive use of the DSTO developed GPS based wreckage mapping and analysis equipment to aid in the investigation of the accident. Within five days of the accident, the Australian investigation team had mapped 900 items of the aircraft wreckage, of which about 300 were identified and photographed. The initial wreckage distribution maps produced within that period assisted in the development of a detailed preliminary analysis of the disintegration of the aircraft after impact.

The rapid production of accurate wreckage maps and the preliminary analysis enhanced the overall capability of a small team assigned to conduct the on site investigation phase of an accident which involved the total destruction of a large transport-category aircraft.

2 ANALYSIS

2.1 Introduction

At the time of the occurrence, the moist onshore monsoon winds ascending up the steeply sloping coastal terrain to the north of Baucau resulted in instrument meteorological conditions at and around the aerodrome. Under those circumstances, a visual approach to runway 14 was not possible. The flight crew elected to make an instrument approach to the runway, using the onboard GPS navigation system for azimuth and distance guidance to the runway. That was not an approved approach procedure for Baucau.

The operator’s operations manual contained instructions that the flight crew were to set the barometric altimeter subscale settings to QFE during descent, and that the QFE setting was to be derived from local sea QNH. There were no aerodrome forecasts for Baucau at the time of the occurrence, and air traffic services were not available at Baucau for non-UN operations. Therefore, there were no mechanisms in place to provide the flight crew with an accurate QNH altimeter subscale setting for the approach to Baucau. During the descent, the pilot in command set 760 mm Hg as the subscale setting on his altimeter. That equalled a sea level pressure setting of 1,013.2 hPa, or standard atmosphere sea level pressure. The pilot in command subsequently set his altimeter subscale setting to 714 mm Hg. That setting equalled 952 hPa, and corresponded to the 62 hPa aerodrome elevation that was published on the Jeppesen Baucau aerodrome chart, that is, 1,013.2 less 62 hPa = 952 hPa. The pilot in command therefore set his altimeter subscale to an estimated QFE for Baucau.

It could not be determined how the flight crew established the initial altimeter subscale setting of 760 mm Hg (1,013.2 hPa). That setting equalled QNE and not QNH, and was therefore unsuitable for establishing elevation AMSL. The Australian BoM reported that the QNH at Baucau was typically 2 hPa higher than Dili Comoro. The QNH at Comoro was 1008.9 hPa at the time of the occurrence, and on that basis, the QNH at Baucau was likely to have been about 1011 hPa. An altimeter subscale setting of 760 mm Hg (1,013.2 hPa) would therefore have resulted in the altimeter indicating a height above a datum that was about 18.3 m (60 ft) below sea level. A QFE altimeter subscale setting of 714 mm Hg would also have resulted in an 18.3 m (60 ft) error.

The aircraft was fitted with several self-contained onboard navigation systems that were not reliant on signals from ground-based radio navigation aids to provide the flight crew with navigation data. Those systems included a GPS. The CVR data revealed that the flight navigator was using the GPS to provide the pilot in command with navigation data during the approaches at Baucau.

The flight navigator seemed surprised by the unexpected appearance of the runway when the aircraft overflew the aerodrome at Baucau. The aircraft again overflew the runway earlier than the flight crew expected during the first landing approach. At that point, that flight crew realised that there was a discrepancy in the data they were using for azimuth and distance guidance to the runway, and that it was not where they expected it to be. As a result, during the second landing approach, the flight navigator provided the pilot in command with navigation data about distance to run, based on his revised estimate of where he thought the runway threshold was located.

That revised estimate was incorrect. During the second landing approach, as the aircraft was on the final leg of the approach, the flight navigator advised the pilot in command that the aircraft was high on the approach. The pilot in command increased the rate of descent, and descended the aircraft below the published minimum descent height. The descent was also below the ideal approach path for a stabilised approach to the runway.

The combination of:

- environmental threats, in terms of the poor prevailing weather conditions at Baucau and the sharply rising terrain beneath the intended approach path to runway 14
- poor planning by the flight crew
- poor flight crew coordination
- the flight crew's non-compliance with standard operating procedures
- their disregard of the published instrument approach procedures
- their intentional descent below the published minimum descent altitude (height)
- their apparent lack of appreciation and/or disregard of the risks associated with their proposed actions

Resulted in the aircraft's impact with terrain. This analysis examines the interrelation of those factors.

2.2 Aircraft and systems

2.2.1 General

The Lao DCA-issued certificates of airworthiness and registration for the aircraft were current at the time of the occurrence.

There was no evidence from either the recorded data, or the wreckage, to suggest that any malfunction of the aircraft, its engines, or systems, would have precluded the successful and safe conduct of either of the published NDB non-precision approaches at Baucau. There was also no evidence of an inflight break-up, explosion or deflagration before impact. Nor was there any evidence among the aircraft wreckage of any items or equipment onboard the aircraft that could have acted as a source of electromagnetic interference to the onboard navigation equipment.

The number of satellites in view at Baucau and the HDOP at the time of the occurrence would have resulted in little effect on the integrity of the lateral navigation data that was provided by the aircraft's GPS.

The minimum fuel warning (time 06:04:54) meant that 2 tonnes of fuel was remaining for each of the aircraft's engines. Based on the fuel on board the aircraft when it departed Macau (75 tonnes), and the pilot in command's estimate of the fuel remaining at Baucau (25 tonnes) during the arrival briefing, the investigation concluded that the aircraft had more than the minimum total amount of 8 tonnes of fuel on board that would have triggered the minimum fuel warning. Additionally, if only 8 tonnes of fuel had been on board at the time the minimum fuel warning was triggered, the warning would have remained activated. It did not, and activated only momentarily. The FDR pitch plot revealed that minimum fuel warning was coincident with a sudden nose-down pitch of the aircraft, and the investigation concluded that the minimum fuel warning was a false warning triggered by the sudden pitch change.

2.2.2 Automatic direction finders

Because of the level of destruction of the aircraft, it was not possible to identify or find the ADF frequency selector units within the cockpit wreckage area or elsewhere in the wreckage. The recorded voice data recovered from the CVR revealed that the pilot in command briefed the flight crew that the landing approach at Baucau would be conducted with reference to the Baucau NDB.

Shortly after, the pilot in command stated that the NDB was 'set', then three seconds later the flight navigator stated 'Good too'. There was no evidence on the CVR to confirm that the pilot in command, copilot, or navigator positively identified the morse code identifier of the Baucau NDB or tested the radio compass to prove that it was functioning correctly. It is unlikely that there was enough time in the three seconds between the pilot in command's reference to setting the Baucau NDB, and the navigator's statement 'Good too', for the flight navigator to have checked the morse code identifier of the Baucau NDB through his headset. The investigation concluded that it was likely that the flight navigator's statement may have been in response to him seeing the relative bearing indicator on his radio magnetic indicator pointing towards the Baucau NDB.

At no time during the approaches did any of the flight crew make comment to suggest that the Baucau NDB was inoperative and therefore not available for the conduct of either of the published non-precision approaches. When the NDB monitor in the Baucau control tower was checked during the evening after the occurrence, it indicated that the NDB was not working at that time. The investigation was unable to positively establish from that source whether the Baucau NDB was operating at the time of the occurrence.

Impact forces had substantially damaged the two CIs found in the wreckage. The desired heading pointers on the recovered CIs were on magnetic headings of about 134 and 135 degrees respectively. That was consistent with the magnetic heading of the aircraft at the point of impact. The relative bearing pointers on both units were offset by 3 degrees to the left of the aircraft nose.

The impact point was 1,877 m to the northwest of the threshold of runway 14, on the extended centreline of the runway. The aircraft heading at the point of impact was 136 degrees magnetic. The bearing to the runway from the impact point was 139 degrees. Under those circumstances, the relative bearing pointers should therefore have been offset by 3 degrees to the right of the aircraft nose. The 3 degree left offset was therefore consistent with the aircraft having been inverted at the time electrical power to the CIs was lost during the impact sequence. The position of the relative bearing pointers in relation to the aircraft nose was also consistent with them pointing to the NDB at that time. That suggested it was likely that the NDB was working at the time of the occurrence, and had therefore been available to the flight crew to conduct either of the published NDB non-precision approaches at Baucau.

2.2.3 Recorded barometric altitude

The topographic elevation of the impact point was 495 m (1625 ft) above the 760 mm Hg (1,013.2 hPa) datum. The FDR barometric altitude data revealed that the aircraft barometric altitude with reference to the 760 mm Hg (1,013.2 hPa) pressure datum was 609 m (1,998 ft) at impact. There was therefore a discrepancy of about 114 m (374 ft) between the impact elevation and that recorded on the FDR barometric plot. However, the variable nature of the FDR recorded barometric altitude meant that it was possible that there could be as much as a 120 m error in the barometric altitude plot.

The barometric altitude data recorded during the last 2 seconds of flight indicated that the aircraft rate of descent was about 120 m/sec (393 ft/sec, or 23,622 ft/min). That was not possible, and the excessively high derived rate of descent was probably due to the disturbance of airflow around the barometric pressure source when elevator was suddenly applied to increase the aircraft pitch angle shortly before impact.

The evaluated pressure altitude varied slightly from the ‘smoothed’ true pressure altitude derived from the variable recorded barometric altitude data, because it relied on ‘g’ being applied to true pressure altitude. The high rate of descent during the final few seconds of flight would likely have distorted the recorded value of ‘g’, further affecting the accuracy of the evaluated pressure altitude.

2.2.4 Radio altimeter system

As discussed in subsection 1.12, the two damaged radio altimeter units were the only components of the radio altimeter system that were identified and located in the aircraft wreckage. It was therefore not possible to conduct a technical investigation of all the elements comprising the radio altimeter system to determine its serviceability prior to impact.

The FDR did not record any information from the aircraft radio altimeter system, although it was designed to do so. That was substantiated by a note found within the FDR unit, and which the IAC concluded had been the result of previous maintenance testing of the unit. The IAC reported that the absence of recorded radio altitude data was probably due to a malfunction in the flight data acquisition unit of the FDR, and that the absence of that data did not imply that the radio altimeter system was inoperative before impact. The FDR had not recorded any radio altitude data during the five flights preceding the occurrence flight, however, the CVR data revealed that the flight navigator provided the pilots with radio altimeter data during the landing approach on the flight prior to the occurrence flight.

The CVR provided no evidence to suggest that the red warning lamps located on the flanges of the radio altimeter indicators of the pilot in command, copilot and flight engineer had illuminated at any stage during the overflight and two landing approaches at Baucau. The investigation concluded that had those red warning lamps illuminated, the flight crew would most likely have commented on the fact that the radio altimeter system was inoperative.

The flight crew did not have, and did not attempt to obtain, a confirmed QNH for Baucau, and they initially set the altimeter subscales to 760 mm Hg (1,013.25 hPa). The BoM subsequently reported that the Comoro QNH was 1,008.9 hPa at the time of the occurrence, and on that basis, the QNH at Baucau was likely to have been about 1,011 hPa (758.3 mm Hg). The investigation was unable to determine on what basis the flight crew assumed that the sea level pressure at Baucau was 760 mm Hg (1,013.25 hPa). Nevertheless, based on that assumption, the flight crew then adjusted the barometric altimeter subscale settings so that they provided barometric altitude readouts in relation to height AGL at Baucau (QFE).

The IL-76TD Flight Manual contained no procedure for establishing a QFE altimeter setting in the absence of a confirmed QNH. The only way that the flight crew had of confirming that the QFE altimeter subscale settings they had selected were correct was by cross-referencing the barometric altitude readings with radio altitude data as the aircraft overflew the aerodrome. The CVR provided no evidence to corroborate that the flight crew used the radio altimeter system to confirm barometric altitude of the aircraft as it overflew Baucau aerodrome on the first occasion, or at any other time.

The only PB-150 radio altimeter indicator was mounted on the pilot in command's instrument panel. That indicator had been dislodged from the instrument panel during the impact sequence, and was located in the aircraft wreckage. The investigation could not determine why the reference bug on the pilot in command's PB-150 radio altimeter indicator was not set to 60 m for the non-precision approach, as it was required to be. Had it been set to 60 m, it is unlikely the impact forces would have dislodged the reference bug to the slightly less than zero altitude reading as found.

The investigation therefore concluded that the reference bug was not set for the landing approaches. Had the bug been set to 60 m, descent below that absolute altitude would have illuminated the 'DECISION HEIGHT' annunciators on both pilots' instrument panels and sounded the 'BELOW PRESELECTED ALTITUDE' aural voice warning. No radio altitude aural warning voice was recorded by the CVR. The time interval between the flight crew conversations recorded by the CVR was less than 10 seconds at the time. The CVR disengaging delay of about 15 seconds (+/- 5 sec.) would therefore have resulted in the radio altimeter system aural voice warning being recorded, had it been triggered at 60 m.

The aircraft was in a high rate of descent when it when it descended through that altitude. Consequently, even with the bug correctly set, impact with terrain was unlikely to have been avoided once the aircraft descended below 60 m.

2.2.5 The flight navigator's reference to radio altitude during the second landing approach

The flight crew assumed that sea level pressure at Baucau was 760 mm Hg (1,013 hPa). During the descent into Baucau, they set their barometric altimeter subscales to 714 mm Hg, which was the pressure setting that they calculated would provide indications of height above the aerodrome (QFE).

At 06:05:07, when the aircraft was established on final approach during the second landing approach, the flight navigator informed the pilot in command 'On radio altimeter 300 we have, continue descending".

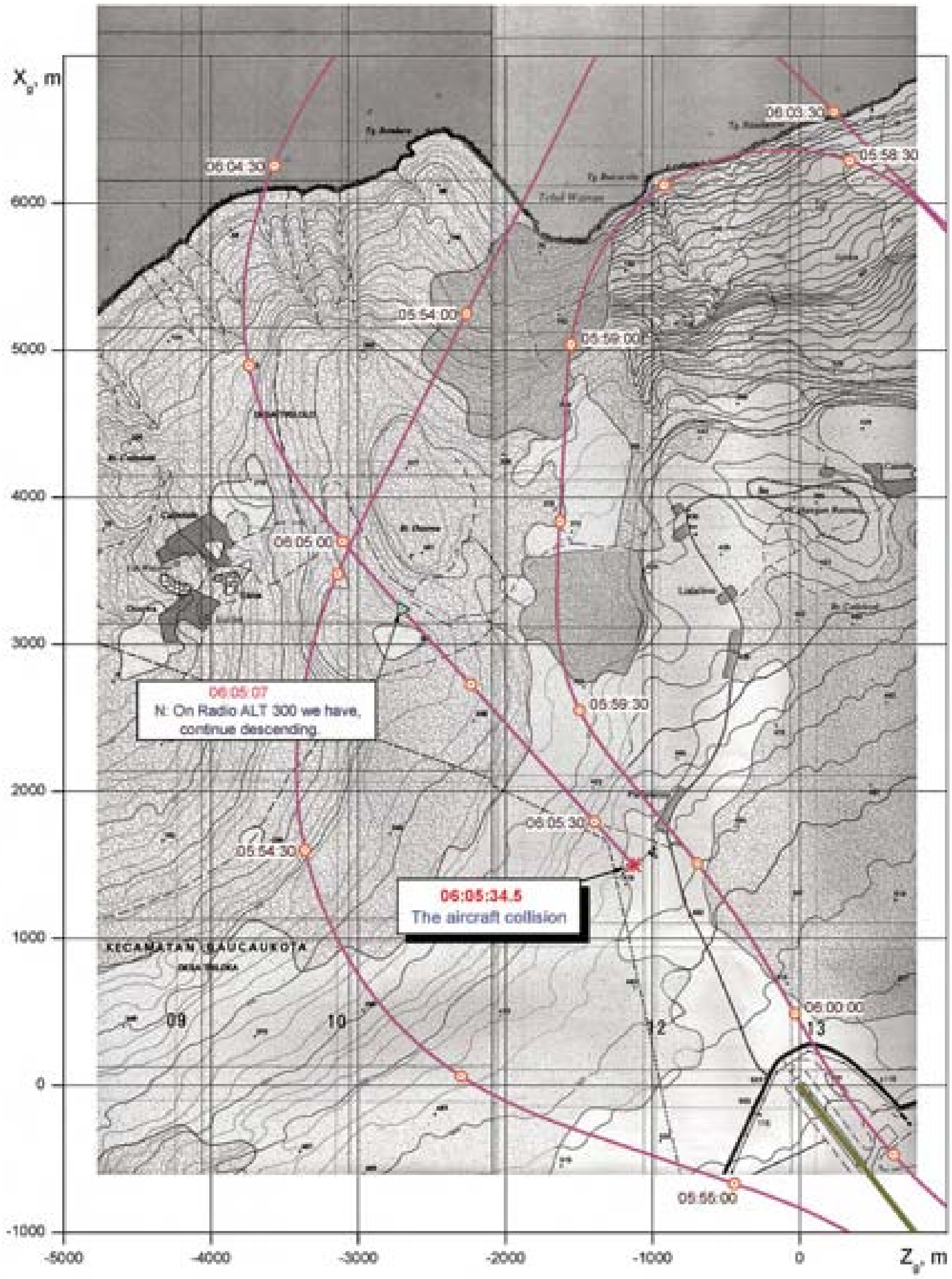
The Australian investigation team analysed the recorded flight data, and estimated that the aircraft would have been overhead the 320 m terrain contour at time 06:05:07. They therefore concluded that the absolute altitude would have been greater than 300 m at that point. The matter was referred to the IAC for further analysis and comment, because the IAC had performed the initial FDR and CVR readouts and analyses for and on behalf of the Australian investigation team.

The IAC plotted the aircraft's flight path onto the Baucau, East Timor 2507-42 T754 Edition 2 topographic map. The map displayed contour elevations in metres AMSL. The IAC reported that it concurred with the Australian investigation team that the aircraft had been overhead the 320 m (1,050 ft) contour at time 06:05:07 (see Figure 37).

The IAC reported that the QFE barometric altimeter subscale setting of 714, as selected by the flight crew, was equivalent to a height of 523 m (1,716 ft) above the 760 mm Hg datum, and that 714mm Hg therefore corresponded to the threshold elevation of runway 14. The IAC calculated that at time 06:05:07 the aircraft was between 480 and 507 m (1,575 and 1,663 ft) above terrain, and thus between 800 and 827 m (2,625 and 2,713 ft) above the 760 mm Hg datum. Accordingly, they estimated that the aircraft was between 277 m and 304 m ((800 and 827 m) less 523 m) (909 and 997 ft) above the elevation of the threshold of runway 14 at that point.

The IAC reported that at time 06:05:07 the aircraft was therefore at about 300 m (984 ft) barometric altitude with the altimeter subscales set at 714 mm Hg, and not at 300 m absolute altitude. The IAC concluded that under those circumstances, the flight navigator had mistakenly referred to barometric altitude as radio altitude. The Australian investigation team concurred with the IAC's conclusion.

FIGURE 37:
Aircraft position over the terrain at 06:05:07



2.2.6 Ground proximity warning system

About 17 seconds before impact (time 06:05:17), the flight navigator told the pilot in command that the aircraft was high on the descent profile. At that point, the aircraft was less than 250 m (820 ft) above field elevation. The pilot in command responded by increasing the rate of descent of the aircraft to about 18 m/sec (3,543 fpm), and by so doing, exceeded the linear trigger threshold limits for a GPWS excessive rate of descent warning. The CVR data revealed that no aural warning signal was recorded when the linear trigger threshold limits for excessive rate of descent were exceeded. No GPWS aural warning was recorded by the CVR. The time interval between the flight crew conversations recorded by the CVR was less than 10 seconds at the time. The CVR disengaging delay of about 15 seconds (+/- 5 sec.) would therefore have resulted in the GPWS aural warning signal being recorded, had it sounded.

