

Aircraft Accident Investigation Report
KNKT/07.06/07.02.35

**NATIONAL
TRANSPORTATION
SAFETY
COMMITTEE**

BOEING 737-497

PK-GZC

ADI SUCIPTO AIRPORT, YOGYAKARTA

INDONESIA

7 MARCH 2007



**REPUBLIC OF INDONESIA
MINISTRY OF TRANSPORTATION
NATIONAL TRANSPORTATION SAFETY COMMITTEE**

This report was produced by the National Transportation Safety Committee (NTSC), Karya Building 7th Floor Ministry of Transportation, Jalan Medan Merdeka Barat No. 8 JKT 10110, Indonesia.

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GLOSSARY OF ABBREVIATIONS

AD	Airworthiness Directive
AFM	Airplane Flight Manual
AGL	Above Ground Level
ALAR	Approach-and-landing Accident Reduction
AMSL	Above Mean Sea Level
AOC	Air Operator Certificate
ATC	Air Traffic Control
ATPL	Air Transport Pilot License
ATS	Air Traffic Service
ATSB	Australian Transportation Safety Bureau
Avsec	Aviation Security
BMG	Badan Meterologi dan Geofisika
BOM	Basic Operation Manual
CAMP	Continuous Airworthiness Maintenance Program
CASO	Civil Aviation Safety Officer
CASR	Civil Aviation Safety Regulation
CPL	Commercial Pilot License
COM	Company Operation Manual
CRM	Cockpit Recourses Management
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
DFDAU	Digital Flight Data Acquisition Unit
DGCA	Directorate General Civil Aviation
DME	Distance Measuring Equipment
EEPROM	Electrically Erasable Programmable Read Only Memory
EFIS	Electronic Flight Instrument System
EGT	Exhaust Gas Temperature
EIS	Engine Indicating System
FL	Flight Level
F/O	First officer or Copilot
FDR	Flight Data Recorder
FOQA	Flight Operation Quality Assurance
GPWS	Ground Proximity Warning System
Hrs	Hours
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IIC	Investigator in Charge

ILS	Instrument Landing System
kg	Kilogram(s)
km	Kilometer(s)
kts	Knots (NM/hour)
mm	Millimeter(s)
MTOW	Maximum Take-off Weight
NM	Nautical mile(s)
KNKT / NTSC	Komite Nasional Keselamatan Transportasi / National Transportation Safety Committee
°C	Degrees Celsius
PIC	Pilot in Command
QFE	Height above aerodrome elevation (or runway threshold elevation) based on local station pressure
QNH	Altitude above mean sea level based on local station pressure
RESA	Runway End Safety Area
RPM	Revolution Per Minute
SCT	Scattered
S/N	Serial Number
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
TS/RA	Thunderstorm and rain
TAF	Terminal Aerodrome Forecast
TSN	Time Since New
TT/TD	Ambient Temperature/Dew Point
TTIS	Total Time in Service
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

SYNOPSIS

On 7 March 2007, a Boeing Company 737-497 aircraft, registered PK-GZC, was being operated by Garuda Indonesia on an instrument flight rules (IFR), scheduled passenger service, as flight number GA200 from Soekarno-Hatta Airport, Jakarta to Adi Sucipto Airport, Yogyakarta. There were two pilots, five flight attendants, and 133 passengers on board.

The pilot in command (PIC) was the pilot flying, and the copilot was the support/monitoring.

The aircraft overran the departure end of runway 09, to the right of the centerline at 110 knots. The aircraft crossed a road, and impacted an embankment before stopping in a rice paddy field 252 meters from the threshold of runway 27 (departure end of runway 09). The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were 119 survivors. One flight attendant and 20 passengers were fatally injured. One flight attendant and 11 passengers were seriously injured.

The investigation determined that the flight crew's compliance with procedures was not at a level to ensure the safe operation of the aircraft.

The PIC intended to make an instrument landing system (ILS) approach to runway 09 at Yogyakarta and briefed the copilot accordingly. Yogya Approach cleared the aircraft for a visual approach, with a requirement to proceed to long final and report runway in sight. Although the crew acknowledged the visual approach clearance, they continued with the ILS approach, but did not inform the controller. The descent and approach were conducted in visual meteorological conditions.

At 23:55:33, when the aircraft was 10.1 miles from the runway, it was 1,427 feet above the initial fix of 2,500 feet published in the approach chart, and the airspeed was 283 knots. The pilot in command descended the aircraft steeply in an attempt to reach the runway, but in doing so, the airspeed increased excessively. Because the aircraft was being flown at speeds that were in excess of the wing flaps operation speed, the copilot elected not to extend the flaps as instructed by the PIC. During the approach, the Ground Proximity Warning System (GPWS) alerts and warnings sounded 15 times and the copilot called for the PIC to go around.

The PIC continued the approach with flaps 5 degrees, and the aircraft attained the glideslope near the runway 09 threshold. Flaps 5 degrees is not a landing flap setting. The aircraft crossed the threshold, 89 feet above the runway, at an airspeed of 232 knots, 98 knots faster than the required landing speed for flaps 40 degrees. The wind was north easterly at 9 knots. The groundspeed was 235 knots. The aircraft touched down at an airspeed of 221 knots, 87 knots faster than landing speed for 40 degrees flap. Shortly after touching down, the copilot called, with high intonation, for the PIC to go around.

The aircraft was flown at an excessive airspeed and steep flight path angle during the approach and landing, resulting in an unstabilized approach. The PIC did not follow company procedures that required him to fly a stabilized approach, and he did not abort the landing and go around when the approach was not stabilized.

His attention was fixated or channelized on landing the aircraft on the runway and he either did not hear, or disregarded the GPWS alerts and warnings and calls from the copilot to go around.

The copilot did not follow company procedures and take control of the aircraft from the PIC when he saw that the pilot in command repeatedly ignored the GPWS alerts and warnings. The Garuda Simulator Pilot – Proficiency Check records showed no evidence of training or proficiency checks in the vital actions and responses to be taken in the event of GPWS or EGPWS alerts and warnings, such as ‘TOO LOW TERRAIN’ and ‘WHOO, WHOO, PULL UP’.

The Garuda Basic Operation Manual instructed a copilot to take control of the aircraft from the PIC, and execute a go around, when an unsafe condition exists. The records also showed no evidence that the copilot had been checked or received simulator training in the appropriate vital actions and responses required to retrieve a perceived or real situation that might compromise the safe operation of the aircraft.

The Directorate General of Civil Aviation’s flying operations surveillance of Garuda was not effective in identifying these and other safety deficiencies.

The Yogyakarta Airport’s rescue and fire fighting services vehicles were unable to reach the accident site and some did not have appropriate fire suppressant. The delay in extinguishing the fire, and the lack of appropriate fire suppressant agents, may have significantly reduced survivability. The airport emergency plan and its implementation were less than effective.

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

The report includes a number of recommendations made by the NTSC, with the intention of enhancing the safety of flight by Indonesian airlines. These recommendations are drawn to the attention of DGCA, and Indonesian airport and airline operators and maintainers, and include flying operations procedures, training and checking, safety and regulatory oversight and surveillance, serviceability of flight recorders, and airport emergency planning and equipment.

A number of safety actions by Angkasa Pura I to address safety deficiencies with respect to airport emergency preparedness and associated services and equipment are also included. Since the accident, an access road between the airport perimeter and the area of the accident site has been constructed.

On 2 April 2007, Garuda issued a notice to its pilots reinforcing its mandatory policy relating to a pilot monitoring to take control of an aircraft and execute a go around in instances of unstabilized approach, when the pilot flying does not make an appropriate response. The notice assures pilots that the company will not take disciplinary measures for a go around executed under any unsafe or unstabilized approach.

1 FACTUAL INFORMATION

1.1 History of the flight

On 7 March 2007, a Boeing Company 737-497 aircraft, registered PK-GZC (Figure 1), was being operated by Garuda Indonesia¹ on an instrument flight rules (IFR), scheduled passenger service, as flight number GA200 from Soekarno-Hatta Airport, Jakarta to Adi Sucipto Airport, Yogyakarta. There were two pilots, five flight attendants, and 133 passengers on board.



Figure 1: Boeing 737 PK-GZC on a previous flight, during the landing approach

The pilot in command (PIC) and copilot commenced duty in Jakarta at about 21:30 Coordinated Universal Time² (UTC), or 04:30 local time, for the flight to Yogyakarta. Prior to departing Jakarta, during the push back, the PIC contacted the ground engineers and informed them that the number-1 (left) engine thrust reverser fault light on the cockpit instruments had illuminated. The engineers reset the thrust reverser in the engine accessories unit and the fault light extinguished.

The scheduled departure time was 23:00. The aircraft took off from Jakarta at 23:17, and the PIC was the pilot flying for the sector to Yogyakarta. The copilot was the monitoring/support pilot.

¹ Garuda Indonesia will be referred to in this report as Garuda.

² The 24-hour clock used in this report to describe the time of day as specific events occurred, is in Coordinated Universal Time (UTC). Local time, Western Indonesian Standard Time (WIB) is UTC+ 7 hours.

During the cruise, just before top of descent, the crew was instructed by Jakarta Control to ‘maintain level 270 and contact Yogya Approach 123.4’³. The copilot acknowledged; ‘contact Yogya 123.4, Indonesia 200’⁴.

The PIC started to give a crew briefing at 23:43 stating: ‘in case of holding, heading of 096’. The briefing was interrupted by a radio transmission from Yogya Approach, giving GA200 a clearance to Yogyakarta via airway W 17 for runway 09, and a requirement to report when leaving flight level 270.