The FDR data also revealed that there was also no registration of 'dangerous speed of ground approach' when those limits were exceeded. The zone where the GPWS would have been active during the second landing approach is depicted at Figure A.6.

None of the components of the GPWS system were identified within the aircraft wreckage. It was therefore not possible to conduct a technical investigation of all the elements comprising the GPWS to positively determine its serviceability prior to impact.

The copilot called for the pilot in command to increase altitude 2.7 seconds before impact and about 6 seconds after the conditions for the actuation of the GPWS were met. Because of the high rate of descent during that stage of the approach, there would have been little time for the pilot in command to react to any GPWS warning and to avoid impact with terrain.

2.2.7 Navigation data

The aircraft's navigation equipment included a GPS, an integrated flight and navigation system, a Doppler navigation system, and an inertial navigation system. The GPS provided navigation data in feet and NM. The integrated flight and navigation system, the Doppler navigation system, and the inertial navigation system each provided navigation distance information in km.

The CVR data revealed that the flight navigator was providing navigation distance data to the pilot in command in metric units. The flight data plots revealed that the distance information the flight navigator was providing to the pilot in command was accurate in relation to where the flight crew thought the runway was located, as depicted on the Jeppesen charts. However, it was not accurate in relation to where the runway was actually located.

Between times 06:04:46 and 06:05:27, while the aircraft was on the second landing approach, the flight navigator became confused about the distance to run to where he thought the runway was located.

If the flight navigator had used the metric distance data from the integrated flight and navigation system, the Doppler navigation system, and the inertial navigation system, it is unlikely that he would have been confused. If he had been using the imperial distance data from the GPS, he would have needed to convert it into the metric data he was providing the pilot in command. During the second landing approach, the flight navigator's distraction about the aircraft descent profile may have interfered with his ability to accurately convert the GPS data from imperial to metric units. That may have resulted in the confusing distance information that the flight navigator provided the pilot in command between times 06:04:46 and 06:05:27.

The investigation concluded that the flight navigator configured the onboard GPS with data from the Jeppesen charts to provide navigation data to the pilot in command for the initial overflight and the two landing approaches at Baucau.

During the investigation, the IAC expressed concern to the Australian investigation team about the disparity between the Jeppesen data and the actual runway threshold coordinates and elevations. The Australian accredited representative noted that concern. Nevertheless, the Jeppesen charts were not the approved charts for non-precision approaches at Baucau. The Baucau NOTAMs, current at the time of the occurrence, included NOTAM GO111/02, which stated:

> … INST APP PROC DATED 1 APRIL 2001 FOR RWYS 14/32 AVBL FM CIVIL AVIATION DIV EAST TIMOR UPON REQUEST VIA FAX TO +61 (8) 89463900 EXT 6151 …

The flight approval issued by CAD for the occurrence flight included information that NOTAMs for Timor-Leste were available for download from the Airservices Australia website. It also included a note that information on airports, air traffic management, flight planning requirements, flight approval procedures, facilitation and aeronautical fees were posted on the Timor-Leste government website.

The airport service log for Macau International Airport provided confirmation that the flight crew of the occurrence aircraft were provided with NOTAMs and weather information for the planned flight to Baucau, however, the weather information did not include TAF & METAR for Baucau because those forecasts were not produced for Baucau. Additionally, following the accident, the Singapore-based agent confirmed that it forwarded the relevant CAD-issued Baucau charts to the aircraft operator before the aircraft's departure from Macau.

The investigation was unable to determine whether the operator provided the flight crew with the CAD-issued Baucau charts. The flight crew was provided with the relevant NOTAMs before departure from Macau, and those NOTAMs included details that the Baucau instrument approach charts, dated 1 April 2001, were available from CAD. The Jeppesen charts were dated 30 August 2002. The discrepancy between the NOTAM chart date and the Jeppesen chart date should have provided the flight crew with sufficient reason to question and determine whether there were any significant differences between the charts. Had they done so, they may have realised that the position of the runway as depicted on the Jeppesen chart differed from where it was depicted on the CAD-issued charts. The investigation concluded that under the circumstances, the flight crew's reliance on the Jeppesen charts was not appropriate because they were not the charts specified in the Baucau NOTAMs that were provided to the flight crew before the flight commenced.

Furthermore, the flight crew did not follow the published runway 14 non-precision instrument approach procedure, but used the Jeppesen charts to estimate the coordinates of the threshold of runway 14 upon which they constructed a non-approved, user-defined, precision approach to where they thought the runway was located.

2.3 Flight crew

2.3.1 Physiological factors

The severity of the injuries sustained by the occupants prevented identification of any physiological factors that may have adversely affected their performance.

2.3.2 Experience of the flight crew

The investigation was unable to determine the individual total levels of experience on the IL-76 TD aircraft type for the pilot in command, copilot, flight engineer or flight navigator. An IL-76 TD type rating was entered in each of the flight crew's Russian flight crew licences, and all had held those type ratings for at least 10 years. Based on their individual total flight hours, all of which exceeded several thousand hours, each had considerable experience on IL-76 TD aircraft. The investigation concluded that the flight crew did not lack experience on the aircraft type, and that experience was not a factor in the events leading up to the accident.

The investigation was also unable to determine either pilot's experience in conducting non-precision instrument approaches with reference to ground-based radio navigation aids. Therefore, it could not be determined whether that was a factor in the decision to conduct the non-approved, user-defined, approaches in preference to the approved (published), non-precision instrument approach procedures at Baucau.

2.3.3 The pilot in command's arrival briefing

The pilot in command briefed the other crewmembers that he would conduct a non-precision instrument approach at Baucau, with reference to the Baucau NDB. The flight instruments fitted in the occurrence aircraft provided readings of height, speed and distance in metric units. The pilot in command's briefing included information on the relevant heights for the missed approach procedure expressed in feet, and not in their metric equivalents. None of the other crewmembers commented on that fact, or confirmed those heights in their metric equivalents.

The pilot in command did not refer to the source of data that he used for the briefing on the intended NDB approach at Baucau, and the briefing contained no information or discussion on:

- the planned altimeter subscale settings for the descent to Baucau
- the applicable MSA within 10 NM (18 km) of the Baucau NDB; the MSA was 9,300 ft (2,834 m) AMSL
- the commencement altitude for the runway 14 NDB approach at Baucau, which was 5,500 ft (1,676 m) AMSL
- the LSALT for the last route sector into Baucau, which was 4,500 ft (1,372 m) AMSL
- the applicable MDA(H) for the approach
- the expected weather at Baucau
- the Baucau NOTAMs.

None of the other crewmembers commented on the omission of this critical information. As a result, the arrival briefing was not effective, and did not draw the attention of the flight crew to the relevant environmental threats that existed at Baucau.

The LOSA collaborative has determined that non-standard briefings frequently result from intentional non-compliance. The investigation was unable to conclude that the pilot in command's non-standard and ineffective briefing resulted from intentional non-compliance with the operator's standard operating procedures. Nevertheless, the flight crew's subsequent unquestioning disregard of the relevant safety heights and the published instrument approach procedures suggested that they were accustomed to operating in a non-compliant fashion. Moreover, the events in the circuit area at Baucau, which involved mismanaged procedures and decisions, led to an undesired aircraft state in terms of an unstabilised approach. The consequent CFIT event was consistent with the LOSA hypothesis that flight crews who commit at least one intentional non-compliance error were twice as likely to commit unintentional errors (procedural, decision etc.), and to have a mismanaged error.

2.3.4 Expectation of weather at Baucau

The lowest safe LSALT for the last route segment of the flight between Ambon and Baucau was 4,500 ft (1,372 m) AMSL. The forecast provided to the flight crew before departure from Macau contained information that there would be up to 7 OKTAS of cloud coverage below the LSALT on the last route segment. The flight crew should therefore have been aware that a non-precision instrument approach would most likely be required at Baucau.

2.3.5 Expectation of the provision of ATS at Baucau

The NOTAMs that were current for Baucau at the time of the occurrence included information that air traffic services were only available for aircraft conducting United Nations troop rotations at Baucau. The pilot in command made no mention of that NOTAM during the descent approach briefing.

Between times 05:31:22 and 05:52:37, the CVR revealed that the copilot made 26 unsuccessful attempts to contact Baucau Tower during the descent into Baucau, which suggested that the flight crew was expecting that ATS would be provided at Baucau. The investigation was unable to determine whether that expectation was because the flight crew:

- was unaware of the NOTAM
- was aware of the NOTAM, but assumed their arrival at Baucau would coincide with UN troop rotation activities
- assumed that arrangements had been made to provide ATS to the occurrence flight.

None of the flight crew advocated contacting Dili ATS to find out why contact with Baucau Tower could not be established. Had they contacted Dili ATS, it may have provided them with an opportunity to seek updated information about the actual weather at Baucau. It may also have allowed them the opportunity to review their intended approach plan in consideration of that updated information and any subsequent advice regarding the availability of ATS at Baucau.

After the copilot's twentieth attempt to contact Baucau, the flight navigator advocated to the pilot in command that they overfly the aerodrome on the first approach, and land off the second approach. The pilot in command concurred, and informed the other crewmembers that he would conduct the overflight on a magnetic heading of 135 degrees (time 05:48:15). However, he neither specified the minimum descent height for the overflight, nor did he specify the applicable MDA(H) that would apply for the landing approach. None of the other crewmembers commented on the omission of this critical information. They also did not inquire whether the pilot in command intended to maintain the direct Ambon – Baucau track until the aircraft had passed overhead the Baucau NDB.

The lack of an operationally thorough briefing by the pilot in command regarding the change of approach plan, and therefore the changed context of the flight, meant that the flight crew as a whole had no clear understanding of the parameters and limitations that were intended to be applied for the revised approach plan. The flight crew therefore had no benchmark against which to identify those events that could affect the achievement of the intended approach.

Consequently, the flight crew did not appear to have any appreciation of the potential hazards and therefore any possible evolving risks because of the changed context of the flight.

When the flight navigator finally established contact with Baucau Tower (time 05:53:59), the controller advised the flight crew that landing at Baucau would be at their discretion. Although the flight navigator acknowledged the controller's advice, he did not seek information from the controller about the prevailing weather at the aerodrome. That was another missed opportunity for the flight crew to obtain updated information on the weather at Baucau, including the QNH. Had the flight crew sought and received that information, it may have provided them with an improved situational awareness of the prevailing weather, and its likely effect on the changed context involving the intended improvised approach procedure.

The investigation could not determine if updated weather information may have influenced the flight crew to consider conducting either of the two available published NDB non-precision approach procedures, in favour of a non-approved and improvised user-defined instrument approach procedure.

2.3.6 Expectation of the location and elevation of runway 14 at Baucau

The Baucau NOTAMs included information that instrument approach charts for Baucau were available from CAD. However, the flight crew did not refer to those charts, but appeared instead to have relied on data from the Jeppesen instrument approach and aerodrome charts to create a non-approved user-defined runway approach for runway 14. The notion that the flight crew relied on the Jeppesen charts was supported by:

- the pilot in command's reference to the runway 14 magnetic heading at Baucau as 135 degrees, which was the heading published on the Jeppesen charts[48]
- the flight navigator's surprise that the runway was not where they expected it to be during the first overflight and the first landing approach. That suggested his expectation of the position of the runway was based on its location as depicted on the Jeppesen charts
- the flight navigator's calculation of the QFE at Baucau as being 714mm Hg (951 hPa), based on the flight crew's apparent assumption that the QNH was 760 mm Hg (1,013.2 hPa). The 46 mm Hg correction equalled a field elevation of 62 hPa which was published on the Jeppesen aerodrome chart, but which was not published on the CAD charts.

The flight navigator's reference to distance and lateral offset during the overflight and the first landing approach corresponded to the aircraft's position in relation to the threshold of runway 14, as depicted on the Jeppesen charts. The navigation data provided by the flight navigator was therefore accurate in terms of where he expected the threshold of runway 14 to be. However, erroneous data on the Jeppesen charts meant that it was inaccurate in terms of where the actual threshold of runway 14 was actually located. The flight crew's inappropriate reliance on that data therefore increased the risk of a CFIT event.

Had the flight crew followed the non-precision runway 14 NDB approach procedure as published on either the CAD or Jeppesen charts, and not descended below the relevant MDA(H) until visual flight was assured, the position of the runway, as depicted on the Jeppesen, charts would have been irrelevant. Although the runway would not have appeared where the flight crew expected it to be at the MDA(H), in VMC a safe approach could have been conducted to the actual threshold of runway 14. Alternatively, if a visual approach could not be made from the relevant MDA(H), a safe missed approach could have been conducted by following the published missed approach procedures.

48 The CAD charts did not include information on the runway heading at Baucau.

The published threshold elevation of runway 14 was 527 m (1,729 ft) AMSL) and coincided with the survey result from the 2001 survey of Baucau aerodrome. The investigation determined that the threshold elevation for runway 14 was 519 m (1,703 ft) AMSL. The investigation concluded that the minor difference between the actual threshold elevation and the published elevation was not a factor in the occurrence.

2.3.7 The decision to conduct the improvised approaches at Baucau

The pilot in command briefed the flight crew on the approach for runway '…135…' NDB at Baucau, but did not follow that procedure. The procedure, as briefed, would have required the pilot in command to maintain the Ambon – Baucau track to the Baucau NDB. It would also have required the pilot in command to maintain either the LSALT or the NDB non-precision approach commencement altitude until overhead the NDB, if the aircraft was in IMC. The pilot in command would then have needed to establish the aircraft in the holding pattern that was depicted on the approach plate, before commencing the published approach procedure. The investigation was unable to determine whether the aircraft was in IMC or VMC as the aircraft was on descent to Baucau prior to conducting the overflight of the aerodrome.

The pilot in command did not specify the relevant MDA(H) for the intended approach at Baucau during the descent approach briefing, and stated that he would fly the aircraft at 250 km/h (135 kts) '…on glideslope…'. The flight crew may therefore have assumed that a straight-in landing would be made, and that it was the intention of the pilot in command to descend the aircraft to the published straight-in MDH of 531 ft (162 m) above the elevation of the threshold of runway 14.

After many unsuccessful attempts by the copilot to contact Baucau Tower, the flight navigator advocated to the pilot in command to overfly the aerodrome on the first approach and to land off the second approach. The pilot in command concurred, and his decision to conduct the overflight on a magnetic heading of 135 degrees effectively nullified the descent approach briefing. The flight navigator stated, 'Yes, we'll turn left and I'll give you the data for landing, will be no problems' (time 05:48:17). That statement suggested the flight navigator and the pilot in command had taken a decision to intentionally depart from the approach procedure originally briefed by the pilot in command, and to conduct an improvised approach.

The decision to overfly would have allowed the flight crew to visually confirm that the runway was unobstructed if weather conditions permitted, without ATS advice to that effect. However, if VMC did not prevail, the overflight should only have been conducted if visual flight was possible at the completion of the published runway 14 NDB non-precision approach procedure. Alternatively, if visual flight was not possible, then a missed approach should have been carried out in accordance with the published procedures, as originally briefed by the pilot in command prior to the descent into Baucau.

The decision by the pilot in command to overfly Baucau on a heading of 135 degrees magnetic, based on the Jeppesen aerodrome chart data, was at variance with the published inbound track of 146 degrees magnetic for the runway 14 NDB non-precision approach procedure. The track that the pilot in command intended to overfly the aerodrome was 11 degrees different from the published inbound track. The obstacle clearance tolerances of the published inbound track diminished the risk of CFIT. They did not apply to the intended overflight track, and obstacle clearance on the intended track was no longer guaranteed if flown at the published MDA(H). None of the flight crew seemed aware that obstacle clearance on the intended overflight track was not guaranteed, and that the risk of a CFIT event was therefore increased. The CVR data provided no evidence that the flight crew reviewed the context of the proposed approach in terms of hazards, and therefore the likelihood of an increased CFIT risk. Had they done so, they may have realised that the likelihood, and therefore risk, of a CFIT event was rapidly increasing.

The CVR data revealed that the pilot in command did not attempt to ensure that the copilot and flight engineer fully understood what the flight navigator's and his own intentions were. The copilot and flight engineer had an opportunity to express any concerns they may have had regarding the intended overflight and subsequent landing approach, and to suggest an alternative plan of action. They did not do so, nor did the pilot in command invite them to. Flight crew co-ordination issues are further examined at subsection 2.3.10.

The pilot in command did not re-brief the other crewmembers about the revised approach procedure. Nor did he brief them about the relevant MDH for the intended landing approach, as he was required to do in accordance with the operator's published procedures. The flight crew as a whole therefore had no clear guidance or understanding about whether the descent would be to the published straight-in MDH of 531 ft (162 m) above the elevation of the threshold of runway 14, or to the published circle-to-land MDH of 500 ft (152 m) above the elevation of the aerodrome.

The pilot in command also provided no instructions to the other crewmembers regarding his expectations of the support role they were expected to play during the overflight, and did not ensure that they were reminded of the need to:

- constantly monitor the height of aircraft in relation to the ground
- observe and verify ('call out') the relevant safe heights for the intended landing approach
- monitor the approach to ensure it complied with stabilised approach procedures.

The requirement that the flight crew be aware of those procedures was specified in the operator's operations manual as part of the operator's inflight procedures for CFIT avoidance.

As the aircraft approached Baucau, it was not on the direct Ambon – Baucau track. Because the aircraft was no longer tracking directly towards the Baucau NDB, the LSALT for the direct track no longer applied. As stated previously, the investigation was unable to determine whether the aircraft was in IMC or VMC as the aircraft was on descent to Baucau prior to commencing the overflight of the aerodrome. If the aircraft was in IMC, then the pilot in command was obliged to descend the aircraft no lower than the published MSA. Between 46.3 km and 18.5 km (25 NM and 10 NM), the MSA was 1,128 m (3,700 ft) AMSL and within 18.5 km, it was 2,835 m (9,300 ft).

At time 05:51:12, when the aircraft was about 13.7 km (7.4 NM) from the Baucau NDB, the pilot in command stated that the aircraft was maintaining 400 m (1,312 ft), which was in reference to the aircraft height above field elevation. The aircraft was therefore at an altitude of about 950 m (3,116 ft) AMSL, which was below the published MSA.

The CVR data revealed that none of the flight crew commented on the MSA, or that the pilot in command had descended the aircraft below the respective limit altitudes. That suggested that the flight crew:

- were unconcerned by that deviation from standard procedures
- were unaware of the ramifications of the MSA within 18.5 km (10 NM) of the Baucau NDB, and that it indicated the presence of significantly high terrain near to the aerodrome
- were unconcerned that obstacle clearances were no longer being guaranteed as a result of the aircraft being below the published MSA

- were unconcerned because the aircraft was in VMC at that point
- were unaware of the increased risk of a CFIT event.

The published MSAs provided appropriate buffers to diminish the risk of a CFIT event. The pilot in command's disregard of the MSAs resulted in obstacle clearances no longer being guaranteed during flight in IMC, and the risk of a CFIT event was therefore increased. The CVR data provided no evidence that the flight crew identified, analysed, evaluated or treated that risk.

As the aircraft approached Baucau for the overflight, the flight navigator provided the pilot in command with navigation data about the aircraft's distance from Baucau, and the lateral offset distance of the aircraft from the extended centreline. The recorded flight data revealed that the pilot in command overshot the extended centreline. The flight navigator then provided the pilot in command with heading information to position the aircraft overhead where the flight crew expected the runway to be (time 05:54:40). Had the aircraft been in VMC at the time, and with the aerodrome in sight, it is unlikely that the pilot in command would have overshot the extended centreline. Alternatively, the aircraft may have been in VMC, but the aerodrome was not visible to the flight crew because it was obscured by cloud.

The CVR data revealed that it was unlikely that the flight navigator saw the runway until the aircraft was almost overhead the runway during the overflight and on the first landing approach. Additionally, when the flight navigator asked if the pilot in command could see the runway as the aircraft was on the downwind leg during the first landing approach, the pilot in command replied 'No' (time 05:57:12).

Those factors, along with the visibility as reported by witnesses at the aerodrome at the time of the accident, suggested that the weather conditions were such that a circling approach to land in VMC following the overflight was not possible. Under those circumstances, a safe landing approach would only have been assured if the pilot in command had complied with the published procedures of either of the Baucau NDB non-precision instrument approaches.

The flight crew's disregard of the published procedures bypassed all the safety criteria and inbuilt risk treatments in the design of those procedures. That disregard directly contributed to the development of the occurrence.

That disregard also increased the risk exposure of a CFIT event to an extreme level, because the safe completion of the flight could no longer be assured. The CVR data provided no evidence to support any notion that the flight crew considered, or were concerned by, the increased risk.

2.3.8 The conduct of the improvised approaches at Baucau

The visibility as reported by witnesses at the aerodrome at the time of the accident, was less than the minimum prescribed in the IL-76 Flight Manual and the Jeppesen runway 14 NDB approach chart to conduct an NDB approach. It was also less than the minimum prescribed in the IL-76 TD Flight Manual to conduct a visual approach.

As discussed in subsection 2.2.2, it appeared likely that the Baucau NDB was working at the time of the occurrence. The relative bearing indicators on the CIs should therefore have provided the flight crew with confirmation that the aircraft passed by the NDB at about the same time as the flight navigator saw the runway below the aircraft (time 05:55:08). The Jeppesen charts depicted the position of the NDB as being about 1.7 km (0.92 NM) to the northwest of the threshold of runway 14. The incorrectly depicted position of the runway as shown on the Jeppesen charts may have led the flight crew to believe that they would fly past the NDB before reaching the runway.

None of the flight crew appeared to have been monitoring the CIs to confirm that the aircraft had passed the NDB before reaching where they expected the runway to be. Had they done so, it would have been obvious that the NDB and runway were co-located. The flight crew could therefore have used that information to resolve the ambiguity that arose about their perception of where the runway was located. That may then have allowed them to reassess their intended approach plan, and to conduct the landing approach with reference to the NDB, with the certain knowledge that it would provide them with accurate navigation reference to where the runway was actually located.

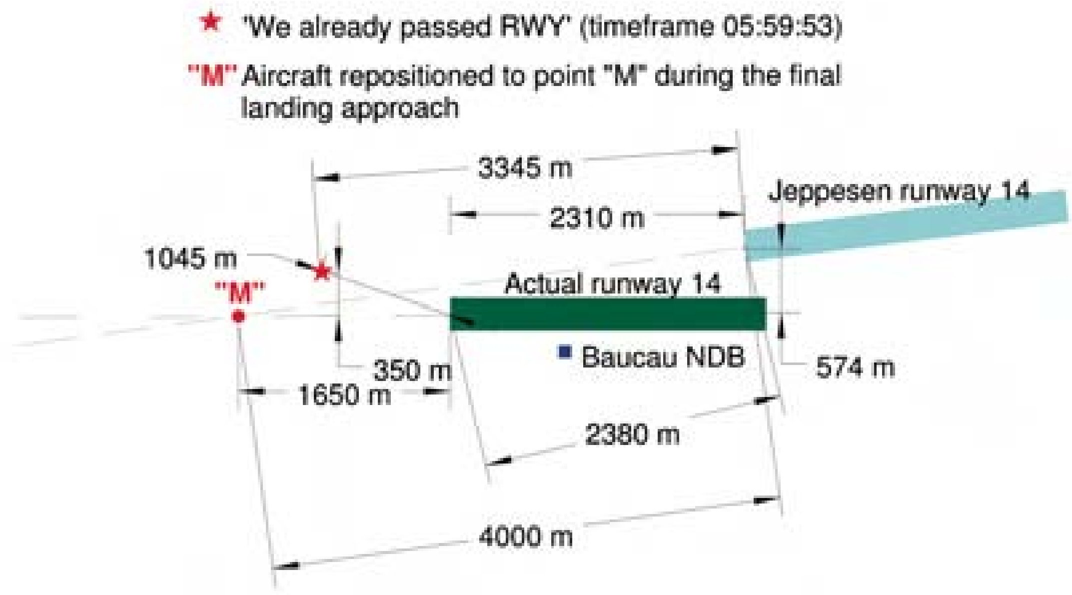
During the first landing approach, when the copilot stated 'Threshold' (time 06:59:50), the aircraft was about 1.28 km (0.69 NM) to the north of the actual threshold of runway 14. When the pilot in command stated 'Threshold', then 'We already passed runway' (time 05:59:53), the aircraft was about 1.04 km (0.56 NM) to the north of the actual threshold of runway 14, and about 350 m (0.2 NM) left of the extended centreline.

Again, as occurred during the first overflight, neither the pilot in command, the copilot nor the flight navigator appeared to have been monitoring the CIs to confirm that the aircraft had passed the NDB before reaching where they expected the runway to be. At the point when the pilot in command stated 'We already passed runway', the aircraft was still about 1.9 km (1.02NM) to the northwest of, and heading almost directly towards the NDB. Had the flight crew integrated the relative bearing information being provided by the CIs, it would have confirmed that the data they were relying on was wrong. It may also have confirmed to them that either of the published NDB non-precision approaches could be relied on to safely position the aircraft to the actual runway.

As a result of the pilot in command's statement that the aircraft had passed the runway, the flight navigator revised his estimate of the position of the runway threshold. The flight navigator then informed the pilot in command that he would apply a correction of '…minus 3 km [1.6 NM], approximately, even 4 [2.1 NM]…' (time 06:01:26).

The flight navigator appeared to have assumed that the aircraft was overhead the runway when the pilot in command stated 'We already passed runway'. The aircraft was not overhead the runway at that point, but was still 1.04 km (0.56 NM) to the north of the threshold. The distance between the actual position of the threshold of runway 14 and its position as depicted on the Jeppesen chart, was 2.38 km (1.24 NM). At 05:59:53, the onboard navigation equipment would therefore have showed that the aircraft was still about 3.34 km (1.80 NM) from the Jeppesen runway 14 threshold (see Figure 38).

FIGURE 38:
Navigation distances for the actual position of runway 14 vs. the Jeppesen runway position



The CVR data revealed that the flight navigator decided to apply a 4 km (2.16 NM) correction to the Jeppesen data for the second landing approach. That decision was based on his assumption that the aircraft was overhead the runway at 05:59:53. The flight navigator therefore appeared to have reached a preconceived conclusion on the basis of limited information, and to have assumed that conclusion was correct without giving consideration to, or ignoring, other relevant information. Had the flight navigator visually confirmed when the aircraft was abeam the threshold of runway 14, at about time 06:00:05, the onboard navigation equipment would have shown that the aircraft was about 2.38 km (1.30 NM) from the position depicted on Jeppesen charts of where the runway 14 threshold was located. A correction of 2.38 km to the Jeppesen data would therefore have provided accurate navigation data to reposition the aircraft to the actual threshold of runway 14.

By applying the 4 km correction, the flight navigator was providing the pilot in command with inaccurate data, and resulted in the aircraft being repositioned towards point "M", depicted at Figures 38, and A5 and A6. That point was about 1.65 km (0.88 NM) northwest of the actual position of the threshold of runway 14. That incorrect data substantially increased the hazards of the user-defined approach procedure, and the risk of a CFIT event at that stage of the flight increased to a high degree. The flight crew did not appear to identify the hazards associated with the intended improvised approach procedure, and were therefore not in a position to manage the associated risks.

As the aircraft turned on to the final approach heading, the flight navigator thought that the aircraft was high on the approach profile, based on his assumption of the location of the threshold of runway 14. When the flight navigator stated 'We are flying above again' (time 06:05:17) the aircraft was at an altitude of about 200 m (656 ft) above field elevation. At that point, the flight navigator assumed the aircraft was 2 km (1.08 NM) from his estimated position of the threshold, and based on that assumption, the aircraft should have been at a height of about 100 m (328 ft) above field elevation at that point. However, the aircraft was about 3.2 km (1.7 NM) from the actual threshold, and should therefore have been at a height of about 160 m (525 ft).

The pilot in command increased the rate of descent of the aircraft (time 06:05:19) to about 18 m/sec (3,543 fpm), and stated ‘Increased’. None of the other crewmembers commented on the high rate of descent, or drew the pilot in command’s attention to the fact that the approach was unstabilised at that point. The risk of a CFIT event is diminished by a stabilised approach, and the high descent rate in close proximity to terrain at that stage of the flight increased the risk of a CFIT event to the point where collision with terrain was almost certain. The CVR data provided no evidence that the flight crew was monitoring the elevating risk and evaluating whether to discontinue the approach to treat that risk.

The flight engineer misinterpreted the pilot in command’s statement ‘Increased’ to be an instruction for him to increase the engine thrust, and he advanced the thrust levers. It took about 2 seconds for the pilot in command to realise that engine thrust had been increased, and he reacted by calling ‘No, I increased vertical speed’ (time 06:05:23) and reduced the engine thrust. The flight engineer’s action in increasing engine thrust was a significant distraction to the pilot in command at that stage of the flight, and probably diverted his attention from the primary task of flying the aircraft to restoring the thrust to the proper setting.

At about the same time, the aircraft was descended through 162 m, which was the published MDH for a straight-in landing on the runway 14 NDB approach. Neither the pilot in command nor the copilot appeared to be concerned by that fact, and it is probable that both were distracted at that point by the flight engineer’s erroneous action. The risk of a CFIT event is diminished if an approach is flown no lower than the published MDA(H) of an instrument approach procedure until visual flight can be assured and maintained. At that stage of the flight, descent below the MDH in IMC at a high rate of descent meant that the risk of a CFIT event had increased to an unacceptably high level where it was no longer able to be treated, and impact with terrain was almost certain.

The flight navigator then advised the pilot in command that there was 2 km to run (time 06:05:27). At that point the aircraft was less than 1 km (0.54 NM) from point ‘M’, and about 2.5 km (1.35 NM) from the actual threshold of runway 14. Based on the flight navigator’s advice, the aircraft should therefore have been at a height of 100 m above field elevation, however at that point it was at a height of 200 m.

The high rate of descent continued unchecked until slightly less than 2 seconds before impact. It is probable that the pilot in command and the copilot were both unaware of the high rate of descent, because neither was monitoring the flight instruments while they were looking ahead of the aircraft and trying to establish visual contact with the ground.

The pilot in command applied back elevator to increase the aircraft pitch attitude in response to the copilot’s urgent expression of concern that impact with terrain seemed almost certain (CVR time 06:05:31.8, ‘Ach, increase altitude!’). However, the pilot in command did not simultaneously increase the engine thrust, and it remained unchanged. Consequently, the pilot in command’s attempt to avoid impact with terrain was unsuccessful because of the inertia of the aircraft and its close proximity to terrain.

The investigation estimated that the height of the first group of trees impacted by the aircraft was about 17 m (55.8 ft) high before the impact. The flight crew established the QFE for Baucau on their apparent assumption that the QNH was 760 mm Hg (1,013.2 hPa). However, BoM estimated that the QNH at Baucau at the time of the accident was about 1011 hPa (758.3 mm Hg). The 1.7 mm Hg (2.2 hPa) difference between the flight crew’s estimate and that provided by BoM equalled a difference of about 20 m (66 ft). Had the flight crew sought and obtained an accurate QNH for Baucau, it would have provided an additional margin of 20 m (66 ft). That margin may therefore have been sufficient to avoid impact with those trees.

The terrain between the impacted trees and the aerodrome contained no other significant groups of trees of similar height to those impacted (see Figures 19 and 20). The investigation concluded that had the correct QNH had been used to establish QFE, impact with the trees may have been avoided. The investigation also concluded, however, that the likelihood of impact with terrain at a point closer to the runway would probably have remained almost certain. Under those circumstances, even though the aircraft would probably have sustained severe damage by impact forces, the consequences of the CFIT event may not have been as catastrophic.

2.3.9 Flight crew compliance with standard procedures

The operator's standard operating procedures provided a framework by which the flight crew was intended to operate the aircraft. The procedures provided guidance to ensure that the flight crew conducted operations in a predictable, uniform and safe manner, and they were therefore an important factor in assuring flight safety. There was, however, significant flight crew non-compliance with those procedures during the descent into Baucau. Moreover, the flight crew's non-compliance with the published non-precision instrument approach and/or missed approach procedures at Baucau during flight in instrument meteorological conditions was a significant factor in the events leading up to the occurrence.

The flight crew was provided to the operator as part of the lease agreement between the operator and the aircraft owners. It is likely therefore that they were familiar with one other, and were used to working together as a crew in unsupervised non-scheduled operations in diverse areas and to many different destinations.

When the aircraft arrived at Baucau, it was carrying enough fuel to continue on to Makassar in the event that a landing was not possible at either Baucau or the planned alternate Kupang. A diversion to Kupang, however, would have resulted in a considerable delay to the intended arrival at Rayong, Thailand. Had the flight crew diverted to Kupang instead of persisting with the landing approaches in marginal weather conditions at Baucau, the aircraft would not have arrived back at Baucau until the early evening, allowing for the additional flight time between Baucau-Kupang-Baucau and the turnaround at Kupang to refuel the aircraft. The aircraft was about 9 hours behind schedule when it arrived at Baucau, and if the flight crew diverted to Kupang then returned to Baucau, the aircraft would likely have been more than 12 hours behind schedule by the time it arrived at Rayong, Thailand. Under those circumstances, the flight crew may have felt under pressure to place schedule before safety to expedite the flight to Baucau.

The ICAO follow-up audit of the Lao DCA in March 2002 found that the Lao DCA lacked a viable system for compliance and enforcement. It therefore appeared to have adopted a passive role towards inspection and surveillance, and was probably not in a position to assess the adherence of the operator to regulatory requirements. It is possible therefore that under those circumstances the operator's compliance with those requirements may have been less than adequate. It is also possible that if a culture of schedule before safety existed within the operation, then non-compliance with standard procedures was probably tolerated to expedite flights. That notion was supported by the flight crew's attempts to land the aircraft in marginal weather conditions when conducting a user-defined approach at Baucau.

Although not a factor in the occurrence, none of the flight crew was dressed in uniform for the conduct of the flight, even though they were required to be. The pilot in command was responsible for ensuring that the flight crew complied with that requirement. The non-compliance with that basic requirement by the flight crew, and the pilot in command's obvious disregard of his responsibility to ensure its compliance, supported the notion that there was a tolerance to non-compliance within the operation.

There was no evidence of any inflight emergency that would have warranted the flight crew of the occurrence aircraft to disregard, or deviate from, published inflight procedures. There seemed to be an almost casual attitude amongst the flight crew in the manner in which the operation was being conducted, and in their willingness to deviate from standard procedures. The investigation was unable to determine however, whether that attitude was because:

- the flight crew were familiar with each other and had become accustomed to operating in an unsupervised environment
- there was possibly a tolerance to non-compliance within the operation
- there were other factors that were not evident to the investigation.

The investigation was also unable to determine whether that attitude reflected the nature of the operation, and may thus have indicated a wider systemic issue, or whether it was confined to the occurrence flight crew alone.

During the period that the copilot tried to contact Baucau Tower, none of the other crewmembers monitored the Timor Common High frequency of 123.45 MHz while the aircraft was above 10,000 ft (3,048 m). They also did not monitor the Timor Common Low frequency of 127.1 MHz while the aircraft was below 10,000 ft, or broadcast their intentions and traffic information on that frequency. Therefore, the flight crew had no assurance that there was no conflicting traffic. The flight crew's disregard of the requirement for traffic information broadcasts within Timor-Leste airspace increased the potential risk of an inflight collision.

The recommended procedures for a stable non-precision approach were exceeded at various times during the approach. An earlier recognition and response to the unstable approach and reduced height above ground level by the other crewmembers may have provided the pilot in command with an awareness that the aircraft was becoming dangerously close to the ground. That recognition and response may then have provided the pilot in command with the necessary stimulus to discontinue the approach.

The pilot in command conducted the approach briefing 13 minutes before the descent point. The briefing took 35 seconds to conduct, and concluded with the pilot in command asking the other crewmembers if they had any questions about the intended approach. None of them raised any questions.

The briefing given for the intended approach at Baucau did not refer to the source of data that was being used for the briefing, nor did it contain any information or discussion on:

- the relevant published minimum descent altitude/height (MDA(H)) for the approach
- NOTAMs relating to Baucau
- the anticipated weather at Baucau or potential problems as a result of the weather
- MSA for the last route sector into Baucau
- guidelines for specific flight crew actions, duties or responsibilities.

The FSF ALAR Task Force found that the conduct of an inadequate approach briefing was a factor in those accidents and incidents studied by the Task Force. Of the 76 accidents and incidents studied, 72 per cent involved omission of action/inappropriate action. The Task Force determined that an approach briefing should include the following eight items:

- MSA
- Terrain and man-made obstacles
- Weather conditions and runway conditions
- Other approach hazards, as applicable
- Minimums (ceiling and visibility or runway visual range)
- Stabilisation height
- Final approach descent gradient (and vertical speed)
- Go-around altitude and missed-approach initial steps.

Of the eight items recommended by the FSF ALAR Task Force, only the missed approach procedure was briefed by the pilot in command of the IL-76TD. The omission of reference to the intended MDA(H) for the landing approach was contrary to the operator's standard procedures. The investigation concluded that because the briefing did not cover all relevant safety considerations to ensure that the approach was error resistant, it was therefore not operationally thorough. Thus, it resulted in the flight crew having a less than adequate awareness of all relevant factors associated with the intended arrival and landing phases at Baucau, and contributed to the steadily increasing risk of a CFIT event to the point where it had become almost certain.

Despite having briefed the missed approach procedure, it was not conducted by the pilot in command during either of the go-arounds. None of the other crewembers expressed concern when the pilot in command did not follow the go-around procedure as briefed.

2.3.10 Flight crew coordination

Only the pilot in command and the flight navigator seemed involved in the exchanges of information and decisions that were taken during the approach sequences. They did not consult the copilot or the flight engineer about the intended approach, nor did they include the the copilot or flight engineer in the decision-making process. The pilot in command and the flight navigator did not therefore effectively use the copilot or the flight engineer as valuable operational resources available to them to assist in their decision making. Consequently, all crewmembers were not working together as an integrated team to ensure the safe operation of the aircraft, and the flight crew coordination was less than effective.