When radio communication was completed, the PIC continued with the crew briefing for an ILS approach (Figure 2), stating:

When clear approach ILS runway 09, course 088. (C)⁵ Frequency 1091, aerodrome elevation three hundred fifty, (C) leaving two thousand five hundred by 6 point 6 DME ILS, (C) to check four DME one thousand six hundred seventy, (C) crossing two DME one thousand thirty seven. Decision Altitude ILS Cat I, five eight seven, two three seven both set, approach flap forty, auto brake two. Speed one three six, one five one, two twenty. Timing from final approach-fix to VOR 6 DME. (C) With airspeed approximately one four one, two minutes thirty six. (C) In case localizer, MDA seven hundred, localizer, miss approach, at point six. (C) DME ILS India Juliet oscar golf. (C) On landing, to the left standby parking stand. Go-around miss approach climb one thousand five hundred turn left. To holding fix via Yogya VOR, continue climb four thousand feet, to cross Yogya at or above two thousand five hundred DME eight. (C)

Twelve minutes and 17 seconds later, Yogya Approach cleared GA200 ‘for visual approach runway zero nine, proceed to long final, report runway in sight’. The copilot acknowledged the clearance and asked for confirmation that they were cleared to descend to circuit altitude, Yogya Approach replied ‘descend to two thousand five hundred initially’.

The crew informed the investigation that they were conducting an Instrument Landing System (ILS) approach to runway 09 (Figure 2), in visual meteorological conditions (VMC). However they did not inform Yogya Approach or Yogyakarta Tower that they were flying the 09 ILS approach.

At 23:58:10, the aircraft overran the departure end of runway 09 at Yogyakarta Airport. The PIC reported that as the aircraft was about to leave the runway, he shut down both engines. The aircraft crossed a road, and impacted an embankment before stopping in a rice paddy field 252 meters from the threshold of runway 27 (departure end of runway 09). The aircraft was destroyed by the impact forces and an intense, fuel-fed, post-impact fire. There were 119 survivors. One flight attendant and 20 passengers were fatally injured. One flight attendant and 11 passengers were seriously injured.

³ Yogya Approach 123.4 referred to Yogyakarta approach air traffic controller and the very high frequency radio frequency 123.4 Mhz.

⁴ For air traffic control purposes, the GA 200 flight number was Indonesia 200.

⁵ (C) During the course of the crew briefing, the copilot responded by saying ‘check’ after every item of the crew briefing.

ILS APPROACH CHART
RWY 09 (IJOG - 109.1)

Trans. Level : FL 130
Trans. Alt : 11000 QNH

AERODROME
ELEV 350 FT

YOGYAKARTA, INDONESIA
Adi Sutjipto Apt / WARJ

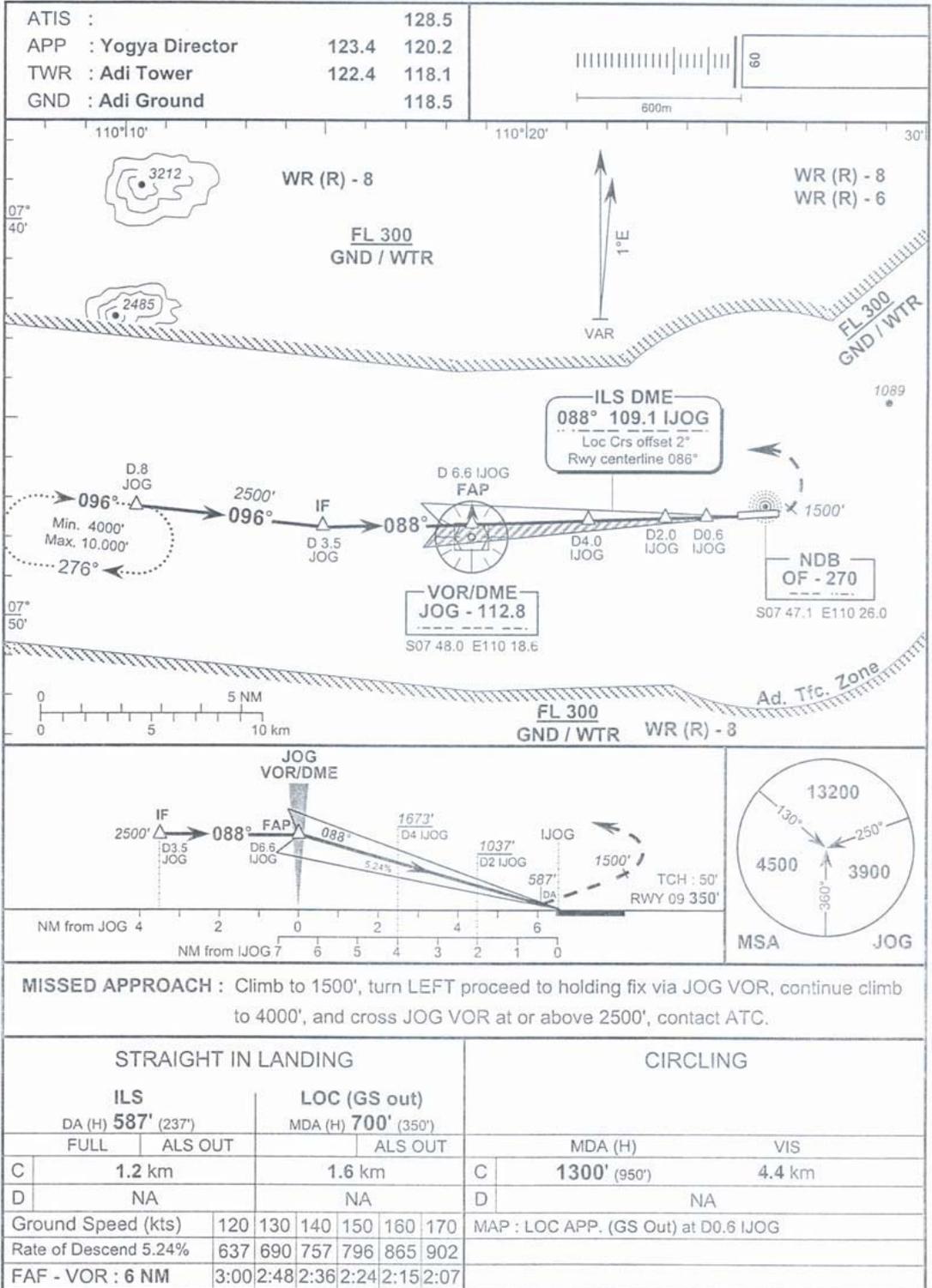


Figure 2: Garuda's Yogyakarta runway 09 instrument landing system approach chart valid at the date of the accident

The SSFDR data shows that the aircraft crossed the threshold, 89 feet above the runway, at an airspeed of 232 knots, 98 knots faster than the required landing speed for flaps 40 degrees. The wind was north easterly at 9 knots. The groundspeed was 235 knots. The aircraft touched down at an airspeed of 221 knots, 87 knots faster than landing speed for 40 degrees flap (134 knots) at the aircraft's landing weight of 53,366 kilograms. Shortly after touching down, the copilot called, with high intonation, for the PIC to go around.

The aircraft bounced twice, touching down on the main landing gear before the nose landing gear touched the ground. At the third (final) touchdown, the nose landing gear touched down heavily before the main landing gear. The g force was about +2.91 g, and the aircraft's pitch angle was about -1 degree (nose down).

Main-wheel tire marks and nose-wheel axle and oleo impact and scraping marks were found along the runway (Figure 3 and Figure 4). The aircraft initially tracked along the runway centerline, but it left the sealed runway about 10 meters to the right of the runway centerline leaving nose landing gear wreckage (Figure 5) along the runway.



Figure 3: Nose and left main landing gear impact marks on the runway



Figure 4: Nose landing gear scrape on runway approximately 15 cm wide



Figure 5: Nose landing gear wreckage layout

About 160 meters from the end of runway 09, the aircraft crossed a road and the nose of the aircraft impacted an embankment as the engines impacted a concrete gutter (Figure 6).



Figure 6: Left engine impact on road and gutter

1.1.1 Actual flight profile and prescribed ILS profile

The chart (Figure 8), prepared by the Australian Transport Safety Bureau, was derived from the Jeppesen Instrument Landing System (ILS) chart for runway 09 at Yogyakarta, and recorded data taken from the SSFDR for the accident flight. During the approach, GA200 was above the ILS approach profile (glideslope). The runway touchdown zone for the ILS approach was between 150 and 620 meters from the runway 09 threshold. The aircraft touched down about 860 meters from the threshold.

The plan view of the Garuda approach plate was also applied to the animated flight path. The approach ground track flown approximately followed the approach on the Garuda instrument landing approach chart (Figure 7).

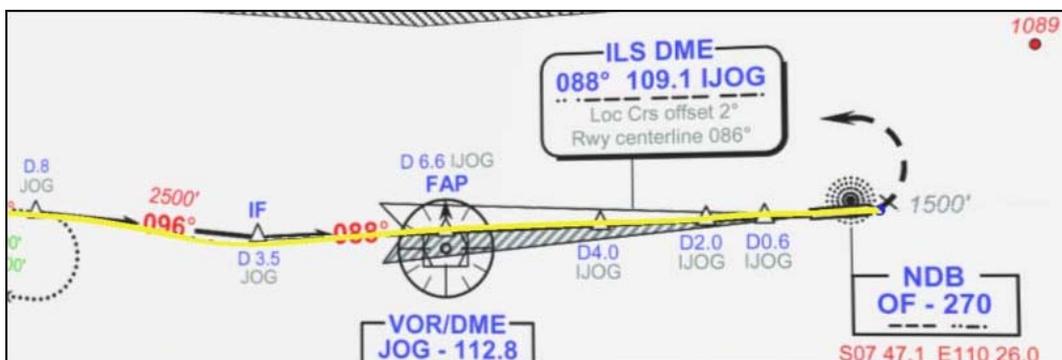


Figure 7: Screenshot of the animated flight path (yellow) over the Garuda Yogyakarta approach plate (plan view)