In addition, neither the copilot nor flight engineer raised any issues with, or questioned, the captain's and flight navigator's decisions, or the pilot in command's disregard of standard procedures. The flight crew operating environment therefore appeared to be one that did not encourage effective communication. In particular, it did not appear to encourage inquiry, advocacy or assertiveness by each of the flight crew working together as an integrated team. The lack of assertiveness by the copilot and flight engineer, who were both acting in the capacity as support crewmembers, contributed to the breakdown in flight crew coordination that ultimately compromised the safety of the flight.

As stated in subsection 2.3.2, the flight crew did not lack experience on the aircraft type, and experience was not considered a factor in the events leading up to the accident. However, the less than effective flight crew coordination resulted in the flight crew being effectively split into two disparate groups. The group comprising the pilot in command and flight navigator controlled the decision-making processes and the conduct of the flight. The group comprising the copilot and flight engineer performed routine procedural functions only, and made no significant contribution to the conduct of the flight. That resulted in the dysfunctional performance of an otherwise experienced flight crew.

The pilot in command was responsible for the safety of the flight crew, cargo and aircraft, and had full control of, and authority for, the operation of the aircraft. The supporting crewmembers had a duty and responsibility to ensure that the flight was operated safely, yet they appeared to either passively condone, or did not question, the unsafe operation of the aircraft during the latter stages of the flight.

The copilot and flight engineer therefore did not effectively discharge their responsibilities in the operation of this aircraft, which required more than one crewmember on the flight deck for its safe operation. Even though the pilot in command was the handling pilot for the sector, the copilot and flight engineer each had a responsibility to alert the pilot in command about deviations from standard operating procedures, which resulted in the aircraft being operated in an unsafe manner. The CVR data revealed, however, that they only performed routine procedural functions, and made no significant pro-active contribution to ensure that the aircraft was operated safely during the final stages of the flight.

The flight crew did not exercise an effective team-based problem solving technique when they realised that there was a problem with the data being relied upon to position the aircraft to where they though the runway was located. The flight navigator attempted to resolve the problem without seeking assistance from any of the other crewmembers, and developed a solution to the problem by applying a correction of '…minus 3 km, approximately, even 4…' (time 06:01:26). The other crewmembers appeared content to rely on the confidence of the flight navigator to resolve the problem. The flight navigator did not seek any opinion or contribution from the other crewmembers regarding a solution to the problem, nor was any offered. An effective problem-solving technique would have involved seeking opinions from each crewmember. Under those circumstances, different suggestions may have been made based on all the facts available to the flight crew, and an alternative plan of action been developed to assure a safe landing approach.

None of the flight crew displayed any perception, understanding or ability to predict the probable outcomes of the navigation data that was being used for the landing approaches, or of the descent below the published MDA(H) in IMC. That lack of situational awareness by the flight crew as a whole seemed to be the result of poor planning on their part.

During the second landing approach, the pilot in command lacked terrain awareness, which was critical in circumstances involving a high rate of descent as the aircraft came into close proximity with terrain. That was probably because of his attention being channelled on trying to establish an optimum descent profile in relation to the navigation data being provided by the flight navigator. It was probably also due to the distraction that would have resulted from the flight engineer inappropriately increasing the engine thrust, and from the pilot in command probably experiencing overload and task saturation at that point.

The copilot had a responsibility to monitor the other crewmembers' actions and to provide input where appropriate, in particular, in situations where the safety of flight was being compromised. The CVR data revealed that apart from his attempts to contact Baucau tower during the descent into Baucau, the copilot provided no input into the decision to conduct the improvised approaches. Under the circumstances where the demands of the approach led to the pilot in command focussing his attention on the approach profile, the copilot had the responsibility to warn the pilot in command when the approach became unstable, and the aircraft was descended below the MDA(H). During the latter stages of the second landing approach, the pilot in command did not appear to be cognisant of the unstabilised approach. That was probably due to a combination of his having been distracted by the flight engineer's inappropriate actions, and because of the less than effective flight crew coordination that resulted, in part, from the copilot's lack of assertiveness. The reasons for the copilot's lack of input or apparent unwillingness to communicate could not be determined.

The copilot expressed no concerns, and provided no warning to the pilot in command, until he identified that the risk of collision with the ground was almost certain. However, there was insufficient time to treat that risk, due to the high rate of descent of the aircraft and its close proximity to terrain at that point. Until then the copilot made no comment about the conduct of the approach. Irrespective of what the copilot may have thought about the way in which the approach was being conducted, it suggested that he had acceded to the pilot in command's decisions and actions, even though they had involved broad non-compliance with standard operating procedures.

The CVR data revealed that apart from reporting on aircraft configuration changes, the flight engineer also provided no input into the decision to conduct the improvised approaches. The flight engineer inappropriately increased the engine thrust when the pilot in command increased the rate of descent of the aircraft (time 06:05:19) and stated 'Increased'. That inappropriate action may have resulted from his concern about the aircraft's flight path and its proximity to terrain, and he may have assumed that the pilot in command was signifying that he was discontinuing the approach. The flight engineer, however, made no effort to clarify what the pilot in command's intentions were. The reasons for the flight engineer's lack of input, or apparent unwillingness to communicate, also could not be determined.

2.4 Post-impact break-up sequence

The post-impact break-up sequence is described in detail at Appendix D.

2.5 Organisational factors

2.5.1 Operator of the aircraft

On 30 December 2002, the Lao DCA issued a letter stating that the Cambodian-based operator was an operator of the aircraft owned by the UAE-based owners.

The investigation was unable to determine how the Lao DCA arrived at that conclusion. Neither the Lao-based company, nor the Cambodian-based company, had sought consent from the UAE-based owners for the proposed sublease, and therefore the sublease had not been finalised. The Lao-based company remained responsible for supervision over flight, technical and commercial operation of the aircraft, irrespective of the status of the sub-lease. There was no apparent basis therefore, upon which the Cambodian-based operator could be regarded as an operator of the Lao PDR-registered aircraft without holding an AOC issued by the Lao DCA authorising it to do so.

The investigation therefore concluded that the Lao-based company was the operator of the aircraft, and that the Cambodian-based company had acted as an intermediary for the occurrence flight. Therefore, the Lao PDR was the State of the Operator.

2.5.2 Certification of the operator

On 9 November 2002, the Lao DCA issued AOC-002/02 to the Lao-based operator. The operator had submitted an operations manual to the Lao DCA, presumably as part of the certification process for the issue of the AOC. The manual included details of specific factors for the operator's flight deck procedures for descent, approach and landing. The investigation was unable to determine what procedures had been followed by the Lao DCA to assess that those procedures were adequate to ensure the operator's compliance with the standards of Annex 6. The investigation was also unable to determine whether staff of the Lao DCA Flight Operations and Inspection Section were qualified to make that assessment.

2.5.3 Supervision of the operator

The aircraft was operated on non-scheduled freight operations. A short period of time had elapsed between the time the aircraft was entered onto the Lao PDR register and when it departed on the series of flights on behalf of the Cambodian-based operator. Those factors suggested that the Lao DCA had limited scope or opportunity to establish a system for the continued surveillance of the Lao-based operator to ensure the required standards of operation were maintained.

2.5.4 Flight crew licences

In December 2002, the Lao DCA issued commercial pilot licences - aeroplane to the pilot in command and the copilot. Those licences included information that they had been issued in accordance with the SARPS of Annex 1 to the *Chicago Convention*.

The pilot in command was required to hold an airline transport pilot licence (aeroplanes) issued by the Lao PDR entitling him to act in that capacity in a Lao-registered aircraft engaged in air transportation operations. In accordance with the SARPS of Annex 1, the pilot in command did not therefore hold the proper class of flight crew licence to conduct the flight. Also, in accordance with the SARPS of Annex 1, neither pilot was properly authorised to pilot a Lao-registered aircraft under IFR.

The investigation concluded that the Lao PDR flight crew licences held by the flight crew were not relevant to the factors leading up to the occurrence, but were the result of an oversight by the Lao DCA in the manner in which those licences had been issued.

2.6 CFIT Risk

The Transport Canada simple method of conducting a risk analysis is decribed in Appendix E. It involves the evaluation of the:

- severity (S) of a occurrence which may arise from a hazardous activity
- probability (P) of the occurrence of the event
- exposure (E) to the hazard.

Numerical values are assigned to the S, P and E factors, and a Risk Index is then calculated from the product of those factors.

CFIT resulted in 35 hull losses and 2,111 fatalities in the period 1990 to 1999.[49] CFIT events therefore result in fatal or life threatening injury to human life and damage to property and/or the environment. Based on those outcomes, and using the Transport Canada simple method of risk analysis, the severity (S) of a CFIT occurrence is a Level 4 Risk.

CFIT events also occur frequently, in the order of one or more per year. It has been predicted that with increasing numbers of commercial aeroplane departures, if the current rate of CFIT occurrences continue, then it could result in one major airline hull loss (and associated fatalities) each week by the year 2010. Based on those outcomes, and also using the Transport Canada simple method of risk analysis, the probability (P) of a CFIT occurrence is also a Level 4 Risk.

Using the Transport Canada simple method of risk analysis, and disregarding any assessed value for exposure (E), the Risk Index value becomes:

Risk Index	=	(4 S) x (4 P)
	=	16

That value excludes any assessment of exposure because of its dependence on a variety of factors, such as destination risk factors, type of operation, area of operation, weather/night conditions, an operator's corporate culture and flight standards, hazard awareness and training, and aircraft equipment.

A Risk Index of between 11 and 30 calculated using the Transport Canada simple method of risk analysis represents a Level Two Moderate Risk situation. Based on the historical data relating severity of CFIT events and the probability of their occurrence, all flights would therefore appear to be at moderate risk of a CFIT event. That suggests that it is perhaps inadvisable to commence or continue flights until all necessary action is taken to manage that risk.

Specific interventions to manage risk may take the form of those recommended by the FSF, including:

- the use of standard operating procedures, standard call-outs and checklists
- the content and conduct of descent approach briefings
- crew resource management
- strategies and procedures for handling interruptions/distractions
- procedures for barometric and radio altimeters
- descent and approach profile management
- terrain awareness
- the use of stabilised approaches
- the use of constant angle non-precision approaches.

In the events leading up to this occurrence, the flight crew did not adhere to many of the procedures outlined in the operator's operations manual. They also did not follow the published instrument approach procedures at Baucau, and the approaches were not stabilised. The non-adherence to procedures by the flight crew increased the risk of a CFIT event until it could no longer be avoided.

49 See subsection 1.18.3

The flight crew did not appear to appreciate the steadily increasing risk that was associated with their decision to conduct the improvised landing approaches at Baucau. Consequently, their ability to recognise and react to that risk was compromised, and the safety of flight was no longer assured.

The investigation evaluated the specific risk factors associated with the flight and the operator, using the FSF CFIT risk-assessment safety tool.[50] The Destination CFIT Risk Factors Total for the occurrence flight was -160, and the Risk Multiplier Total for the flight was 14.2. Therefore, the Risk Factors Total Score was -2,272. The aircraft equipment total was assessed as +55 and the operator's CFIT Risk Score was therefore:

	CFIT Risk Factors Total	(-)	2,272
add	CFIT Risk-reduction Factors	(+)	55
=	Risk Score	(-)	2,217

The CFIT Checklist included information that a negative CFIT Risk Score indicates a significant threat, and a risk score of -2,217 represented a high CFIT risk.

During the course of the investigation, the Lao DCA was requested to provide detailed information about the operator to allow an objective assessment to be made about the adequacy of the operator's corporate culture, flight standards, and hazard awareness and training, but did not do so. In the absence of that information, and based on the FSF CFIT risk-assessment safety tool, the maximum possible scores for the corporate culture, flight standards, and hazard awareness and training risk reduction factors were used to determine the following:

corporate culture	+155 points
flight standards	+335 points
hazard awareness and training	+315 points

The maximum available score for those combined factors was +805 points, and when added to the aircraft equipment total of +55 points, the maximum available score for the operator's Risk-reduction factors was +860 points.

The operator's CFIT Risk Score with optimum corporate culture, flight standards, hazard awareness training and actual aircraft equipment was therefore:

	CFIT Risk Factors Total	(-)	2,272
add	CFIT Risk-reduction Factors	(+)	860
=	Risk Score	(-)	1,412

Without any information to objectively assess the operator's corporate culture, flight standards, and hazard awareness and training risk reduction factors, even allowing for a maximum available score for those factors, the risk score of -1,412 meant that the flight would still have been exposed to significant threat of a CFIT event.

The FSF CFIT risk-assessment safety tool highlights that even if corporate culture, flight standards, and hazard awareness and training risk reduction factors are of high standard, attention must also be given to ensuring that aircraft equipment is also of a high technological standard to assist in the prevention of CFIT. The maximum possible score for aircraft equipment was +180. Had the operator's risk reduction factors all been at their respective

50 Refer to Appendix F.

optimum values (805 + 180 = 985), then the operator's maximum available CFIT Risk Score would have been:

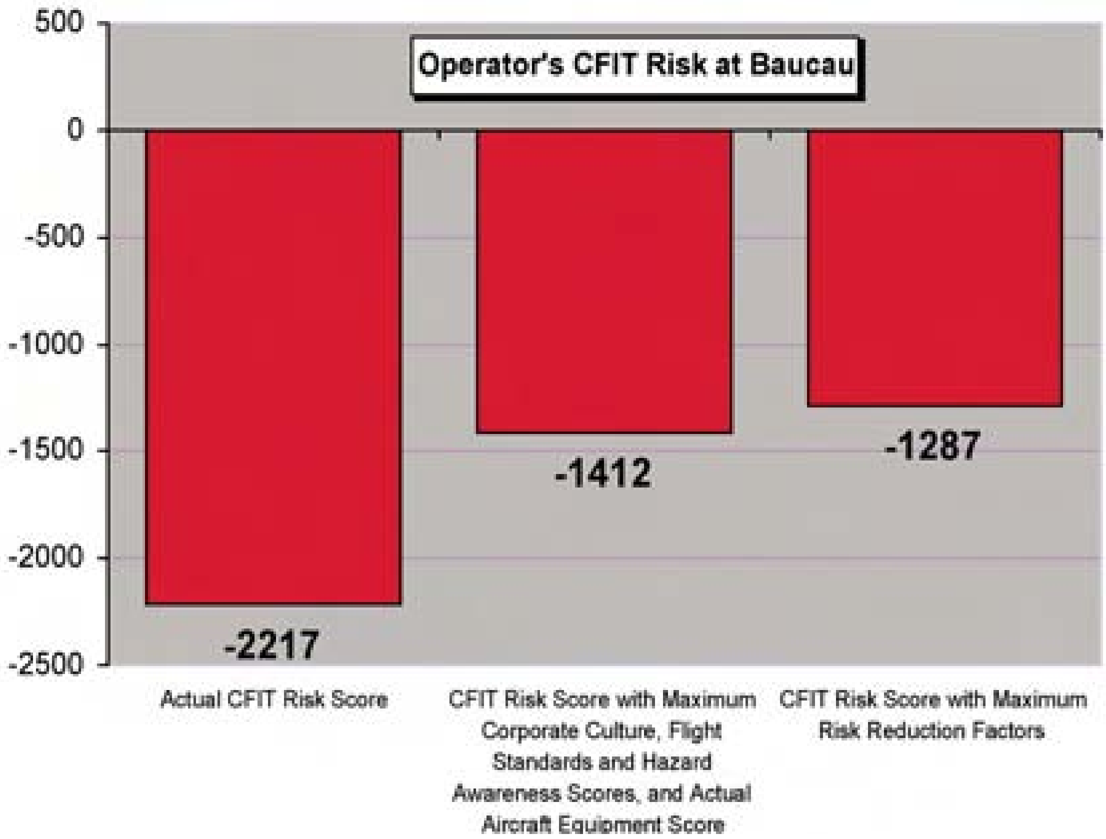
	CFIT Risk Factors Total	(-)	2,272
add	Maximum CFIT Risk-reduction Factors	(+)	985
=	Risk Score	(-)	1,287

With a risk score of -1,287, it can be seen that the flight would still have been exposed to significant threat of a CFIT event. That was due to the high destination CFIT risk factors and the risk multiplier that applied to the particular operation.

The alternative CFIT risk scores discussed above are depicted at Figure 39.

The FSF intended the CFIT checklist to be used to evaluate specific flight operations and to enhance pilot awareness of the CFIT risk. Pilot awareness of CFIT risk is only possible if the results of destination CFIT risk assessments are made known to them, or alternatively, if they are actively involved in those assessments. The FSF CFIT risk-assessment safety tool is an important tool to identify risks associated with an intended flight. It is nevertheless an 'in arrears' risk management tool once a flight has commenced to a destination identified with CFIT risk factors. The variable nature of flight means that the emergence of unforseen threats may result a changes to the context of flight, as is evident in the circumstances leading up to this occurrence. Flight crews must therefore have the knowledge, skills and experience to manage risks in the dynamic inflight operational environment that result from those changes of context.

FIGURE 39:
CFIT Risk at Baucau



Choice (or lack of choice) of a particular destination may mean that risk factors associated with that destination cannot be influenced or reduced by an operator or a flight crew. Similarly, the nature of a particular operation may be such that the risk multiplier for a flight is also unable to be reduced. In those circumstances, an operator must ensure that adequate defences are in place to minimise all the risk elements of a potential CFIT occurrence that it has the ability to influence or control. Those defences include high CFIT risk-awareness, risk management through adequate standard operating procedures and flight crew communication and decision-making processes, and the availability and optimum use of current technology/equipment.

CFIT events involving transport-category aircraft will almost certainly result in major to catastrophic consequences involving fatal or life threatening injury, and damage to property and/or the environment, as this occurrence demonstrates. During the second landing approach at Baucau, the likelihood of CFIT increased to the point where it became unavoidable. The flight crew seemed unaware of the severity of the risk until they recognised that impact with terrain was imminent. At that stage, however, the risk could no longer be treated.

This occurrence highlights that all flights appear to be at moderate risk of a CFIT event. It also highlights that the risk may steadily elevate to the point where that event becomes almost certain if there is an absence or failure of the defences necessary to effectively manage that risk.

3 CONCLUSIONS

3.1 Findings

Aircraft

1. The aircraft's certificates of airworthiness and registration, issued by the on Lao DCA 13 December 2002, were current at the time of the occurrence.
2. The aircraft was operating on an international non-scheduled cargo flight at the time of the occurrence; as such, it was engaged in commercial air transport operations.
3. The aircraft departed Macau with sufficient fuel onboard for the planned flight to Baucau.
4. The aircraft probably departed Macau at a weight greater than its certificated maximum takeoff weight.
5. The aircraft was equipped for instrument flight.
6. There was no evidence of airframe failure or system malfunction before the accident.
7. The aircraft was complete and intact before impact, and did not break-up in flight.
8. There was no evidence of inflight fire.
9. There was no evidence that the cargo had shifted during the flight and led to controllability problems of the aircraft.
10. There were 11 satellites in view at Baucau at the time of the occurrence, which was a sufficient number to provide GPS RAIM integrity monitoring.
11. The calculated horizontal dilution of precision at Baucau at the time of the occurrence was less than 1, and would have resulted in little effect on the integrity of lateral navigation data that was being provided by the aircraft GPS.
12. The FDR did not record information from the radio altimeter system due to an apparent failure of the altitude recording channel.
13. The CVR did not record the 'BELOW PRESELECTED ALTITUDE' aural voice warning when the aircraft descended through 60 m absolute altitude during the second landing approach.
14. The reference bug on the pilot in command's radio altimeter was not set to 60 m for the landing approaches, as required by the IL-76TD Flight Manual.
15. The CVR did not record an audible warning signal when the GPWS linear trigger threshold limits for excessive rate of descent were exceeded, even though it was designed to do so.
16. The FDR did not record a 'dangerous speed of ground approach' when the GPWS linear trigger threshold limits for excessive rate of descent were exceeded, even though it was designed to do so.
17. The CVR was not equipped with a cockpit area microphone, and was therefore unable to record the flight deck aural environment as required in accordance with the standard described in 2.1.1.b) of Attachment B to Annex 6 Part I to the *Chicago Convention*.