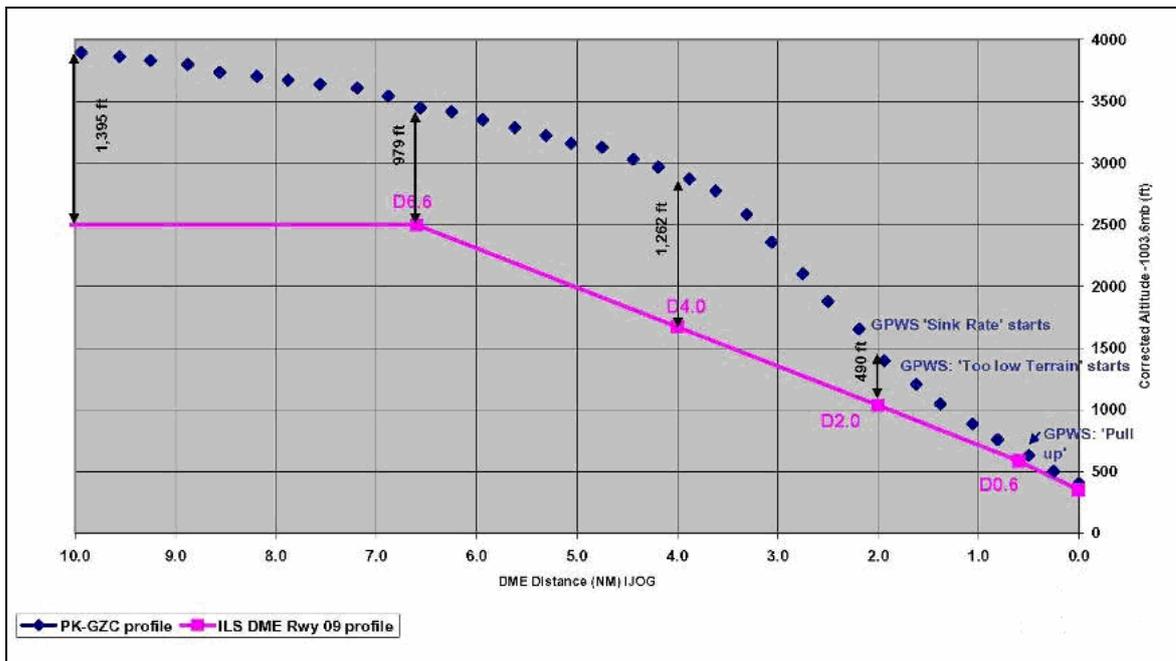


Figure 8: Comparison of PK-GZC and ILS DME approach profiles for Yogyakarta runway 09 approach

1.2 Injuries to persons

Injuries	Crew	Passengers	TOTAL
Fatal	1	20	21
Serious	1	11	12
Minor	2	98	100
None	3	4	7
TOTAL	7	133	140

1.3 Damage to aircraft

The left nose-wheel hub contacted the runway and fractured. Metal from the failed left wheel slashed the right nose wheel tire causing deep cuts to the tire crown. The outer hub of the right nose wheel separated leaving pieces on the runway. Figure 5 failed nose landing gear. The inboard hub of the right nose wheel remained attached to the right axle and was scoring the runway during the high speed landing roll; Figure 3 and Figure 4. The nose landing gear torque link failed. There was no evidence of foreign object damage (FOD) on the left nose wheel tire.

The right nose wheel tire had evidence of FOD, which caused the cut to the crown of the tire, probably due to the failed left nosewheel assembly. The inner walls of both tires showed that there was no evidence of overload or under pressure.

The aircraft was destroyed by impact forces and an intense, fuel-fed, post-impact fire.

1.4 Other damage

The impact, liberation of fuel and post-impact fire damaged the runway, airport fences, road, and rice field.

1.5 Personnel information (Cockpit crew)

1.5.1 Pilot in command

Gender	:	Male
Date of birth	:	28 May 1962
Nationality	:	Indonesia
Marital status	:	Married
Date of joining company	:	16 October 1985
License	:	ATPL 3204
Validity period of license	:	30 April 2007
Type rating	:	B737 – 300/400/500
Instrument rating	:	Yes
Medical certificate	:	17 October 2006
Date of last medical	:	09 October 2006
Last Line Check	:	18 August 2006
Last Proficiency Check	:	07 September 2006

Flight time

Total time	:	13,421 hrs: 09 minutes
This make and model	:	3,703 hrs: 59 minutes
Last 90 Days	:	241 hrs: 46 minutes
Last 28 Days	:	90 Hrs: 08 minutes
Last 24 Hours	:	0.55 Hrs
This flight	:	0.55 Hrs

Training completed

Wind Shear recurrency	:	06 September 2006
CRM recurrency	:	15 August 2006
Dangerous Goods and AvSec recurrency	:	14 August 2006
CFIT ⁶ /ALAR ⁷ training recurrency	:	27 February 2006

⁶ Controlled flight into terrain.

⁷ Approach-and-landing reduction.

The PIC held a current Air Transport Pilot License issued by the Directorate General Civil Aviation (DGCA), which was valid until 30 April 2007. He held an endorsement for the Boeing 737-300/400/500 series aircraft. In addition, he held a multi-engine instrument rating.

The PIC had attended an Enhanced Ground Proximity Warning System (EGPWS) introductory seminar on 1 August 2005. However, the records showed no evidence that the PIC had been checked, or received Boeing 737 simulator training, in appropriate vital actions and responses (escape maneuver) with respect to Ground Proximity Warning System (GPWS) or EGPWS alerts and warnings, such as 'TOO LOW TERRAIN' and 'WHOOOP, WHOOOP, PULL UP'.

A Check Pilot noted that during the PIC's Boeing 737 simulator Pilot - Proficiency Check dated 13 September 2005, the pilot maintained 'speed high on touchdown' during single engine landing.

Another Check Pilot noted that during the PIC's Boeing 737 aircraft Line Check dated 18 August 2006, the pilot 'did not comply with speed restriction procedure' during arrival.

The Check Pilot who conducted the PIC's Boeing 737 simulator Pilot - Proficiency Check dated 7 September 2006 did not note a concern about the previously noted speed findings.

Prior to commencing the flight to Yogyakarta, the PIC had logged a total of 13,421 hours and 9 minutes flying experience, of which 3,703 hours and 59 minutes were as pilot in command on Boeing 737 aircraft.

Prior to commencing duty on 7 March 2007, the PIC was free of duty for 35 hours and 20 minutes. The PIC had completed 16 hours and 30 minutes (flight time) in the preceding 4 days; 90 hours and 8 minutes (flight time) in the preceding 28 days; and 241 hours and 46 minutes (flight time) in the preceding 90 days.

His last flight into Yogyakarta was on 28 February 2007 as PIC, when he landed on runway 27. His previous most recent landing on runway 09 was on 23 February 2007.

There was no evidence that the PIC was not fit for duty, however he did not provide the investigation with information about his activities during the 72 hours prior to commencing duty on 7 March 2007.

1.5.2 Copilot

Gender	:	Male
Date of birth	:	18 October 1976
Nationality	:	Indonesia
Marital status	:	Single
Date of joining company	:	19 July 2004
License	:	CPL 5616
Validity period of license	:	31 August 2007
Type rating	:	B737 – 300/400/500
Instrument rating	:	Yes
Medical certificate	:	13 February 2007
Date of last medical	:	12 February 2007
Last line check	:	10 July 2006
Last proficiency check	:	13 September 2006

Flight time

Total time	:	1,528 hrs: 40 minutes
This make & model	:	1,353 hrs: 55 minutes
Last 90 Days	:	248 hrs: 25 minutes
Last 28 Days	:	82 Hrs: 07 minutes
Last 24 Hours	:	0.55 Hrs
This flight	:	0.55 Hrs

Training completed

Wind Shear recurrency	:	06 September 2006
CRM recurrency	:	25 July 2006
Dangerous Goods and AvSec recurrency	:	24 July 2006
CFIT/ALAR training recurrency	:	13 February 2006

The copilot held a current Commercial Pilot License issued by the Directorate General Civil Aviation (DGCA), which was valid until 31 August 2007. He held an endorsement for the Boeing 737-300/400/500 series aircraft. In addition, he held a multi-engine instrument rating.

The copilot had attended an EGPWS introductory seminar on 28 October 2005. However, the records showed no evidence that the copilot had been checked or received simulator training in appropriate vital actions and responses (escape maneuver) with respect to EGPWS or GPWS alerts and warnings, such as ‘TOO LOW TERRAIN’ and ‘WHOOP, WHOOP, PULL UP’.

Prior to commencing the flight to Yogyakarta, the copilot had logged a total of 1,582 hours and 40 minutes flying experience, of which 1,353 hours and 55 minutes were as copilot on Boeing 737 aircraft.

Prior to commencing duty on the day of the accident, the copilot was free of duty for 69 hours and 42 minutes. The copilot had completed 8 hours and 13 minutes (flight time) in the preceding 4 days; 82 hours and 7 minutes (flight time) in the preceding 28 days; and 248 hours and 25 minutes (flight time) in the preceding 90 days.

His last flight into Yogyakarta was on 18 February 2007 as copilot, when he landed on runway 27. His previous most recent landing on runway 09 was on 13 February 2007.

There was no evidence that the copilot was not fit for duty, however he did not provide the investigation with information about his activities during the 72 hours prior to commencing duty on 7 March 2007.

1.6 Aircraft information

1.6.1 Aircraft data

Registration mark	PK-GZC
Manufacturer	Boeing Company
Country of manufacturer	United States of America
Type/ model	737-497
Serial number	25664
Date of manufacture	15 November 1992
Certificate of Airworthiness	1969
Date issued	8 October 2006
Validity	7 October 2007
Certificate of Registration	1969
Date issued	8 October 2006
Validity	7 October 2007
Total airframe hours/cycles at 6 March 2007	35,207 hrs / 37,360 cycles
Maintenance – Last A Check	34,960 hrs / 37,192 cycles
Maintenance – Next A Check	35,260 hrs
Maintenance – Last C Check ‘C-02’	31,942 hrs / 34,933 cycles
Maintenance – Next C Check ‘C-03’	36,442 hrs
Maintenance – Last ‘Heavy Maintenance’ Check	23,720 hrs / 28,339 cycles
Maintenance – Next ‘Heavy Maintenance’ Check	47,720 hrs (D Check) hrs

1.6.2 Engine Data

Left Engine

Manufacturer	General Electric Transportation Aircraft Engines
Type/ model	CFM-56-3C-1
Serial number	867735
Date installed	2 May 2005
Installed at airframe hours/ cycles	27,048 hrs / 20,047 cycles
Total time/cycles since new	32,367 hrs / 23,991 cycles
Total hours/cycles installed on left wing	5,319 hrs / 3,944 cycles

Right Engine

Manufacturer	General Electric Transportation Aircraft Engines
Type/ model	CFM-56-3C-1
Serial number	858917
Date installed	2 October 2006
Installed at airframe hours/ cycles	25,135 hrs / 11,364 cycles
Total time/cycles since new	26,505 hrs / 12,382 cycles
Total hours/cycles installed on right wing	5,888 hrs / 4,861 cycles

1.6.3 Weight and Balance

While a load sheet relating to the accident flight could not be located in the wreckage, a copy of the load sheet was sourced from the airline's dispatch office in Jakarta. The investigation determined that the weight of the aircraft at the time of the accident was below the maximum take-off and landing weights, and within the center of gravity limitations specified in the aircraft's *Approved Airplane Flight Manual*.