18. The position of the relative bearing pointers on both of the recovered course indicators in relation to the aircraft nose was consistent with them pointing to the Baucau NDB. That suggested the NDB had been working at the time of the occurrence, and was available to the flight crew to conduct either of the published NDB non-precision approaches at Baucau.

19. The aircraft was in controlled flight when it impacted terrain.

20. All damage to the aircraft was attributable to the severe impact forces and the fuel-fed post impact fires.

Flight crew

1. At the time of the occurrence, the pilot in command and copilot each held commercial pilot licences - aeroplane that had been issued by the Lao DCA in December 2002.

2. The pilot in command did not hold the appropriate type of flight crew licence to entitle him to act as pilot in command for the flight.

3. The copilot, flight engineer and the flight navigator held appropriate flight crew licences.

4. The pilot in command and the copilot did not hold instrument ratings that entitled them to pilot the occurrence aircraft under instrument flight rules.

5. The pilot in command was the handling pilot during the overflight and two landing approaches at Baucau.

6. The landing approaches were conducted in instrument meteorological conditions.

7. Lack of experience on the aircraft type was not considered a factor in the events leading up to the accident.

8. There was no evidence that any physiological factors or incapacitation affected the performance of the flight crew.

9. Flight crew coordination was less than effective, and compromised the safety of the flight.

10. The flight crew could not analyse the meteorological conditions at Baucau during the pre-flight preparations at Macau in accordance with the published procedures that were contained in the operator's operations manual, because TAFs or METARs were not produced for Baucau.

11. The flight crew did not comply with the requirements of NOTAM GO113/02 and broadcast their intentions and traffic information on either of the frequencies specified in the NOTAM by the Timor Leste DCA.

12. There were a number of significant omissions in the descent approach briefing conducted by the pilot in command, and the briefing was not operationally thorough because:
    - it did not refer to the relevant published MDA(H) for the intended approach; that omission was contrary to both the published normal operating procedures and inflight CFIT avoidance procedures contained in the operator's operations manual.
    - it did not refer to relevant call-outs to verify heights; that omission was contrary to the inflight CFIT avoidance procedures relating to non-precision approaches contained in the operator's operations manual.

13. None of the flight crew commented on any of the information omitted from the descent approach briefing, and which was required to be mentioned in accordance with the published procedures contained in the operator's operations manual.

14. There was no evidence to confirm that the flight crew positively identified the morse-code identifier of the Baucau NDB or tested the radio compass to establish that it was functioning correctly.

15. The flight crew did not attempt to obtain updated weather information or the current QNH from the Baucau controller after being informed by the controller that ATS was not available.

16. The pilot in command diverted the aircraft from the published Ambon - Baucau track before reaching the Baucau NDB.

17. The pilot in command did not comply with the published MSA after diverting the aircraft from the Ambon - Baucau track.

18. None of the other crewmembers commented on the fact that the pilot in command had diverted the aircraft from the published Ambon - Baucau track, and had descended the aircraft below the published MSA, or identified that those factors increased the risk of a CFIT event.

19. The flight crew conducted the overflight and two landing approaches at Baucau in poor visibility conditions.

20. The flight crew conducted the two landing approaches in weather conditions that were below the relevant minima specified in the IL-76 TD Flight Manual for NDB and visual approaches.

21. The flight crew did not use the CAD-issued instrument approach and landing charts for the landing approaches at Baucau and instead relied on selected, but incorrect navigation data from the Jeppesen charts for the user-defined landing approaches at Baucau.

22. The flight crew did not comply with the published (Jeppesen chart) non-precision instrument approach procedures at Baucau with respect to the published MDA(H).

23. The pilot in command permitted the aircraft to descend below the MDA(H) published on both the Jeppesen and CAD runway 14 instrument approach charts during flight in instrument meteorological conditions.

24. The intended overflight track breached the obstacle clearances of the published procedure, bypassed the safety criteria and risk treatments considered in the design of the published procedure, and increased the risk of a CFIT event.

25. The flight crew formulated a user-defined GPS non-precision instrument approach procedure for the approaches at Baucau, based on their incorrect assumption on where the threshold of runway 14 was located from the data published on the Jeppesen charts.

26. The user-defined procedure formulated by the flight crew for the approaches to Baucau deviated from normal practice, bypassed all the safety criteria and risk treatments inbuilt into the design of the published non-precision instrument approach procedures, and increased the risk of a CFIT event.

27. The flight crew did not continually analyse the height of the aircraft's flight trajectory in relation to the ground during either of the attempted landing approaches; that was contrary to the operator's published inflight CFIT avoidance procedures.

28. The approaches into Baucau were not conducted at a constant rate of descent; as such the approaches were not stabilised and increased the risk of a CFIT event.

29. During the second landing approach, the descent was unstabilised and conducted at a high rate of descent in close proximity to terrain, therefore increasing the risk of a CFIT event.

30. The flight crew, as a team, appeared to lack both situational and terrain awareness during the approaches at Baucau.

31. The flight crew lacked terrain awareness during the second landing approach.

32. The pilot in command descended the aircraft below the published MDA(H) in IMC; as such, the minimum safe height of a straight-in landing approach was not observed and increased the risk of a CFIT event.

33. The flight crew's non-adherence to the published procedures and their decision-making processes steadily increased the risk of a CFIT event to an extreme level which compromised approach-and-landing safety.

34. None of the flight crew recognised the need for a missed approach or to execute a missed approach until the point where collision with terrain was almost certain.

35. At the point where the flight crew recognised that the CFIT risk exposure was extreme, the aircraft's inertia and close proximity with terrain meant that treatment of the risk was no longer possible, and the pilot in command's attempts to avoid impact with the ground were unsuccessful.

36. The aircraft was under the control of the flight crew when it impacted terrain.

37. Due to the high impact forces, the accident was not survivable.

Instrument approach procedures

1. Instrument approach and landing procedures were available for runways 14 and 32 at Baucau, using the Baucau NDB.

2. The charts issued by CAD were the approved charts for the non-precision NDB instrument approach procedures at Baucau.

3. The Jeppesen charts incorrectly depicted where the runway was located at Baucau.

4. The Jeppesen runway 14 NDB non-precision approach chart correctly depicted the approved non-precision instrument approach procedure.

5. There was a discrepancy between the published runway 14 threshold elevation and its actual elevation, however the discrepancy was irrelevant.

6. The Baucau NDB monitor indicated that the NDB was not functioning after the occurrence; there was evidence that the NDB was functioning at the time of the occurrence.

7. There were no published GPS Arrival procedures at Baucau at the time of the occurrence.

8. There were no published GPS NPA procedures at Baucau at the time of the occurrence.

Air traffic services

1. ATS was not available at Baucau at the time of the occurrence.
2. There was no procedure in place to provide flight crews of aircraft engaged in non-UN operations with an altimeter subscale setting for Baucau at the time of the occurrence.

Organisational factors

1. Neither the Lao-based company, nor the Cambodian-based company, sought the consent for the proposed sublease, dated 18 November 2002, and accordingly the inferred sublease had not been finalised.
2. The Cambodian-based company was not the operator of the aircraft for the occurrence flight.
3. The Lao PDR was the State of Registry and State of the Operator.
4. The Lao DCA was responsible for the continued surveillance of the operator to ensure that the required standards of operation were maintained.
5. The operator provided flight crews with inflight CFIT avoidance procedures in its operations manual.

CFIT risk exposure

1. The planned flight from Macau to Baucau was exposed to moderate risk of a CFIT event, based on historical CFIT data and the Transport Canada simple method of risk analysis.
2. The destination risk factors, type of operation, area of operation, weather conditions, and flight crew non-compliance with published procedures increased the CFIT risk exposure of the planned flight to an above-average level.
3. The consequences of the accident were catastrophic and resulted in loss of human life and damage to property and the environment.
4. Those catastrophic consequences resulted from the flight crew's disregard of established procedures; that disregard bypassed all the safety criteria and inbuilt risk treatments in the design of those procedures and steadily increased the CFIT risk exposure to an extreme level during the latter stages of the flight.

3.2 Significant factors

1. The flight crew did not comply the published non-precision instrument approach and/or missed approach procedures at Baucau during flight in instrument meteorological conditions.
2. The flight crew conducted user-defined non-precision instrument approaches to runway 14 at Baucau during flight in instrument meteorological conditions.
3. The pilot in command permitted the aircraft to descend below the MDA(H) published on both the Jeppesen and CAD runway 14 instrument approach charts during flight in instrument meteorological conditions.
4. The flight crew did not recognise the increased likelihood and therefore risk of CFIT.
5. The flight crew did not recognise or treat that risk in a timely manner.

4 SAFETY ACTION

4.1 Recommendations

Timor Leste

As a result of the accident, on 9 February 2003 the Australian (ATSB) Accredited Representative and his advisers made the following recommendations to the Government of Timor Leste in the interest of flight safety.

Recommendation 1

The Australian Accredited Representative and advisers recommend that the Government of Timor Leste liaise with United Nations Air Operations to develop and promulgate approved instrument approach and aerodrome charts for Baucau, Timor Leste, as a matter of urgency, to enhance flight safety of aircraft operations into Baucau.

Recommendation 2

The Australian Accredited Representative and advisers recommend that the Government of Timor Leste liaise with Jeppesen Sanderson to ensure that Jeppesen Sanderson is provided with current, approved data for appropriate instrument approach and aerodrome charts for Baucau, Timor Leste, and that charts approved by the Government of Timor Leste are promulgated by Jeppesen Sanderson, to enhance flight safety of aircraft operations into Baucau.

Recommendation 3

The Australian Accredited Representative and advisers recommend that the Government of Timor Leste review the appropriateness of the current provision of Air Traffic Services and facilities to non-United Nations aircraft operations into Baucau, Timor Leste in the interest of enhancing flight safety of aircraft operations into Baucau.

As a result of the accident, the Australian (ATSB) Accredited Representative and his advisers made the following additional recommendations to the Government of Timor Leste in the interest of flight safety.

Recommendation 4

The Australian Accredited Representative and advisers recommend that the Government of Timor Leste liaise with United Nations Air Operations to expedite procedures for notifying pilots of aircraft operating into Baucau on operations other than UN troop rotations, with current weather details and altimeter sub scale settings.

Recommendation 5

The Australian Accredited Representative and advisers recommend that the Government of Timor Leste liaise with United Nations Air Operations to review operations at aerodromes in Timor Leste by non-UN aircraft with the view of improving the safety of those operations.

United Nations Air Operations

As a result of the accident, on 9 February 2003 the Australian (ATSB) Accredited Representative and his advisers made the following recommendation to United Nations Air Operations, Timor Leste in the interest of flight safety.

Recommendation 1

The Australian Accredited Representative and advisers recommend that United Nations Air Operations assist the Government of Timor Leste to develop and promulgate approved instrument approach and aerodrome charts for Baucau Timor Leste, as a matter of urgency, to enhance flight safety of aircraft operations into Baucau.

International Civil Aviation Organization

As a result of the findings and significant factors of this occurrence, on 4 December 2003, the Civil Aviation Division of the Ministry of Transport, Communications and Public Works, Timor-Leste advised the Australian Accredited Representative that it made the following recommendation with the view to '…widely publishing the safety-significant aspects of this accident and the circumstances leading up to it.'

Recommendation 1

The Civil Aviation Division of the Ministry of Transport, Communications and Public Works, Timor-Leste, recommends that the International Civil Aviation Organization publicise the safety information contained in this Final Report, and that it encourage all non-English speaking contracting States to translate and distribute this accident report in the native language of their crews to improve their understanding of the safety information contained in this report.

4.2 Safety action

As a result of the occurrence, the following safety actions were initiated:

CAD Timor Leste

1. As a result of the recommendations made by the Australian (ATSB) Accredited Representative and his advisers to the Government of Timor Leste on 9 February 2003, CAD issued a NOTAM that contained information that with the exception of UNMISET aircraft and aircraft operating on behalf of the UN, aircraft were not permitted to conduct NDB approaches at Baucau. The NOTAM included advice that all approaches and landings at Baucau were to be conducted in VMC, and that the Baucau NDB could only be used for homing or tracking.

2. On 10 February 2003, CAD notified Jeppesen that the location of the runway in relation to the NDB and the aerodrome reference point (ARP) was incorrectly depicted on the Jeppesen charts, and asked Jeppesen to withdraw the charts.

3. CAD issued a new NOTAM that contained information that QNH for Baucau was only available to aircraft operated by and on behalf of UNMISET during periods that ATS was available for aircraft engaged in UN troop rotations.

4. CAD issued a new NOTAM that contained information that UNMISET NDB instrument approach and landing charts for runways 14 and 32 at Baucau, and an aerodrome chart for Baucau, dated 20 February 2003, were available from UNMISET. The NOTAM included advice that the use of those charts was restricted for use only by UNMISET aircraft and aircraft operated on behalf of the UN. The NOTAM also included advice that:

   PREVIOUS NDB IAL CHARTS RUNWAY 14/32 [Baucau] ARE HEREBY WITHDRAWN.

5. CAD advised that it had put in place arrangements to ensure that it is the single point of contact with the Royal Australian Air Force and Jeppesen for East Timor aeronautical data to prevent the possibility of incorrect or conflicting data being used in the preparation of instrument approach and landing charts.

6. CAD advised that it has amending the existing coordination procedures between Timor Leste and the Australian and Indonesian ATS units to ensure that:

   a) Comoro Approach would become the central point of coordination for aircraft entering Timor Leste airspace

   b) crews of all aircraft entering Timor Leste airspace would be required to contact Comoro Approach on the appropriate very high frequency radio (VHF) channel, irrespective of their destination, notwithstanding that Comoro air traffic control's responsibility was confined to the Dili control area.

7. CAD advised that with respect to CAD safety action 6, the amended procedures would ensure that Comoro ATS unit was made aware of all known aircraft entering Timor Leste airspace, and that by being in contact with an air traffic control (ATC) unit, aircraft crews could be provided with a level of ATS service.

8. CAD also advised that with respect to CAD safety actions 6 and 7, because of VHF range coverage, communication with Comoro Approach could not be assured if aircraft were operating at low levels, and that the amended procedures would not affect the existing TIBA arrangements until Timor Leste could establish its own Flight Information Service.

9. CAD advised that it was examining how Baucau QNH could be relayed to Dili so that Comoro Approach could relay that QNH to aircraft other than UNMISET aircraft or aircraft operated on behalf of the UN operating into Baucau.

10. CAD advised that preparation of the Timor Leste aeronautical information publication (AIP) was nearing completion, and that it was intended that the AIP would contain information specifying that pilots shall not use "user-defined" GPS procedures instead of published procedures to conduct instrument approaches.

11. CAD advised that it had issued completely updated aerodrome and instrument approach and landing charts for runways 14 and 32 at Baucau in October 2003, and that those charts were in compliance with ICAO standards and recommended practices.

Jeppesen Sanderson Inc.

1. At the request of CAD Timor Leste, Jeppesen issued Airway Manual Services Revision Letter number 5-03 on 28 February 2003 which provided details of revisions to material in the Pacific Basin edition of the manual, and included instructions that the Baucau 16-1 and 16-2 charts were to be destroyed.

United Nations Mission of Support in East Timor Air Operations

1. On 12 February 2003, UNMISET Air Operations commissioned a survey of Baucau aerodrome to establish its actual elevation above mean sea level.
2. As a result of UNMISET safety action 1, the instrument approach and landing charts for runways 14 and 32 at Baucau, and the aerodrome chart for Baucau were amended with effect 20 February 2003 and issued by UNMISET Air Operations; the charts contained information on the corrected elevations established by the survey, and were restricted for use by UNMISET and UN aircraft.
3. UNMISET advised that the UN would consider, on a case-by-case basis, providing ATS, including notification of QNH, at Baucau to aircraft on humanitarian flights, other than UNMISET aircraft or aircraft operated on behalf of the UN.