Maximum allowable take-off weight ex Jakarta	62,822 kg
Actual take-off weight ex Jakarta	55,961 kg
Maximum allowable landing weight at Yogyakarta	54,884 kg
Actual landing weight at Yogyakarta	53,366 kg
Fuel at take off from Jakarta	6,795 kg (8,711 liters)
Flight planned fuel burn	2,595 kg (3,327 liters)
Fuel at landing Yogyakarta (estimate from flight plan)	4,200 kg (5,384 liters)
Flight planned center of gravity at time of the takeoff	19.4 MAC

1.6.4 Aircraft airworthiness and maintenance

Aircraft history

A review of the aircraft's maintenance documentation showed that the aircraft had been issued with an export Certificate of Airworthiness in the United States on 5 October 2002 and issued with its first Indonesian Certificate of Airworthiness on 8 October 2002. At that time, the aircraft had a total time in service (TTIS) of 24,704 hours.

Aircraft system of maintenance

The aircraft had been maintained in accordance with the DGCA Continuous Airworthiness Maintenance Program (CAMP).

The last recorded Aircraft Maintenance Log entry was on 6 March 2007 reporting a thrust reverser light illumination and referred the engineers to a previous defect entry (sequence 43).

That defect had been rectified and the ground engineer signed the aircraft maintenance log that the thrust reverser system was released as being serviceable. The 6 March 2007 defect was also rectified and the thrust reverser system was certified as serviceable.

The Flight/Maintenance Log was located at the accident site. The documentary evidence available to the investigation indicated that the aircraft was serviceable at the commencement of the accident flight.

The approved system of maintenance required a 12-monthly serviceability inspection of the flight and cockpit voice recorders, including a functional check, to ensure that all parameters and channels were correctly recording.

1.6.5 Thrust reversers

The recorded flight data indicated that only the right thrust reverser was used on the previous two landings. Further examination found that only the right thrust reverser had been used for the previous 27 sectors. This indicated that the left thrust reverser may have been unserviceable for a considerable number of flights immediately prior to the accident flight.

Prior to departing Jakarta, during the push back, the PIC contacted the ground engineers and informed them that the number-1 (left) engine thrust reverser fault light on the cockpit instruments had illuminated. The engineers reset the thrust reverser in the engine accessories unit and the fault light extinguished.

The recorded data showed that both engines' thrust reversers were deployed during the landing roll at 23:57:58, 4 seconds after the touchdown. They were stowed at 23:58:05 approximately seven seconds prior to the aircraft departing the paved runway.

1.6.6 Airworthiness status at the time of the accident

There was no evidence of any defect or malfunction with the aircraft or its systems that could have contributed to the accident.

1.7 Meteorological information

1.7.1 Area forecast

The valid Badan Meteorologi dan Geofisika (BMG) forecast that was available to the crew prior to departure from Jakarta, showed no significant weather on the route and indicated that the en-route wind was:

FL270, westerly at 10 to 15 kts.

FL180, westerly at 35 kts.

There were two tropical cyclones situated about 200 kilometers south of Java, but they did not significantly influence the en-route weather for the flight (Figure 9).

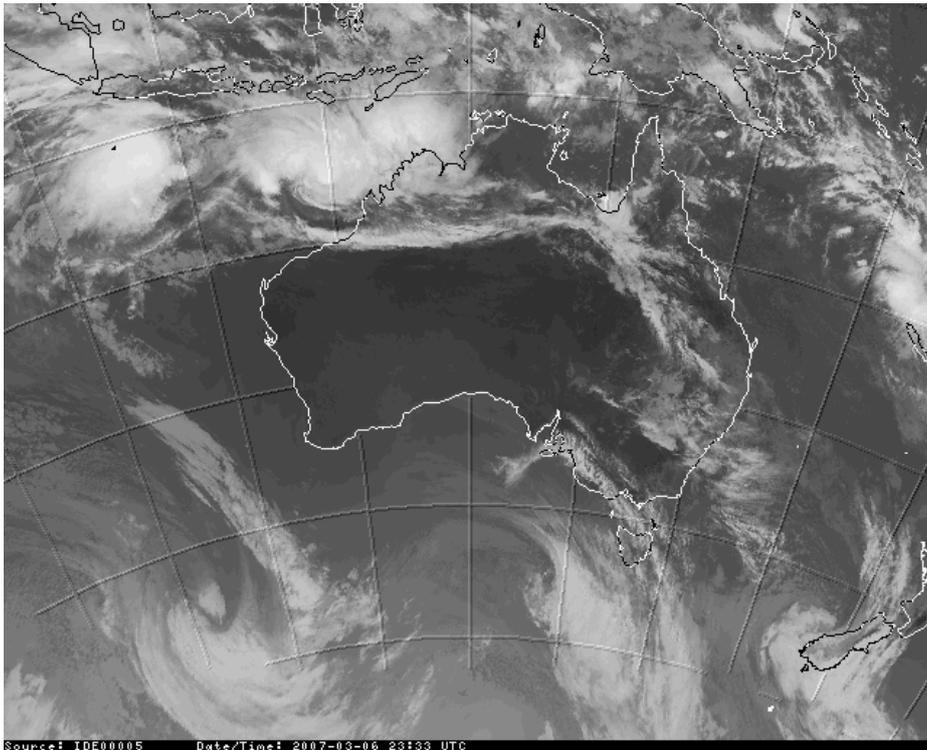


Figure 9: Satellite image of cloud over the Region on 6 March 2007 at 23:33 UTC

1.7.2 Wind data from SSFDR

The wind at:

3,800 feet was 272.8 degrees at 21 knots.

3,000 feet was 268.8 degrees at 19 knots.

2,000 feet was 331.9 degrees at 15 knots.

1,500 feet was 353 degrees at 12 knots.

1,000 feet was 136.4 degrees at 11 knots.

500 feet was 065 degrees at 4 knots.

Note: The listed altitudes are measured as pressure altitude.

1.7.3 Aerodrome forecasts

The BMG issued the following terminal aerodrome forecast (TAF) for Yogyakarta at 06:00 UTC on 6 March 2007. That TAF was available to the crew prior to departure from Jakarta.

WARJ 070007 24010KT 8000 SCT020 TEMPO 0507 5000 TSRA FEW015CB SCT017

TAF (Terminal Aerodrome Forecast) interpretation

Terminal aerodrome forecast for Yogyakarta, valid until 07:00 UTC (14:00 WIB) on 7 March 2007. Wind 240 degrees true at 10 knots; visibility 8 km; scattered cloud at 2,000 feet. Between 05:00 and 07:00 UTC thunderstorms and rain, Few⁸ cumulonimbus cloud with cloud base 1,500 feet. Scattered (SCT⁹) cloud with cloud base 1,700 feet.

1.7.4 Actual weather observations

The Yogyakarta Air Traffic Controller advised the crew:

- QNH¹⁰ 1004 millibars
- Surface wind calm.

There was a westerly wind pattern over the Yogyakarta area and the wind was quite strong at high altitudes such as the cruising altitude for GA200 (Figure 10).

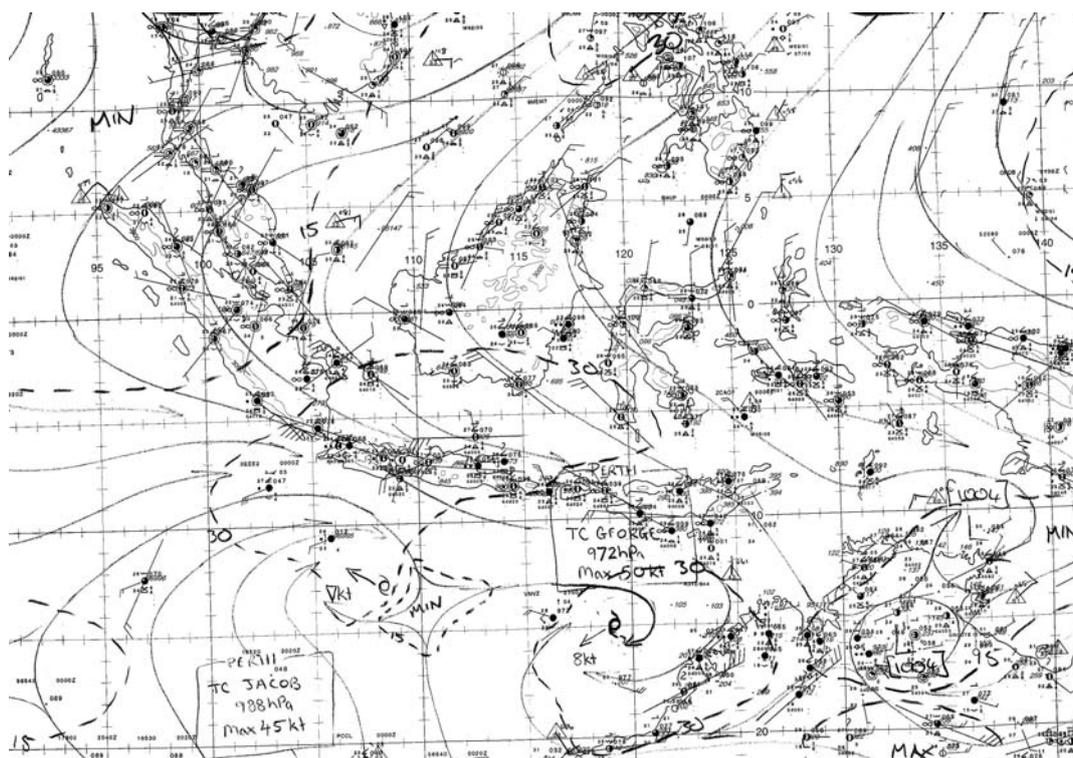


Figure 10: The synoptic chart showing wind patterns on 7 March at 00:00 UTC

⁸ Cloud amounts are reported in oktas. An oktas is a unit of sky area equal to one-eighth of total sky visible to the celestial horizon.