Appendix A – Flightpath and flight data plots

FIGURE A.1:
Aircraft flightpath during the overflight and landing approaches at Baucau

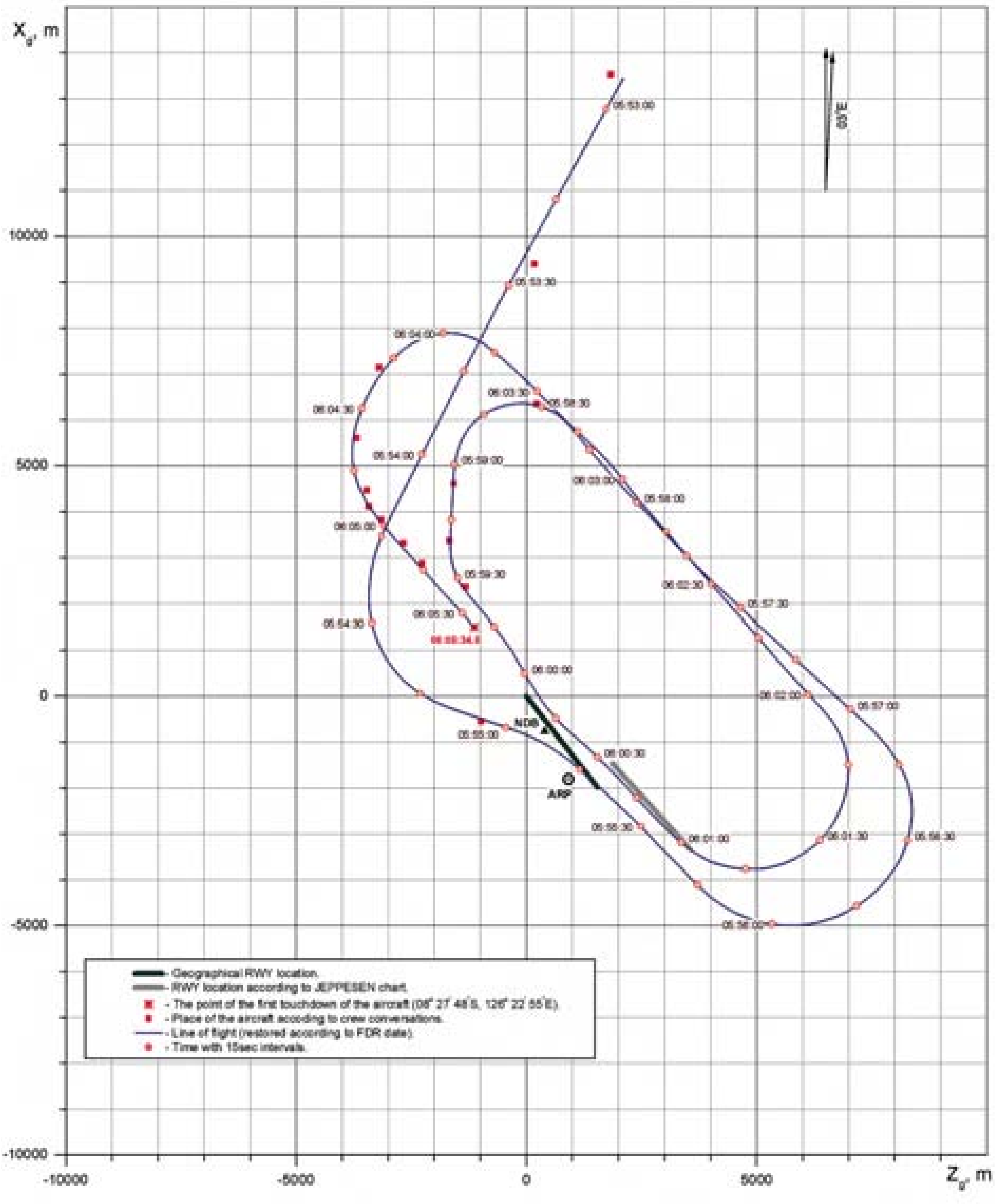


FIGURE A.2:
Aircraft flightpath during the first overflight at Baucau

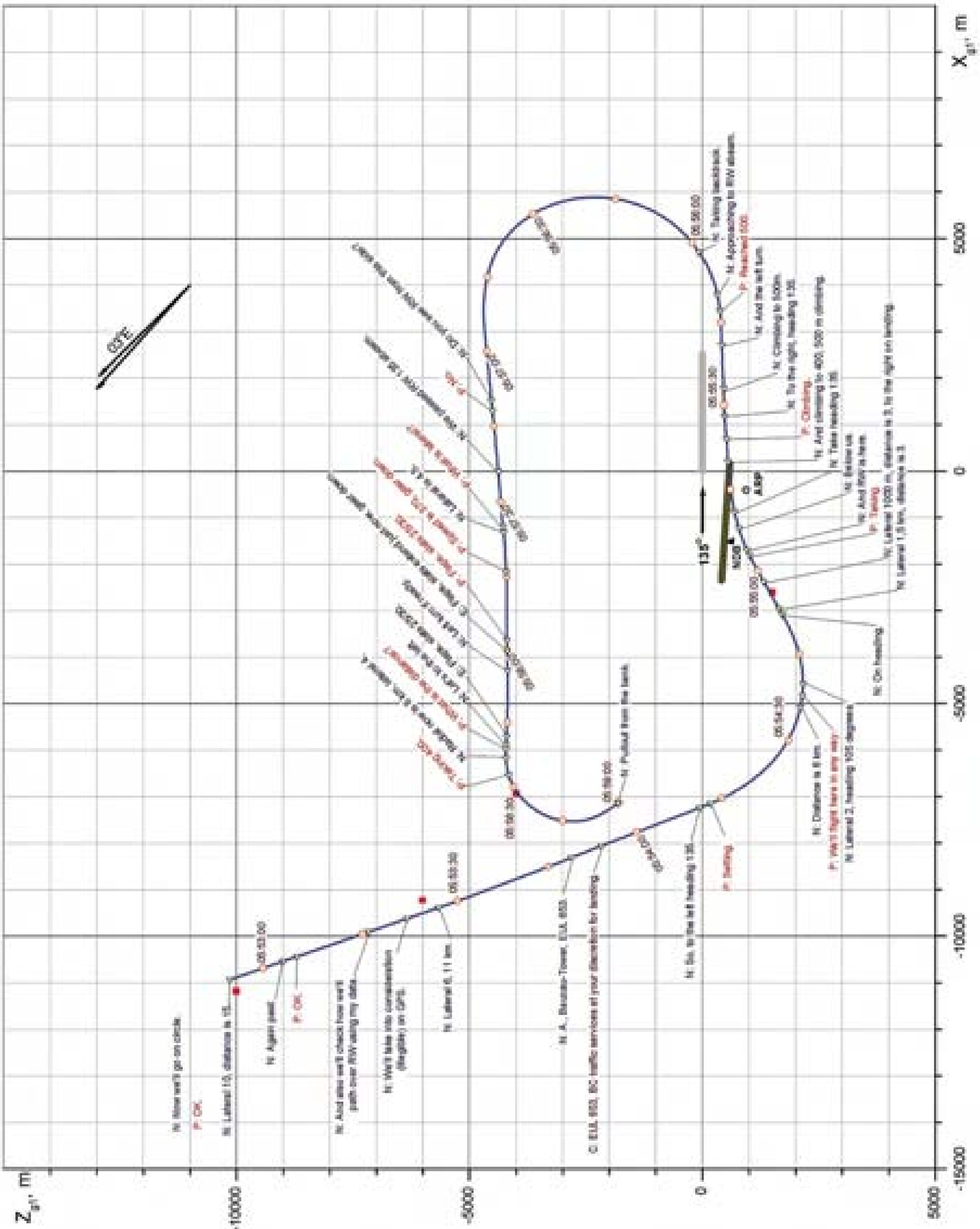


FIGURE A.3:
Aircraft flightpath during the first landing approach at Baucau

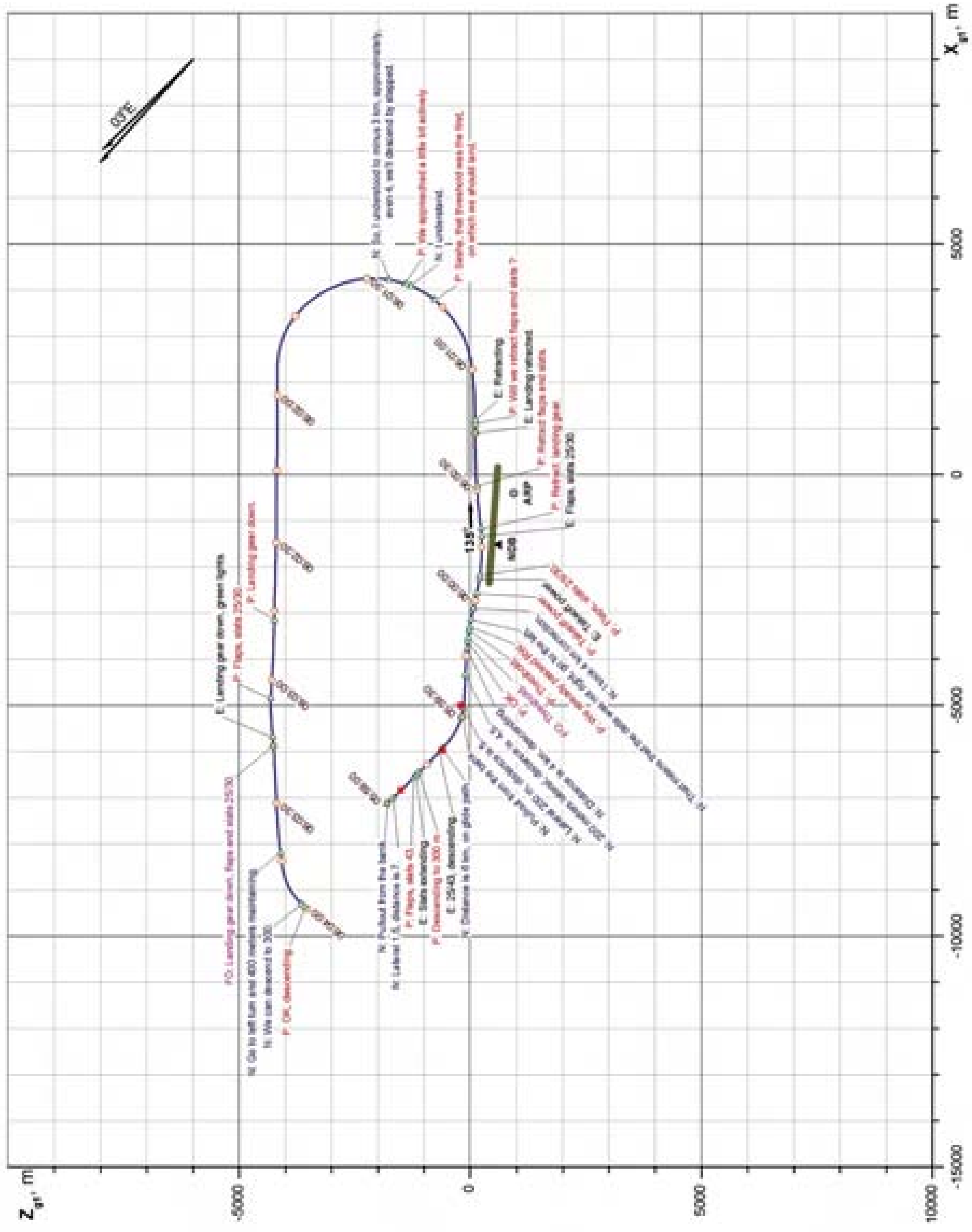


FIGURE A.4:
Actual vs. expected position of the runway during the first landing approach at Baucau

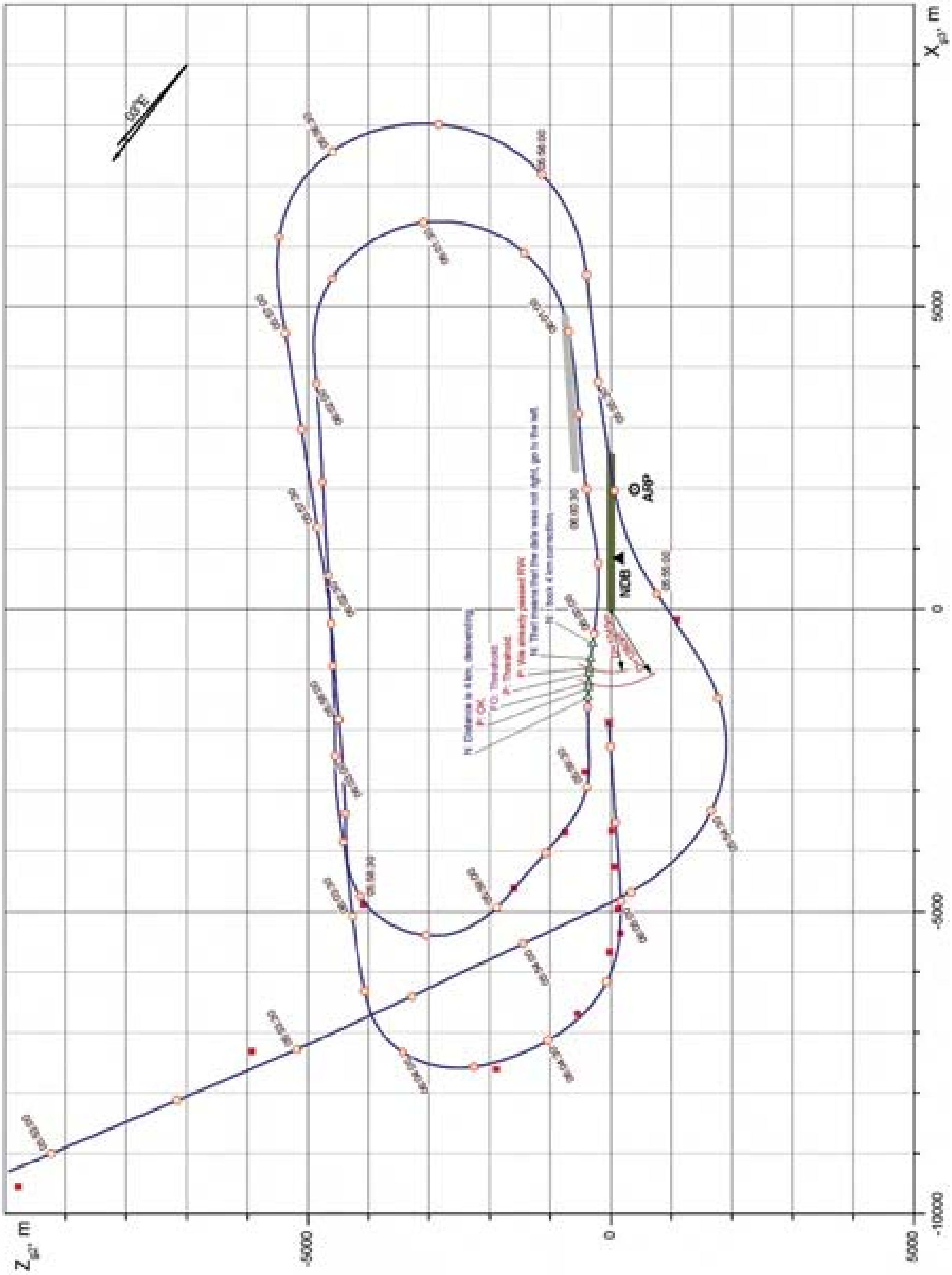


FIGURE A.5:
Aircraft flightpath during the final landing approach at Baucau

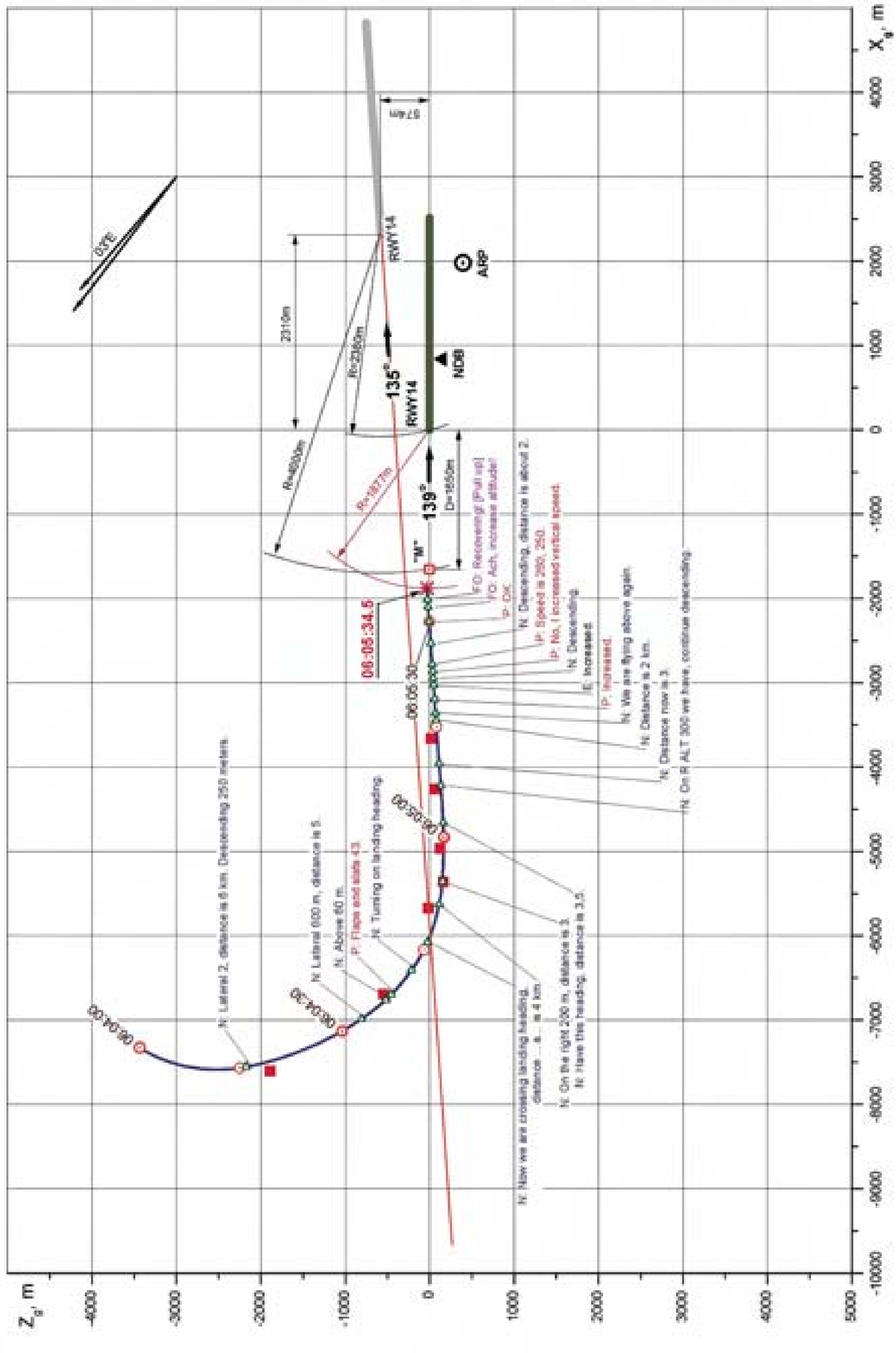


FIGURE A.6:
Vertical flightpath profile for the final approach to the impact point