Few: 1 to 2 oktas.

⁹ SCT (scattered): 3 to 4 oktas.

¹⁰ QNH is the barometric pressure setting that enables an altimeter to indicate altitude, that is, the height above mean sea level.

1.8 Aids to navigation

1.8.1 Instrument Landing System (ILS)

The Yogyakarta ILS was last calibrated on 17 February 2007. No aircraft operating into Yogyakarta reported any abnormalities with the ILS.

1.9 Communications

All communications between air traffic services (ATS) and the crew of GA200 were recorded by ground-based automatic voice recording equipment for the duration of the flight. The quality of the aircraft's recorded transmissions was good. Radio transmissions from the crew of GA200 did not indicate any aircraft defects. Aerodrome information

1.9.1 General

Airport name	Adi Sucipto Airport
Airport identification	WARJ
Airport operator	PT. (Persero) Angkasa Pura I
Certificate number	Adm. OC/015/2005
Certificate dated	1 August 2005
Certificate effective for	5 years
Runway Direction	09 / 27
Runway Length	2,200 m
Runway Width	45 m
Surface Condition	Asphalt Concrete

Adi Sucipto Airport, Yogyakarta is a joint military and civil aerodrome, and has a control tower operated by military air traffic controllers who are both military and civilian licensed. The reference point of the aerodrome is 350 ft above mean sea level.

In accordance with the International Civil Aviation Organization (ICAO) Annex 14 specifications, Yogyakarta Adi Sucipto Airport is a Category 3 airport (Figure 11).

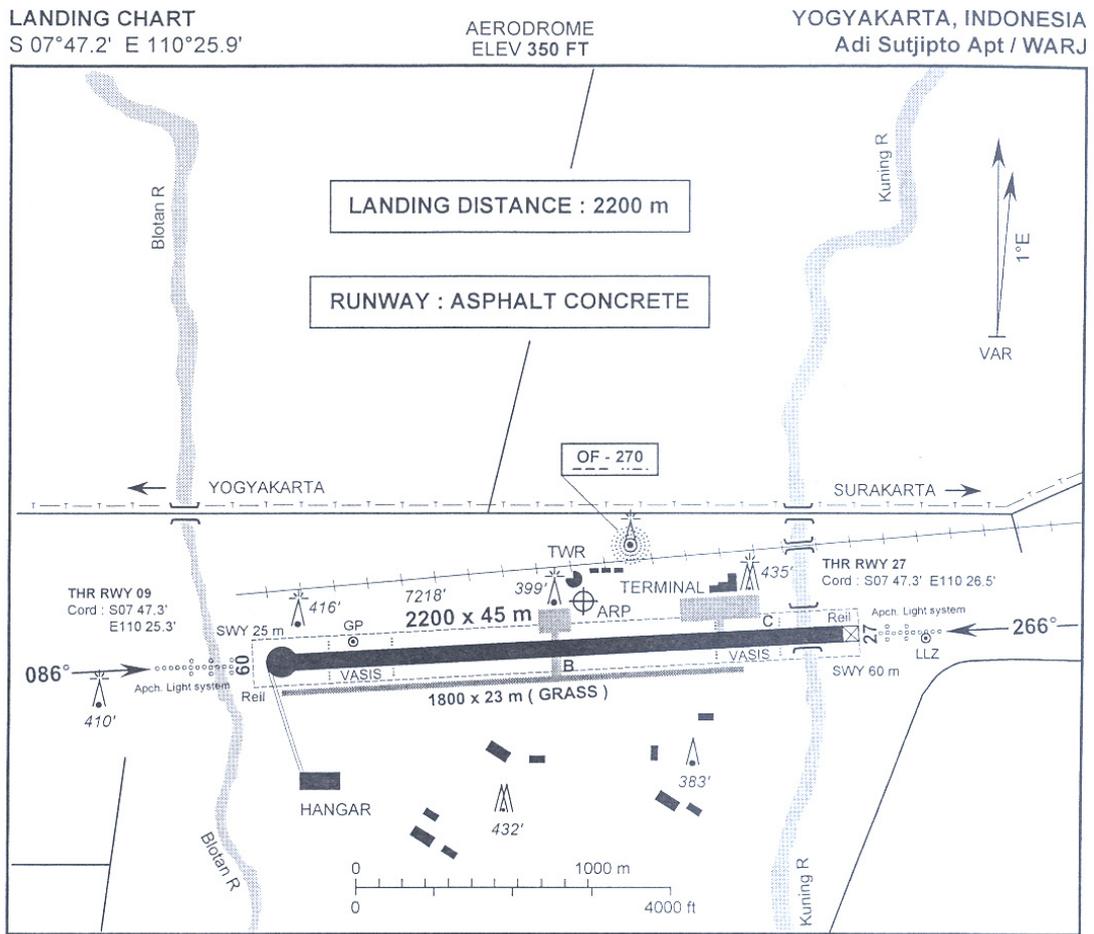


Figure 11: Yogyakarta aerodrome landing chart

1.9.2 Runway End Safety Area (Stopway)

At each end of the 2,200 meter runway there are paved runway end safety areas (RESA); Appendix C:

- Departure end of runway 09. The paved RESA is 60 meters long and an additional grassed area, not defined on the aerodrome chart as a RESA, is 98 meters long.
- Departure end of runway 27. The RESA is 25 meters long.

The RESA did not conform to the International Civil Aviation Organization (ICAO) Annex 14 Standard.

ICAO Annex 14 Paragraph 3.5.2 specified that a RESA shall extend from the end of a runway strip to a distance of at least 90 meters.

ICAO definition of runway strip:

A defined area including the runway and stop-way, if provided, intended:

- a) to reduce the risk of damage to aircraft running off a runway; and
- b) to protect aircraft flying over it during take-off or landing operations.

Paragraph 3.5.3 recommends that for a Category 3 airport such as Yogyakarta, a RESA should, as far as practicable, extend from the end of a runway strip to a distance of at least 240 meters.

Figure 12 shows distances between the runway and the accident site, and significant obstructions.

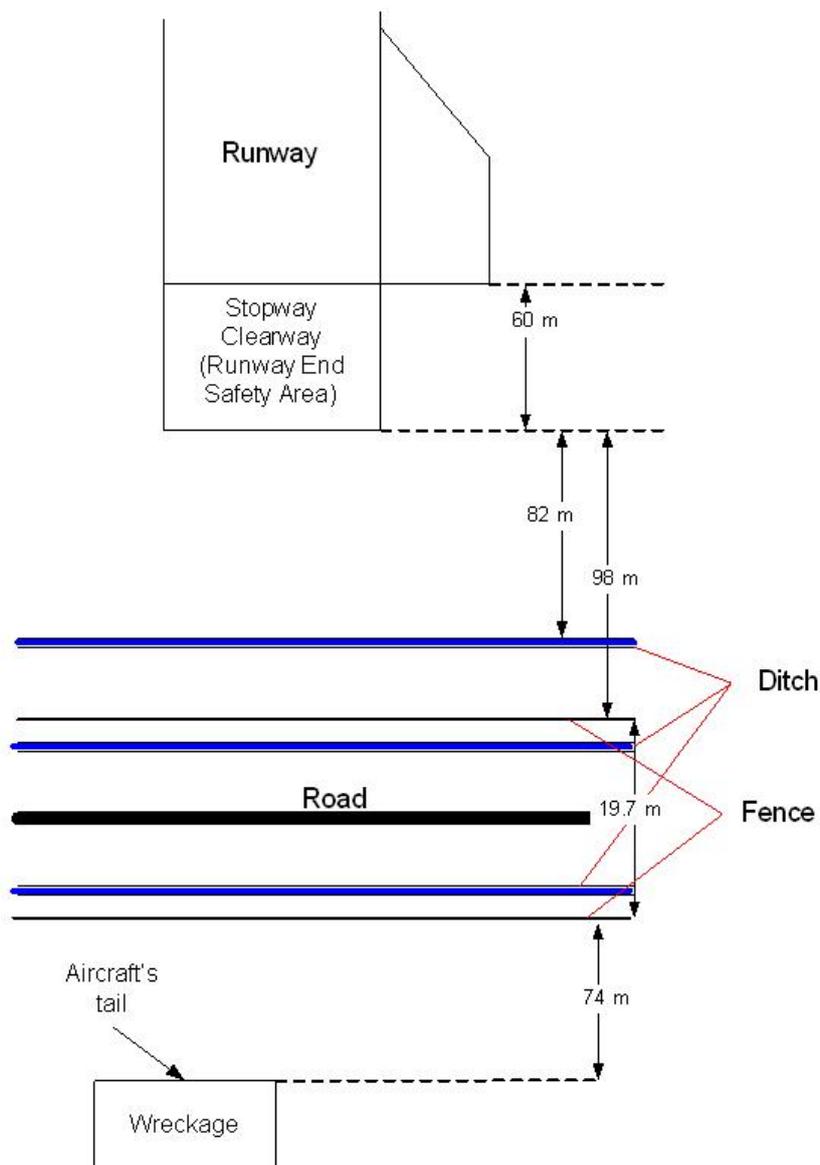


Figure 12: Dimensions from runway 09 departure threshold to tail of aircraft

1.9.3 Rescue and fire fighting

The Fire Fighting personnel of Adi Sucipto Airport, Yogyakarta were standing by on the fire fighting vehicles when GA200 was on final approach. They reported that they saw that the aircraft was landing at an unusually fast speed and was higher than normal; 'tend to high'. They observed the nose wheel tire burst as the wheel touched down. This was followed by sparks produced by the wheel scraping the runway. They responded by mobilizing two fire fighting vehicles to the perimeter fence beyond the end of the runway.

The fire fighting vehicles were dispatched in a timely manner to the crash site, but they stopped on the airport, behind the airport perimeter fence, which was about 158 meters from the departure end of runway 09. After the airport perimeter fence, there was a slope or small embankment between the road and runway. The fire vehicles sprayed the foam fire suppressant from the embankment (near the airport perimeter fence).

The fire fighters realized that the distance was too far to use the spray gun so they decided to use the extension flexible hose. During the deployment of the flexible hose, it was punctured by rescue vehicles and onlookers' vehicles driving over it, as well as sharp objects such as the airport fencing. As a result, the foam spray was leaking from many places along the damaged hose, therefore the discharge pressure from the flexible hose was too weak to be effective. Accordingly, the foam was not able to cover the whole surface of the aircraft wreckage. The lack of an access road, and the difficult/uneven terrain, resulted in the fire vehicles being unable to reach the accident site.

The Airport Emergency Plan (AEP) required, the chief of fire fighting AP1 to lead the fire fighting operation, but at the time of the accident he was not able to lead the operation, due to too many people trying to act as leader and giving commands to fire fighting personnel. About 45 minutes after the accident, two city fire fighting vehicles arrived and were ordered by an un-qualified person to start hosing the fire. However, the city vehicles did not have foam; only water.

The fire was extinguished about 2 hours and 10 minutes after the accident.

The rescue operation continued until late afternoon. The airport operator did not establish a collecting area, care area, or holding area at the accident site, as required in the AEP. Coordination and procedures during the rescue were not in accordance with the AEP manual. There was no specific area to facilitate victims' triage.

There was no appropriate rescue coordination at the crash site, due to the AEP not being followed and too many unqualified people giving instructions.

1.10 Flight Recorders

1.10.1 Flight data recorders

The aircraft was equipped with a Solid State Digital Flight Data Recorder (SSFDR) and a Solid State Cockpit Voice Recorder (SSCVR).

The recorders were recovered from the accident site, sealed in a container, and transported to the Australian Transport Safety Bureau's flight recorder replay and analysis laboratory in Canberra, Australia. They arrived within 48 hours of the accident. At Canberra the container was met by ATSB investigators and taken to the laboratory where the seal was opened under the supervision of officials from the Embassy of the Republic of Indonesia.

1.10.2 Solid State Flight Data Recorder (SSFDR)

The SSFDR was severely burnt during the post-impact fire (Figure 13). However, the crash protection module survived the impact and fire. It contained 53 hours and 28 minutes of data¹¹, including data relating to the entire accident flight and 31 previous flights.



Figure 13: SSFDR from PK-GZC

¹¹ The SSFDR compressed the flight data prior to it being recorded and, as a result, the recording duration of the recorder exceeded the minimum requirement of retaining the most recent 25 hours.

The investigation's examination of the SSFDR revealed that the following engine parameters were not being recorded: N1; N2; Fuel Flow; EGT; oil pressure; oil temperature. Glideslope, localizer, and radio altimeter data were also not recorded. Although the aircraft was equipped with an Electronic Flight Instrument System (EFIS) and Engine Indicating System (EIS), the aircraft's Digital Flight Data Acquisition Unit (DFDAU) was not able to process information from these systems and instead looked to non-existent analogue sources of data for many parameters normally supplied by EFIS and EIS.

While the SSFDR recorded well in excess of 32 parameters, it did not record all of the specific mandatory 32 parameters listed in ICAO Annex 6, Part 1, Table D-1.

Despite the problems due to the lack of some data, the recorded data contained valuable information about the aircraft's systems and its flight profile leading up to the accident.

At the time of the accident, the DFDAU installed on PK-GZC was Teledyne P/N 2227000-45, S/N 895 and the SSFDR was Honeywell P/N 980-4700-003 S/N 3742. These details were confirmed from the Garuda maintenance record titled List 400A PK-GZC Component Install, dated 6 March 2007.

The following information provides the status of the DFDAU and SSFDR from the arrival of the aircraft to the Garuda fleet on 8 October 2002:

a. DFDAU

Teledyne P/N 2233000-4A, S/N 2377 was fitted. This was replaced by Garuda with Teledyne DFDAU P/N 2227000-45, S/N 895, on 16 June 2004.

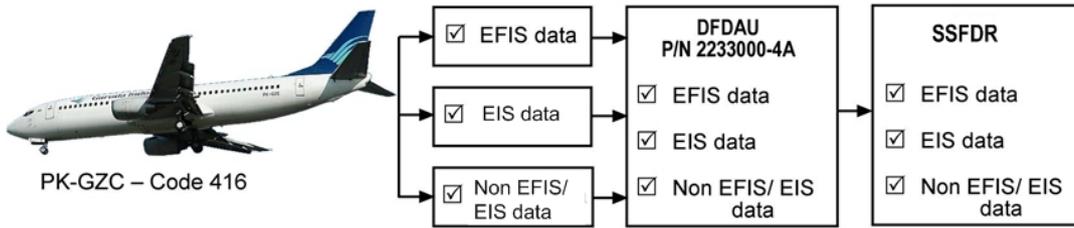
The Illustrated Parts Catalog (IPC) for Boeing 737-300/400/500, 31-24-22-01B page 2 January 12/05 Figure 1B, indicated that the Teledyne DFDAU, P/N 2227000-45 was suitable for aircraft between codes 408 and 410 (Appendix E). However, the aircraft IPC code for PK-GZC was 416. Therefore, the Teledyne DFDAU, P/N 2227000-45 was not appropriate for PK-GZC. The original fitment Teledyne DFDAU, P/N 2233000-4A was suitable for aircraft between codes 415 and 418 (Appendix E) and therefore was appropriate for PK-GZC.

In accordance with the Garuda Component [status] List 400A, the DFDAU, P/N 222700045, which was incorrectly installed on PK-GZC, was only suitable for the Garuda Boeing 737 aircraft registered PK-GWV, GWW, GWX, and GHT.

b. SSFDR

L-3 Communication Aviation Recorders, Solid State Flight Data Recorder (SSFDR) P/N 2100-4043-00, S/N 01990 was fitted. During the service life of the aircraft, the SSFDR was replaced a number of times by Garuda. The last SSFDR, which was installed on 9 February 2007, was P/N 980-4700-003, S/N 3742.

PK-GZC original fitment – DFDAU 2233000-4A effective on PK-GZC (Boeing 31-24-22-01B)



PK-GZC fitment at time of accident – DFDAU 2227000-45 NOT effective on PK-GZC (Boeing 31-24-22-01B)

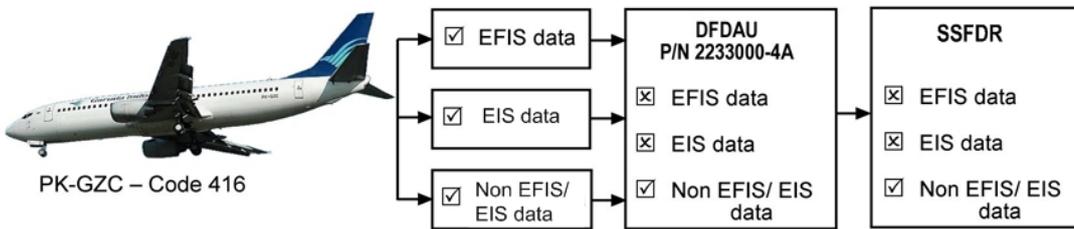


Figure 14: PK-GZC flight recorder system mismatch resulting in SSFDR not recording EFIS and EIS parameters

1.10.3 SSFDR readout

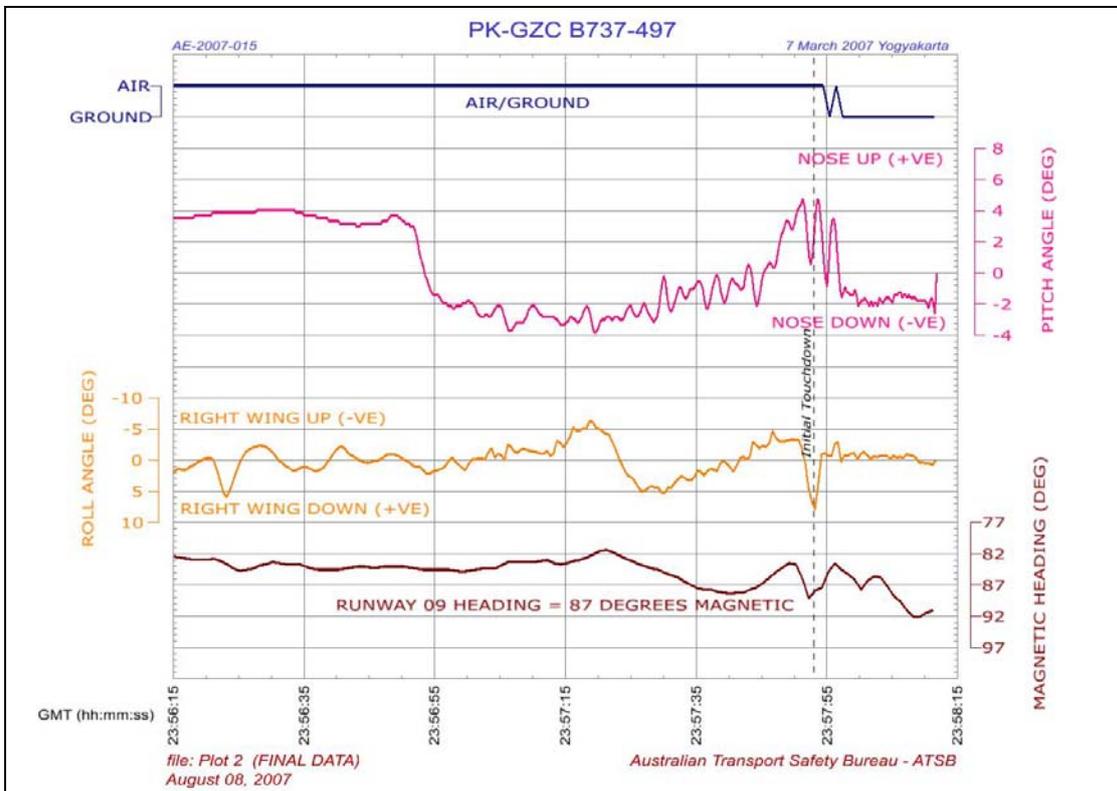


Figure 15: Data from SSFDR of final 2-minute period of accident flight

The SSFDR data was downloaded at the ATSB in Canberra. The data below, covering the flight from 23:51:11 has been corrected for pressure altitude and airspeed components. Some information from the SSCVR, air traffic control recorded information has been included in this section to assist readers understanding of the SSFDR recorded data and the flight events.