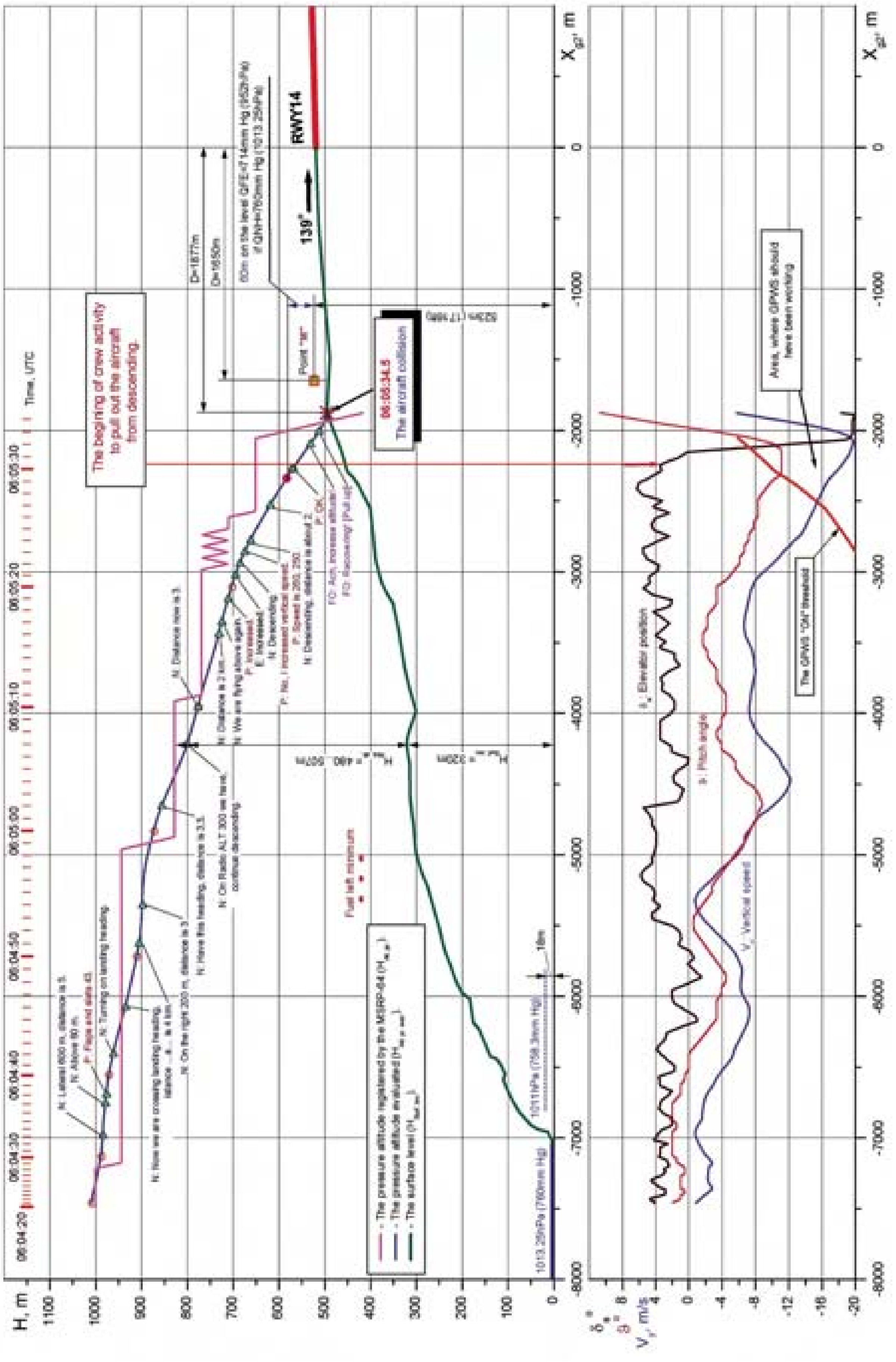


FIGURE A.7:
FDR flight parameter plots for the flight from Macau to Baucau

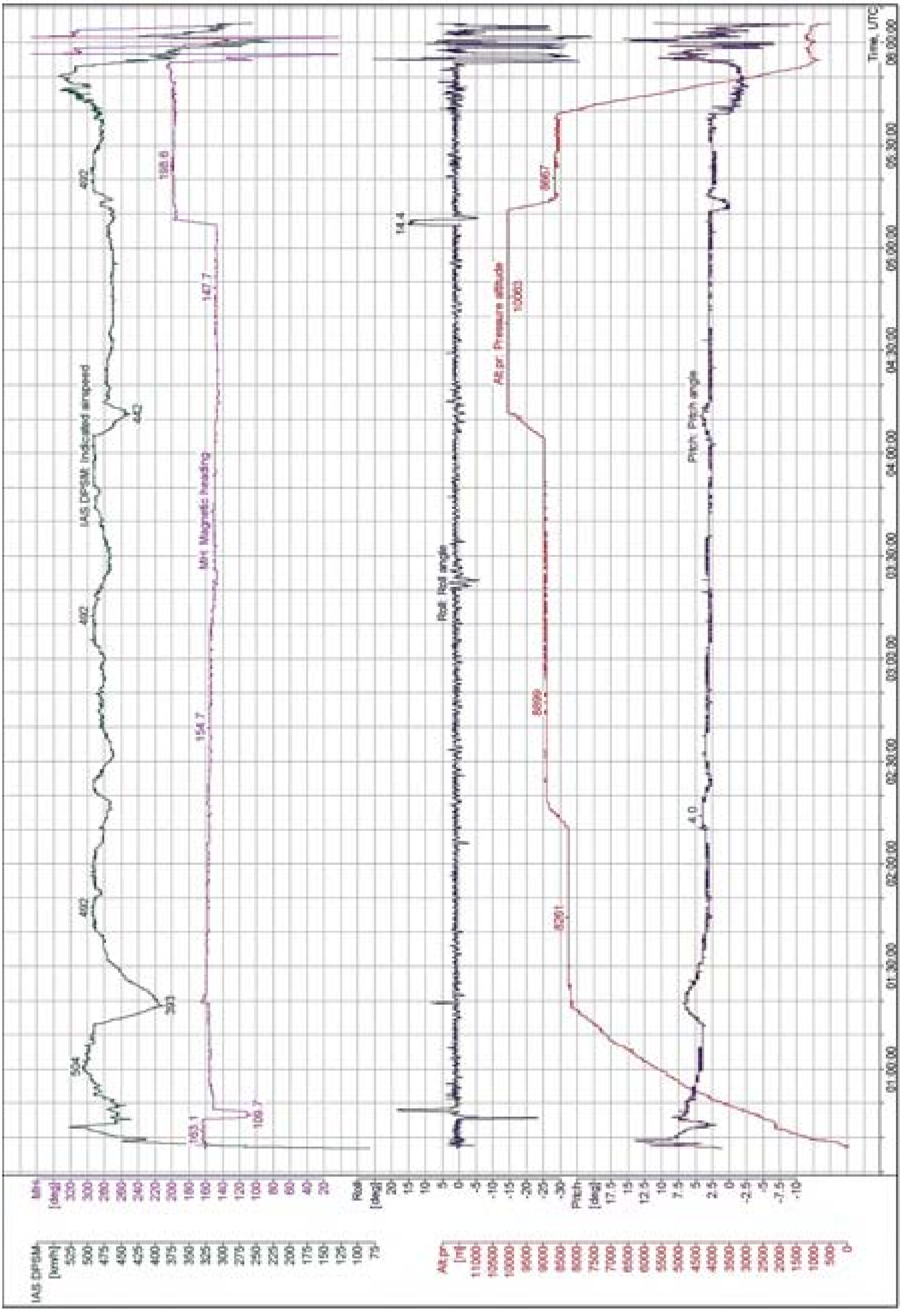


FIGURE A.8:
FDR data plots for the descent, overflight and landing approaches at Baucau

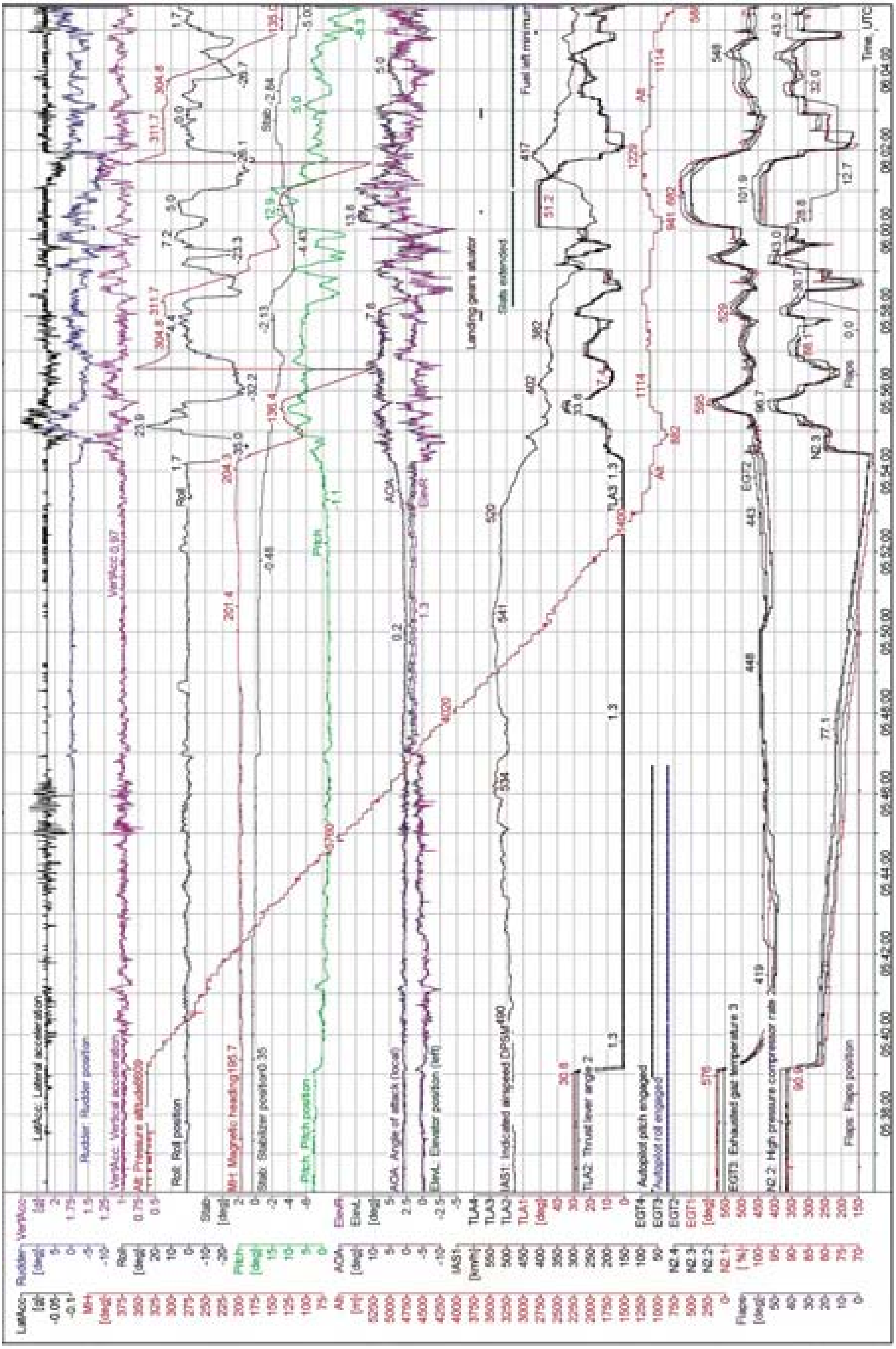


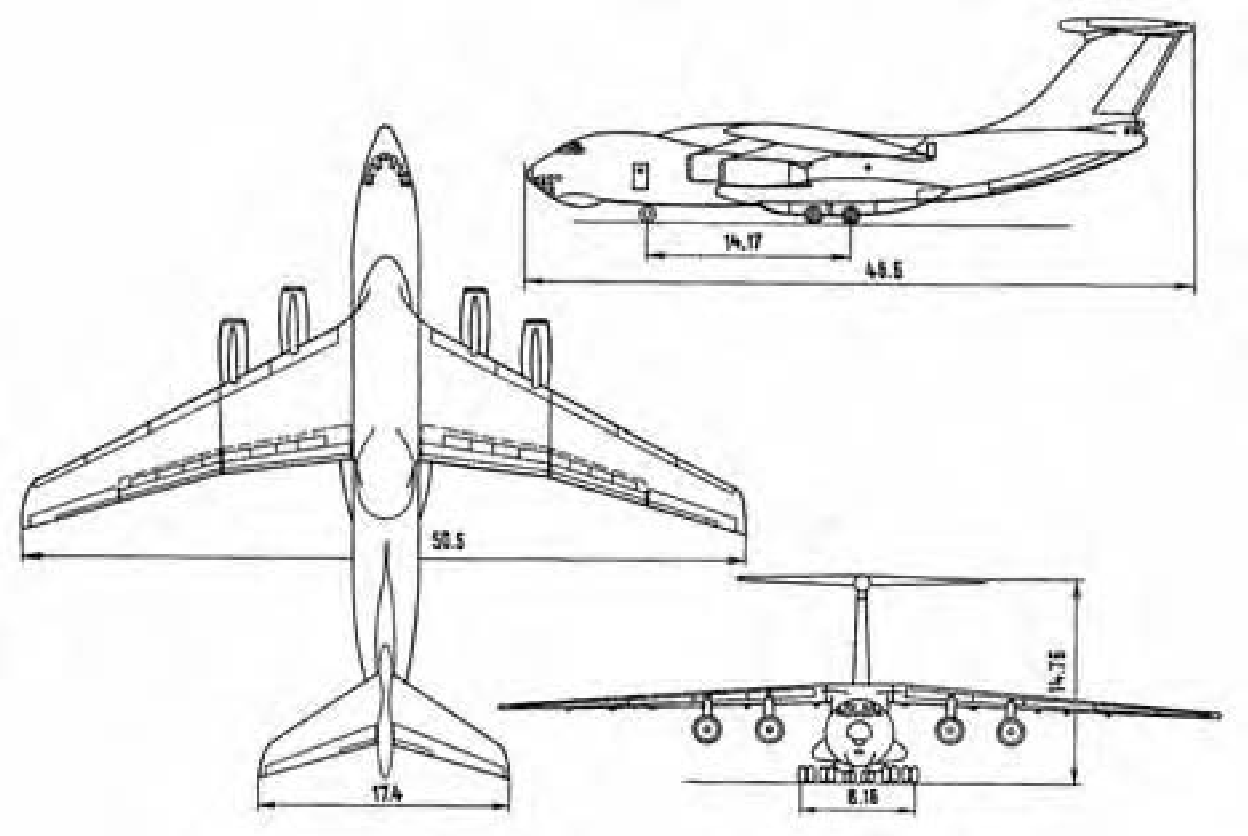
FIGURE A.9:
FDR data plots for the final landing approach at Baucau

Appendix B – Other aircraft technical information

1.1 Dimensions

The principal aircraft dimensions are depicted at Figure B.1.

FIGURE B.1:
Aircraft dimensions



Source: IL-76 TD Flight manual

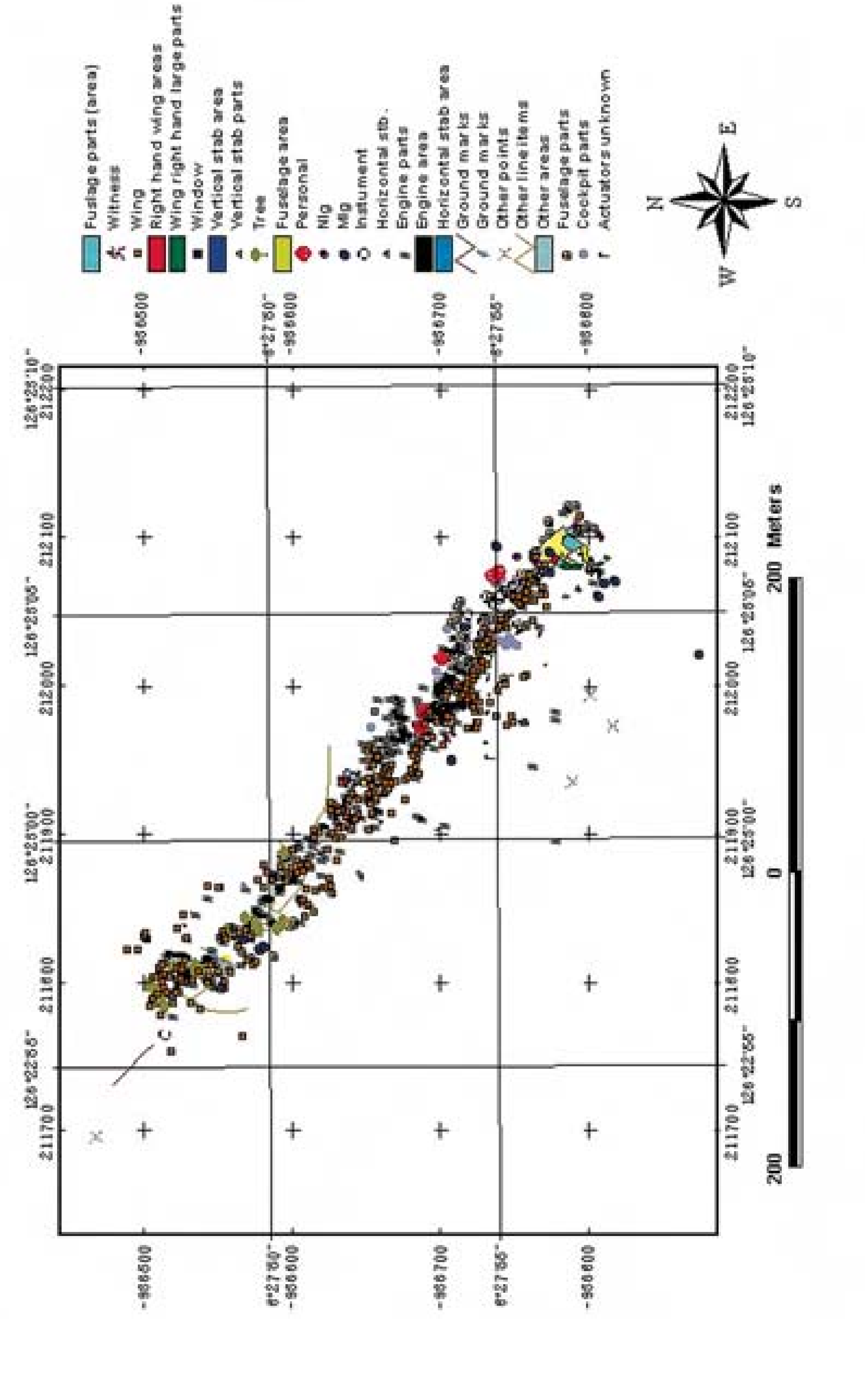
1.2 General information

The occurrence aircraft was originally manufactured as an IL-76MD variant at the Tashkent Aviation Plant in Uzbekistan, Russia on 30 January 1986, but was converted to an IL-76TD variant in 2001. During the conversion, a KLN-90B GPS Navigation System and an SSOS Ground Proximity Warning System GPWS were fitted to the aircraft. The conversion also involved the removal of military equipment that had been installed in the rear turret of the aircraft.

The aircraft wing had a 25 degrees sweepback and an anhedral of 3 degrees outboard of wing centre-section. The aircraft was fitted with conventional hydraulically-boosted flight controls, comprising ailerons, flaps, flight spoilers/airbrakes, and leading edge slats. The tailplane was a variable incidence “T” design with conventional elevators and rudder.

Appendix C – Wreckage distribution map

FIGURE C.1:
Wreckage distribution map



Appendix D – Post-impact break-up sequence

The analysis of the post-impact break-up sequence of the aircraft was developed through examination of the wreckage and the accident site, and through analysis of the data obtained from the DSTO GPS wreckage mapping process.

Four parallel witness marks, where one main landing gear bogie had contacted the slightly rising ground, provided evidence of the aircraft's first point of contact with the ground. The marks were aligned along a magnetic track of about 130 degrees, which corresponded with the aircraft heading at the point of impact which was derived from the recorded flight data.

FIGURE F.1:
Witness scars at the first point of ground contact

The distance between ground witness marks indicated that they had been produced by one of the main landing gear bogies. The impressions in the ground also indicated that the aircraft had been in a slightly nose-up attitude during the period that the main landing gear bogie was in contact with the ground. That notion was substantiated by the fact the ground marks were of an even depth along the rising ground, and by the fact that there was no evidence of contact with the ground by the nose landing gear.

The ground witness marks ended a short distance to the north-northwest of the trees, and indicated that the aircraft was airborne when the left wing struck the trees. A dry stonewall running roughly perpendicular to the imaginary continuation of the ground witness marks had also been struck by the aircraft. There were four indentations in the wall that were consistent with impact by a main landing gear bogie. The height of the indentations indicated that the aircraft landing gear bogies were about 1m above the ground when its left wing impacted the trees.

The slope of the cuts through the trees was between about 1.5 degrees and 4 degrees upwards and away from the track. The aircraft had a reported wing anhedral of 3 degrees, and although that angle would have been expected to reduce under normal flight loads, the cuts in the trees indicated that the aircraft was in a slightly left wing high attitude at the time of its impact with the trees.

The perpendicular distance from the extended centre line of the initial ground witness marks to the furthest damaged tree trunk was about 22 m. Another of the trees was undamaged, and was situated at a perpendicular distance of about 27 m from the extended centre line of the initial ground witness marks.