23:51:11 Pressure altitude 10,336 feet, airspeed 252 knots and wind velocity 205 degrees / 52 knots.

23:53:11 Pressure altitude 8,448 Feet, airspeed 251.5 knots and wind velocity 210.9 degrees / 41 knots.

23:54:10 Pressure altitude 6,560 feet, airspeed 269 knots and wind velocity 230 degrees / 38 knots.

The Approach Controller asked the crew to confirm that they were visual. The copilot responded 'affirm'.

The Approach Controller acknowledged and issued a clearance for GA200 to make a visual approach to runway 09 and track to a long final position and report again to the controller when they had the runway in sight. The copilot read back the clearance and asked if they were cleared to descend to the circuit altitude.

23:54:33 Pressure altitude 5,792 feet, airspeed 279 knots and wind velocity 236.5 degrees / 28 knots.

The controller cleared GA200 to initially descend to 2,500 feet. The copilot acknowledged and read back the clearance limitation 2,500 feet. The controller then informed GA200 that another aircraft would take off in 1 minute for Bali. The copilot responded 'copied'.

23:55:11 until 23:57: 19, (2 minutes and 8 seconds).

The airspeed increased from 288 knots to 293 knots then reduced to 243 knots. The peak airspeed of 293 knots occurred at 4,384 feet pressure altitude, or 3,419 feet above aerodrome elevation.

The pilot was trying to correct the descent profile by using level change mode for descent. In accordance with the Garuda Aircraft Operation's Manual, Part 2.3, Section 2.3.4, Paragraph 5, the maximum control speed when operating in the terminal area below 10,000 feet is 250 knots.

23:55:19 Pressure altitude 4,384 feet, airspeed 293 knots and wind direction from 275.6 degrees at 23:56:17 to 291.1 degrees at 23:55:21, speed 31 knots.

23:56:31 Pressure altitude 3,520 feet, airspeed 243.5 knots and wind direction from 263 degrees at 23:56:29 to 270 degrees at 23:56:31, speed 21 knots.

The copilot established contact with the Yogyakarta Adi Sucipto Airport Tower Controller.

23:56:35 Pressure altitude 3,456 feet, airspeed 239.5 knots and wind direction from 270 degrees at 23:56:31 to 257.3 degrees at 23:56:37, speed 20 knots.

Wing flaps 1 degree position set.

The Yogyakarta Tower Controller, responded 'surface wind calm, continue approach runway 09 report final' and then informed the crew that a military trainer had lined up on the runway.

- 23:56:46 The PIC asked for 'gear down' with the speed 231 knots and pressure altitude of 3,296 feet or 2,596 feet above aerodrome elevation.
- 23:56:51 Pressure altitude 3,200 feet, airspeed 227.5 knots and wind direction from 268.6 degrees at 23:56:49 to 255.9 degrees at 23:56:52, speed 19 knots.
The Yogyakarta Tower Controller informed a departing aircraft that the wind on the ground at Yogyakarta was calm.
- 23:55:19 until 23:57:19, (2 minutes)
The aircraft's speed reduced by 48 knots and its altitude decreased by 2,688 feet.
- 23:56:51 The nose landing gear reached the fully extended position.
- 23:56:53 Both main landing gear reached the fully extended position.
- 23:57:14 The PIC called 'check speed, flaps fifteen'.
- 23:57:15 GPWS sounded a number of "SINK RATE" alerts, followed by a number of "TOO LOW TERRAIN" alerts until 23:57:49.
The terrain closure rate at 23:57:15 was 3,461 feet per minute when the aircraft was 1,369 feet above the aerodrome elevation, and at 23:57:49 the terrain closure rate was 2,892 feet per minute when the aircraft was 25 feet above the aerodrome elevation.
- 23:57:17 The copilot called 'flaps five'.
- 23:57:19 Pressure altitude 1,728 feet, airspeed 243 knots and wind velocity 353 degrees / 9 knots, and the rate of descent was 2,560 feet per minute.
The Tower Controller contacted GA200 and said 'Indonesia 200, wind calm, check gear down and lock clear to land runway 09'.
- 23:57:21 Pressure altitude 1,632 feet, or 1,017 feet above the aerodrome elevation, airspeed 245 knots.
- 23:57:22 Pressure altitude 1,568 feet, or 953 feet above the aerodrome elevation, airspeed 245 knots. At this time the aircraft's approach was not stabilized.
The GPWS sounded the "TOO LOW TERRAIN" alert twice. The rate of descent was 2,880 feet per minute.
- 23:57:23 The copilot selected wing flaps to the five degree position when the aircraft was at 1,536 pressure altitude.
- 23:57:24 Pressure altitude 1,472 feet, airspeed 248.5 knots and wind direction from 353 degrees at 23:57:21 to 066.1 degrees at 23:57:25, speed 6 to 9 knots.
The PIC acknowledged the landing clearance with the Tower Controller by saying, 'Clear to land Indonesia 200'.
- 23:57:29 Pressure altitude 1,248 feet, airspeed 251.5 knots. The PIC asked for 'Check speed, flaps fifteen'.
- 23:57:31 The aircraft's pressure altitude was 1,184 feet, or 569 feet above the aerodrome elevation. The airspeed was 254 knots and the rate of descend was 1,600 feet per minute. The wind velocity was 136 degrees / 8 knots.

- 23:57:34 The flaps reached the five degrees position when the speed was 248 knots, at 1,088 feet pressure altitude or 473 feet above aerodrome elevation.
- 23:57:41 GPWS sounded the ‘WHOOOP, WHOOP, PULL UP’ warning twice until 23:57:45. At 23:57:45 the terrain closure rate was 1,517 feet per minute, and the aircraft was 153 feet above the aerodrome elevation.
- 23:57:43 Pressure altitude 832 feet, or 185 feet above the aerodrome elevation, airspeed 240.5 knots, and wind direction from 170.2 degrees at 23:57:41 to 049.2 degrees at 23:57:45, speed constant at 5 knots.
- The copilot called ‘Wah Capt, go around Capt’.
- 23:57:47 Seven seconds before touchdown, the rate of descent was 1,400 feet per minute and decreasing. The aircraft crossed the runway 09 threshold (Figure 14) 89 feet above the ground (704 feet pressure altitude), at an airspeed of 234 knots (groundspeed of 236 knots).
- The aircraft leveled off about ten feet above the runway¹² for 4 seconds before touching down at 23:57:54



Figure 14: Picture taken from the SSFDR animation

¹² Below 100 feet above ground level the pressure altitude may be influenced by ground effect.

23:57:49 GPWS fifteenth alert/warning ceased.

23:57:54 The aircraft touched down 860 meters from the runway 09 threshold at an airspeed of 221 knots (groundspeed 224 knots). The copilot called with high intonation 'go around'.

The vertical acceleration on the first touchdown was +1.86 g; the subsequent touchdown was +2.26 g; and the last touchdown reached a vertical acceleration peak of +2.91 g.

23:57:58 Thrust reversers deployed.

23:58:05 Thrust reversers stowed.

23:58:10 The aircraft left the sealed runway, to the right of the centerline, at the 09 departure end, at 110 knots.

Aircraft brake data was not a parameter recorded on this SSFDR, nor was it required in accordance with ICAO Annex 6, Chapter 1, Paragraph 1.2, 'Parameters to be recorded'.

1.10.4 SSFDR maintenance program

The maintenance program of the SSFDR was in accordance with the approved Garuda Continuous Airworthiness Maintenance Program (CAMP), specifically:

The SSFDR was required to be checked once a year to verify that all parameters were being recorded. The CAMP started:

3124 010 2 00, TASK CARD B31-24-00-2A, ZONE 108 ACCESS S1082, FUC, Eff ALL, Int 1 YR, MPD B31-24-00-2A; FLIGHT DATA RECORDER, THE FLIGHT DATA RECORDER SYSTEM CHECK TO VERIFY THAT ALL PARAMETERS ARE BEING RECORDED.

1.10.5 Solid state cockpit voice recorder (SSCVR)

The SSCVR sustained heat damage during the post-impact fire, but it appeared to have survived the impact and fire (Figure 15). However, normal recovery methods were unable to facilitate the download of the SSCVR data.

The SSCVR manufacturer was consulted, and methods of recovery described by the manufacturer also failed to aid in the recovery of the data.



Figure 15: SSCVR from PK-GZC

In an attempt to recover data from the SSCVR, the ATSB sent the SSCVR to the SSCVR manufacturer in the United States under the supervision of an ATSB flight recorder investigator. Using specialist equipment at its factory, the SSCVR manufacturer was able to download the data from the SSCVR. This work was witnessed by officials from the Embassy of the Republic of Indonesia, and the US National Transportation Safety Board's Accredited Representative's advisers.

The SSCVR manufacturer found that the pointers contained in the electrically erasable programmable read-only memory (EEPROM) on the SSCVR memory module card were corrupted. It is likely that this occurred during the severe impact sequence. Resetting the pointers was only able to be accomplished at the manufacturer's facility. Following resetting, the SSCVR data was successfully downloaded.