The distance from the centreline of the left and right bogies to the left wing tip was calculated to be 22.4 m and 28.2 m respectively. Because the aircraft was probably in a slightly nose-up attitude at the point of initial ground contact, as discussed above, it is likely that the left rear main landing gear bogie contacted the ground and resulted in the initial ground witness marks.

FIGURE F.2:
Impacted trees

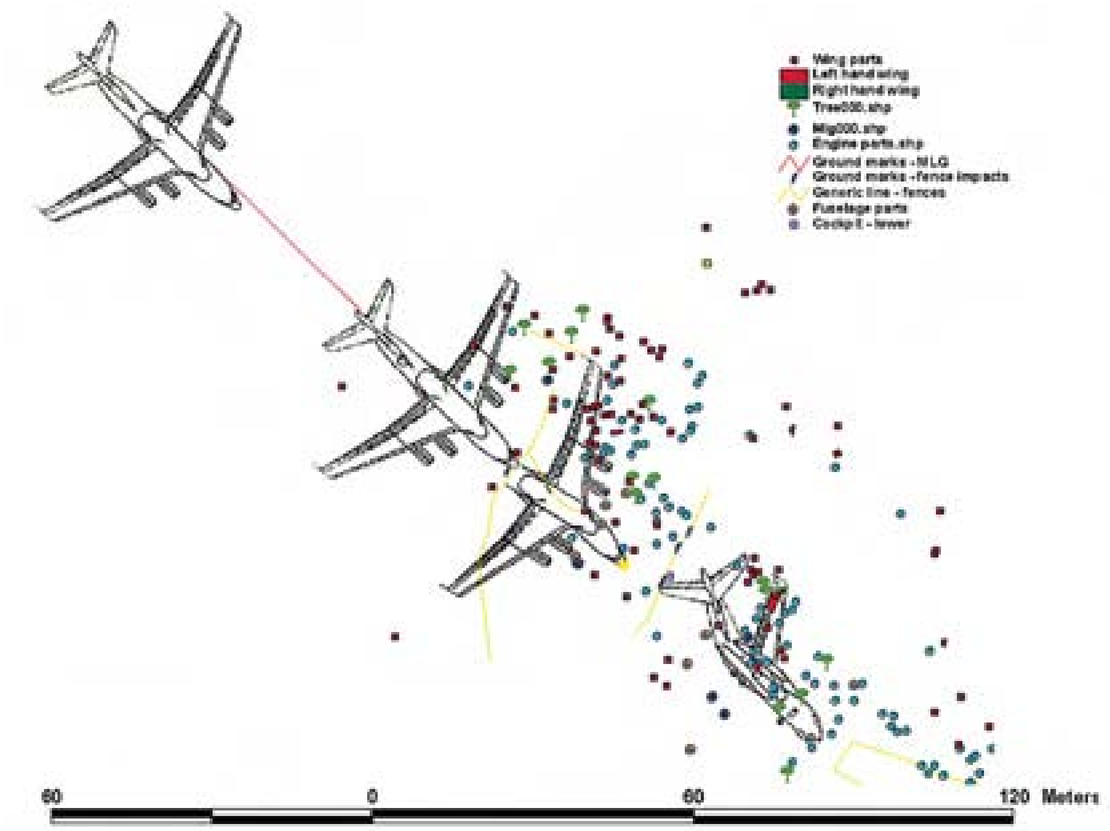
Under those circumstances, the perpendicular distance between the left main landing gear bogie and tree T1 when it was abeam that tree would have been 11 m. That would have resulted in the left wing striking tree T1 just outboard of the outboard engine (engine number-1). The furthermost damaged tree, T3, would therefore have been struck by the left wing about 1 m inboard from the wing tip. That was consistent with a piece of the outboard aileron and various other pieces of the wing having being found directly under the trees. Engine fan blades were also found in the vicinity of the trees and extending away from the trees in the direction in which the aircraft had travelled.

The ground witness marks, and damage to the trees, did not support the hypothesis that the rear right landing gear bogie had initially contacted the ground. If that had been the case, then tree

T1 would have been struck by the left wing between the two left wing engines, and tree T3 would have been struck just outboard of engine number 1. Also, the undamaged tree would have been struck by the left wing, close to the wing tip. Under those circumstances, it is likely there would have been significantly more pieces of the wing structure and engine wreckage in the vicinity of the trees.

The deceleration force imparted by the impact of the left wing with the trees would have provided a sudden and violent yaw towards the left. Additionally, the damage sustained by the left wing would have resulted in the loss of the high lift devices and severe damage to the wing box. Consequently, the left wing outboard of the outer engine appears to have commenced bending upwards, further reducing its lift producing capability. At that stage the right wing was undamaged. With the aerodynamic lift between the left and right wings no longer symmetrical, the aircraft would have commenced to roll to the left.

FIGURE F.3:
Initial break-up sequence



The airframe would have experienced considerable structural loads because of the deceleration force when the left wing impacted the trees, and from the resultant sudden and violent yaw to the left. The combination of those structural loads, asymmetric aerodynamic lift, and the subsequent roll to the left, seems likely to have initiated the partial separation of the aft-most fuselage section from the main body of the aircraft.

The relative disposition of fragments from the left and right wing tip navigation lights provided evidence that the aircraft had rolled more than 180 degrees to the left by the time the right wing tip struck the partially constructed house located about 190 m from the impacted trees. Fragments of the right wing tip navigation light were found in the vicinity of the right wing tip.

Fragments of the left wing tip navigation light were found about 206 m from the impacted trees, and about 23 m to the right of the right wing tip navigation light fragments.

The wing span of the aircraft was 50.5 m before its impact with the trees. The distance between the fragments of the left and right wing tip lights supported the hypothesis that the left wing had struck the trees just outboard of the number 1 engine. Consequently, the outboard section of the left wing folded over onto the inboard section of the wing because of the impact damage and the subsequent roll to the left.

The inverted forward fuselage and cockpit area of the aircraft contacted the serrated hard limestone patch of rising ground heavily beyond where the partially constructed house was located. At that point, the forward fuselage and cockpit separated from the remaining fuselage section. That was likely to have been because of the heavy contact with the ground, and which resulted in the wholesale structural failure of the areas of the aircraft that had been previously damaged during the impact sequence. As the forward fuselage and cockpit area section traversed this area, it was almost entirely shredded into small pieces. That provides an explanation as to why the injuries of the aircraft occupants were so severe, and why it was therefore not possible to positively identify all of the individuals.

The fire trail beyond where the right wing tip had struck the partially constructed house provided evidence that the inverted wing sections yawed in an anti-clockwise direction (when viewed from above) as it continued to travel towards where it finally came to rest. The deceleration forces exerted on the right wing tip as a result of the impact would have initiated that yawing moment, and resulted in the entire wing section yawing about 180 degrees to the left by the time it came to rest in the correct context but inverted.

The final wreckage area contained the remaining inverted wing sections, the burnt-out remains of the aft fuselage section, and the aft T-tail section of the aircraft, which was separated from the remains of the aft fuselage section. The left portion of the horizontal stabiliser section of the T-tail was missing, and had probably separated from the remaining T-tail section during the initial roll sequence, or at the point when the T-tail section separated from the remainder of the aircraft. Had the T-tail remained intact with the rest of the fuselage and in its normal position, it would have sustained much greater damage when the aircraft became inverted before its subsequent impact with terrain near the partially constructed house.

Three of the four main landing gear bogies were located in this area, and although severely damaged by fire, exhibited little or no impact damage. That provided evidence that the fuselage section to which the main landing gears had been attached had travelled inverted to where it finally came to rest.

The centreline of the wreckage trail swung a few degrees to the left after the point where right wing tip had struck the house. The anti-clockwise yawing moment from the deceleration forces exerted on the right wing tip as a result of the impact would account for that leftwards change away the original direction of travel.

Appendix E – Transport Canada simple method of risk analysis

The Transport Canada simple method of risk analysis requires severity, probability and exposure to be individually evaluated and assigned numerical values, as depicted in Tables E.1, E.2 and E.3.

TABLE E.1:
Risk Severity

Severity (S)	
Level 0 Risk	No damage or injury or adverse risks
Level 1 Risk	Personnel – First aid injury, no disability or lost time Public - Minor impact, may lead to briefing note or question period note Environment - Contained release Equipment - Minor damage, potential organisational slowdown/potential downtime
Level 2 Risk	Personnel - Lost time injury, no disability Public - Greater than minor impact, loss of confidence/ some injury potential Environment - Small uncontained release Equipment - Minor Damage, leads to organisational slowdown/minor downtime
Level 3 Risk	Personnel - Disability/ Severe injury Public - Exposed to a hazard that could or will produce injuries Environment - Moderate uncontained release Equipment - Major damage, results in major slowdown/ downtime
Level 4 Risk	Personnel - Fatal, life threatening Public - Exposed to life threatening hazard Environment - Large uncontained release Equipment - Loss of critical equipment, or shutdown of organisation

TABLE E.2:
Risk Probability

Probability (P)	
Level 0 Risk	Mishap impossible
Level 1 Risk	Postulated event. (Has been planned for, and may bepossible, but not known to have occurred)
Level 2 Risk	Has occurred rarely. (Known to have happened, but a statistically credible frequency cannot be determined)
Level 3 Risk	Has occurred infrequently. (Occurs on order of less than once per year and is likely to recur within 5 years)
Level 4 Risk	Has occurred frequently. (Occurs on order of one or more per year and likely to recur in within one year)

TABLE E.3:
Risk Exposure

Exposure (E)	
Level 0 Risk	No Exposure
Level 1 Risk	Below average amount of exposure
Level 2 Risk	Average exposure
Level 3 Risk	Above average exposure
Level 4 Risk	Great exposure

After evaluating S, P and E and assigning each a numerical value, Risk Index is then calculated from the product of those values, and a Risk Level established, as depicted in Table E.4

TABLE E.4:
Risk Index and Risk Level

Risk Index (S x P x E = Risk)		
Values	Risk Levels	Action
0 – 10	Level One	Minimum Risk. Proceed after considering all elements of risk
11 – 30	Level Two	Moderate Risk. Continue after taking action to manage overall level of risk
> 30	Level Three	High Risk. STOP: Do not proceed until sufficient control measures have been implemented to reduce risk to an acceptable level.

Appendix F – Flight Safety Foundation CFIT Risk Assessment Safety Tool

The FSF CFIT risk-assessment safety tool, which comprised a checklist, can be used to evaluate specific flight operations and to enhance pilot awareness of the CFIT risk. The checklist is divided into three parts, and in each part, numerical values are assigned to a variety of factors that the pilot/operator uses to score his/her own situation and to calculate a numerical total for the particular part.

In *Part I: CFIT Risk Assessment*, the level of CFIT risk is calculated for each flight, sector, or leg. In *Part II: CFIT Risk-reduction Factors*, Company Culture, Flight Standards, Hazard Awareness and Training, and Aircraft Equipment are the risk-reduction factors which are calculated in separate sections. In *Part III:Your CFIT Risk*, the totals of the four sections in Part II are combined into a single value (a positive number) and compared with the total (a negative number) in *Part I: CFIT Risk Assessment* to determine the total CFIT Risk Score for the particular flight, sector, or leg.

The various sections of the FSF CFIT Checklist are set out below, and the factors applicable to the occurrence flight are highlighted with a double asterisk (**).

Part I: CFIT Risk Assessment

Section 1: Destination CFIT Risk Factors	***Value***
Airport and Approach Control Capabilities:	
ATC approach radar with MSAWS[51]	0
ATC minimum radar vectoring charts	0
ATC radar only	-l0
ATC radar coverage limited by terrain masking	-l5
**No radar coverage available (out of service/not installed)	-30
**No ATC service	-30
Expected Approach:	
**Airport located in or near mountainous terrain	-20
ILS[52]	0
VOR/DME	-l5
**Non-precision approach with the approach slope from the FAF[53] to the touchdown point shallower than $2\frac{3}{4}$ degrees	-20
**NDB	-30
Visual night "black-hole" approach	-30
Runway Lighting:	
Complete approach lighting system	0
**Limited lighting system	-30

[51] MSAWS - minimum safe altitude warning system

[52] ILS - instrument landing system

[53] FAF - final approach fix

Controller/Pilot Language Skills:	
Controllers and pilots speak different primary languages	-20
Controllers' spoken English or ICAO phraseology poor	- 20
Pilots' spoken English poor	-20
Departure:	
No published departure procedure	-10
Destination CFIT Risk Factors Total	(-) ____

Section 2: Risk Multiplier	***Value***
Company Type of Operation (select only one value):	
Scheduled	1.0
**Non-scheduled	1.2
Corporate	1.3
**Charter	1.5
Business owner/pilot	2.0
Regional	2.0
**Freight	2.5
Domestic	1.0
**International	3.0
Departure/Arrival Airport (select single highest applicable value):	
Australia/New Zealand	1.0
United States/Canada	1.0
Western Europe	1.3
Middle East	1.1
**Southeast Asia	3.0
Euro-Asia (Eastern Europe and CIS)	3.0
South America/Caribbean	5.0
Africa	8.0
Weather/Night Conditions (select only one value):	
Night - no moon	2.0
**IMC	3.0
Night and IMC	5.0
Crew (select only one value):	
Single-pilot crew	1.5
Crew duty day at maximum and ending with a night non-precision approach	1.2
Crew crosses five or more time zones	1.2
Third day of multiple time-zone crossings	1.2
Add Multiplier Values to Calculate Risk Multiplier Total	______

Destination CFIT Risk Factors Total * Risk Multiplier Total = CFIT Risk Factors Total

Section 1: Company Culture	***Value***
Corporate/company management:	
Places safety before schedule	20
CEO signs off on flight operations manual	20
Maintains a centralised safety function	20
Fosters reporting of all CFIT incidents without threat of discipline	20
Fosters communication of hazards to others	15
Requires standards for IFR currency and CRM[54] training	15
Places no negative connotation on a diversion or missed approach	20
Insisting that you fly the way you train	25
Company Culture Total	(+)____

The CFIT checklist provides a grading for company culture, according to how many points are scored, as follows:

115-130 points	-	Tops in company culture
105-115 points	-	Good, but not the best
80-105 points	-	Improvement needed
Less than 80 points	-	High CFIT risk

Section 2: Flight Standards	***Value***
Specific procedures are written for:	
Reviewing approach or departure procedures charts	10
Reviewing significant terrain along intended approach or departure course	20
Maximizing the use of ATC radar monitoring	10
Ensuring pilot(s) understand that ATC is using radar or radar coverage exists	20
Altitude changes	10
Ensuring checklist is complete before initiation of approach	10
Abbreviated checklist for missed approach	10
Briefing and observing MSA circles on approach charts as part of plate review	10
Checking crossing altitudes at IAF[55] positions	10
Checking crossing altitudes at FAF and glideslope centring	10
Independent verification by PNF[56] of minimum altitude during stepdown DME (VOR/DME or LOC[57]/DME) approach	20
Requiring approach/departure procedure charts with terrain in colour, shaded contour formats	20
Radio-altitude setting and light-aural (below MDA) for backup on approach	10
Independent charts for both pilots, with adequate lighting and holders	10

[54] CRM - crew resource management

[55] IAF - initial approach fix

[56] PNF – pilot not flying

[57] LOC - locator

Use of 500 ft altitude call and other enhanced procedures for NPA	10
Ensuring a sterile (free from distraction) cockpit, especially during IMC/night approach or departure	10
Crew rest, duty times and other considerations especially for multiple-time-zone operation	20
Periodic third-party or independent audit of procedures	10
Route and familiarization checks for new pilots	
Domestic	10
International	20
Airport familiarisation aids, such as audiovisual aids	10
First officer[58] to fly night or IMC approaches and the captain to monitor the approach	20
Jump-seat pilot (or engineer or mechanic) to help monitor terrain clearance and the approach in IMC or night conditions	20
Insisting that you fly the way that you train	25
Flight Standards Total	(+)____

The CFIT checklist provides a grading for flight standards, according to how many points are scored, as follows:

300-335 points-	-	Tops in CFIT flight standards
270-300 points	-	Good, but not the best flight standards
200-270 points	-	Improvement needed
Less than 200	-	High CFIT risk

Section 3: Hazard Awareness and Training	***Value***
Company reviews training with the training department or training contractor	10
Company's pilots are reviewed annually about the following:	
Flight standards operating procedures	20
Reasons for and examples of how the procedures can detect a CFIT "trap"	30
Recent and past CFIT incidents/accidents	50
Audiovisual aids to illustrate CFIT traps	50
Minimum altitude definitions for MORA[59], MOCA[60], MSA, MEA[61], etc.	15
Company has a trained flight safety officer who rides the jump seat occasionally	25
Company has flight safety periodicals that describe and analyse CFIT incidents	10
Company has an incident/exceedance review and reporting program	20
Organization investigates every instance in which minimum terrain clearance has been compromised	20
Pilots annually practice recoveries from terrain with GPWS in the simulator	40
Pilots train the way that they fly	25
Hazard Awareness and Training Total	(+)____

58 copilot

59 MORA - minimum off route altitude

60 MOCA - minimum obstruction clearance altitude

61 MEA - minimum en route altitude

The CFIT checklist provides a grading for flight standards, according to how many points are scored, as follows:

285-315 points	-	Tops in CFIT training
250-285 points	-	Good, but not the best
190-250 points	-	Improvement needed
Less than 190	-	High CFIT risk

Section 4: Aircraft Equipment	***Value***
Aircraft includes:	
Radio altimeter with cockpit display of full 2,500 ft range – captain only	20
**Radio altimeter with cockpit display of full 2,500 ft range – copilot	10
**First generation GPWS	20
Second generation GPWS or better	30
GPWS with all approved modifications, data tables and servicebulletins to reduce false warnings	10
Navigation display and FMS	10
Limited number of automated altitude callouts	10
Radio-altitude automated callouts for non-precision approach (not heard on ILS approach) and procedure	10
Preselected radio altitudes to provide automated callouts that wouldnot be heard during normal non-precision approach	10
Barometric altitudes and radio altitudes to give automated“decision” or “minimums” callout	10
Autoflight/vertical speed mode	-10
Auto flight/vertical speed with no GPWS	-20
**GPS or other long-range navigation equipment to supplement NDB-only approach	15
Terrain-navigation display	20
**Ground-mapping radar	10
Aircraft Equipment Total	(+)

The CFIT checklist provides a grading for aircraft equipment total, according to how many points are scored, as follows:

175-195 points	-	Excellent equipment to minimise CFIT risk
155-175 points	-	Good, but not the best
115-155 points	-	Improvement needed
Less than 115	-	High CFIT risk

On completion of the Part II: CFIT Risk Reduction Factors, a total score for the factors could be calculated as follows:

Company Culture ___ + Flight Standards ___ + Hazard Awareness and Training

+ Aircraft Equipment ___ = CFIT Risk-reduction Factors Total (+)___

Part III: CFIT Risk

	Part I CFIT Risk Factors Total	(-)	____
add	Part II CFIR Risk-reduction Factors	(+)	____
=	CFIT Risk Score	(±)	____

The CFIT Checklist includes information that a negative CFIT Risk Score indicates a significant threat, and that the sections in Part II should be reviewed to determine what changes and improvements can be made to reduce CFIT risk.