The downloaded data was secured and sent to the ATSB laboratory in Canberra, Australia, in a sealed container. On arrival, officials from the Canberra Embassy of the Republic of Indonesia observed the sealed container, and it was then placed in a locked safe at the ATSB laboratory to await the arrival of National Transportation Safety Committee (NTSC) investigators. The NTSC investigators removed the seal and analyzed the recorded data. The data provided valuable information about sounds in the cockpit, crew interactions and conversations, and confirmed air traffic control instructions and responses by the crew of GA200.

The maintenance program of the SSCVR was in accordance with the approved Garuda Continuous Airworthiness Maintenance Program (CAMP).

The CAMP required that the SSCVR was to be checked once a year by conducting a functional check of all channels. The CAMP stated:

2371 050 1 00, AMM 23-71-00-735-000 P. 502, FUC, Eff ALL, Int 1 YR,
DGAC AU/5021/DSKU/1975/20, VOICE RECORDER SYSTEM PERFORM
FUNCTIONAL CHECK TO VOICE RECORDER SYSTEM

1.10.6 SSCVR information

During cruise flight, a few minutes before the aircraft left the cruising altitude, the PIC gave a complete crew briefing about the instrument landing system (ILS) approach, including the possibilities of a Localizer approach in the case of glide path failure. However, the PIC did not brief for a visual approach in the event that they might be in visual conditions, and even after the Yogyakarta Tower Controller cleared them for a visual approach, the PIC did not update his intentions to the copilot about how to execute the visual approach.

Up to the time of the top of descent briefing, the oral communication between the PIC and the copilot, air traffic control approach and tower controllers, and the company radio, were in normal tones and in an orderly manner. Subsequently, during the approach below 10,000 feet and prior to reaching 4,000 feet, the PIC was singing and there was some minor non-essential conversation, which was not in accordance with the Garuda Basic Operations Manual policy for a sterile cockpit below 10,000 feet.

At 23:57:13, or 41 seconds before the aircraft touched down, the PIC said ‘check speed, flaps fifteen’. At that time the recorded airspeed was 238 knots. The maximum indicated airspeed for extension of flaps to the 15 position is 205 knots.

The GPWS started to sound the ‘SINK RATE’ alert, followed by other GPWS alerts and warnings, continuously until the aircraft touched down. There was a total of 15 very loud GPWS alerts and warnings during the approach.

The copilot did not give the PIC an oral caution when he did not follow the PIC’s order to extend the flaps to the 15 position. The oral communication between the pilots changed from the previous tone, when the copilot did not act on the PIC’s orders.

For 11 seconds from 23:57:29, when the aircraft’s pressure altitude was around 1,248 feet, or 633 feet above the aerodrome elevation, the PIC requested flaps 15 four times: ‘check speed, flaps fifteen’; ‘flaps fifteen’; ‘flap fifteen’; and finally, ‘Check speed flap fifteen’. The SSFDR data showed that the speed was around 252 knots at the first of these four times the PIC requested flaps fifteen. During that time, and until 1 second before the GPWS sounded ‘ten’, meaning 10 feet above the runway, the GPWS warning continued to sound loudly.

Immediately after the second GPWS ‘WHOOOP, WHOOP, PULL-UP’ warning, at 23:57:45, when the aircraft was 153 feet above the aerodrome elevation, the copilot called out ‘Wah Capt, go-around Capt’ to the PIC. The PIC did not give oral reaction to the warning, but simply asked ‘landing checklist completed, right?’

Immediately after touchdown, the copilot called with high intonation, ‘go-around’, but the PIC did not respond orally, or with actions to comply.

1.11 Wreckage and impact information

1.11.1 Accident site description

The accident site was located in a rice field about 252 meters beyond the departure end of Yogyakarta Adi Sucipto runway 09. It was an open field with airport approach lighting infrastructure. The aircraft stopped adjacent to the runway approach lights, and to the right of the runway extended centerline. The approach lights were not damaged (Figure 16).



Figure 16: Runway approach lights adjacent to the accident site

1.11.2 General wreckage description

The nose wheel assembly separated from the aircraft on the runway. The engines and landing gear separated from the aircraft and were destroyed. The right wing was severed from the fuselage and swung around the fuselage and came to rest on top of the left wing (Figure 17).



Figure 17: Severed right wing on the left wing

The cockpit area folded back and came to the rest inverted on top of the forward passenger cabin. The aircraft was destroyed by impact forces and the intense fuel-fed, post-impact fire (Figure 18).



Figure 18: General view of the accident site looking back along the direction of the landing

The following component information was noted:

- Both thrust reversers were in the closed position; the stowed position.
- All ground spoilers were in the closed position.
- The auxiliary power unit (APU) was off, and the APU door was closed.
- The left rear door slide was out of its container and the slide bar was attached to door frame. No other evacuation slides were deployed.
- The right side of the fuselage was destroyed by the post-impact fire.
- The left over-wing emergency exit windows were opened.
- Both main landing gear assemblies separated from the wings during the impact.
- Flap position. The measurement was taken from the right inboard flap (outboard and inboard screw jacks). The outboard screw jack was at position 31.5 cm from the end stop, and the inboard screw jack was 31.5 cm from the end stop (Figure 19). The flap position corresponded to 5 degrees extended, or flap 5 position.



Figure 19: Flap screw jack

- The wing leading edge slats were extended.
- The landing gear was fully extended.
- Both engines separated from the wings during the impact.
- The avionics compartment was substantially damaged as the lower nose section stuck the ground. Many components were found along the wreckage trail behind the airframe and some of them were burnt.
- Damage to the engines' fan blades was consistent with low RPM at ground impact.

1.11.3 Aircraft structure

The aircraft structural damage was consistent with the application of excessive structural overload during the impact sequence, and the effects of the intense fuel-fed post-impact fire.

1.12 Medical and pathological information

Both pilots were uninjured, and medical tests revealed no evidence of physiological impairment. The results from the tests for drugs and alcohol were negative.

One cabin crew member received fatal burns.

Passengers' injuries resulted from the impact, and the post-impact fire.

1.13 Fire

Fuel from the disrupted right wing fed the intense post-impact fire that consumed the aircraft. The right wing fuel tanks exploded during the impact (Figure 20 and Figure 21).



Figure 20: Lower side of right wing at root end



Figure 21: Close-up view of fuel burn explosion damage to right wing

1.14 Survival aspects

The impact forces and the post-impact fire were initially most severe in the forward section and the right side of the aircraft, where the majority of the victims were seated.

One flight attendant, seated in a cabin crew seat in the forward galley area ahead of the Business Class passenger section, was fatally injured. One other flight attendant was seriously injured.

The remaining flight attendants carried out the evacuation procedures, assisting passengers from the left side of the aircraft. They continued to render assistance to the injured passengers while they waited for ambulance and medical assistance to arrive at the scene.

1.15 Test and research¹³

1.15.1 Controlled Flight Into Terrain (CFIT) and Approach-and-landing Accident Reduction (ALAR)¹⁴

Research conducted by an industry task force, under the auspices of the International Civil Aviation Organization (ICAO), attributed 80 per cent of fatalities in commercial transport aircraft accidents, worldwide, to controlled flight into terrain (CFIT) accidents, and accidents occurring during the approach-and-landing phase. CFIT occurs when an airworthy aircraft, under the control of the flight crew, is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew.

This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phase. This phase begins when an airworthy aircraft, under the control of the flight crew, descends below 5,000 feet above ground level (AGL), with the intention to conduct an approach. It ends when the landing is complete or the flight crew flies the aircraft above 5,000 feet AGL en route to another aerodrome.

In late 1992, in response to a high CFIT accident rate worldwide, the Flight Safety Foundation (FSF) formed a CFIT and Approach and Landing Task Force. By mid-1993, ICAO and FSF had agreed to a cooperative approach to the CFIT problem. A number of teams were formed, focusing on such aspects as aircraft equipment, flight crew training and procedures, flight operations, and ATS training and procedures. From the work of these teams, a number of issues were highlighted. Those relevant to this accident include:

- Ground proximity warning systems (GPWS)

Given the substantial safety benefits of GPWS, the task force considered that all aircraft in commercial and corporate use, including those involved in domestic operations only, should be equipped with GPWS.

- CFIT and Approach-and-Landing Accident Reduction (ALAR) awareness material

The FSF CFIT task force developed a complete CFIT education and prevention package for the aviation community worldwide. The package consisted of a number of safety awareness products, including a CFIT Safety Alert, CFIT Checklist and a number of educational video productions. The checklist was designed to assist aircraft operators in evaluating the CFIT risk for a particular route or flight. It was also useful in highlighting aspects of company operations, which might be contributing to CFIT risk.

A copy of the CFIT checklist is included at Appendix H. In addition, ICAO produced a CD-ROM titled 'CFIT Education and Training Aid'. The FSF task force also produced an ALAR tool kit, which consists of an 'Approach-and-landing Risk Reduction Guide'. A copy of the ALAR tool kit guide is included at Attachment H. The education and training packages were distributed to the worldwide civil aviation industry by the FSF and by ICAO to its Contracting States.

¹³ Information contained in this section was sourced from the ATSB report BO/200105768 (available at www.atsb.gov.au), and includes information from the ICAO and Flight Safety Foundation (FSF) internet web-sites.

¹⁴ Copies of the ALAR education and training programs, including video programs, are available in CD-ROM format and can be obtained directly from the FSF (www.flightsafety.org).

1.16 Organizational and management information

1.16.1 Garuda safety programs and training

At the time of the accident Garuda had not implemented a Flight Operations' Quality Assurance (FOQA) program. Pilot monitoring was through annual line checks, simulator proficiency checks, and a review of selected incidents using flight recorder data.

Garuda has safety programs that include mandatory reporting through Aviation Safety Reports, and Operational Hazard Reports, where line crews can report safety related matters using specific forms. It is not mandatory to provide personal details on the form in order for it to be accepted. Garuda informed the investigation that when a report is received from a crew member, the Safety Department takes necessary action to follow-up.

A Training-Line Operation's Analysis (T-LOA) project, designed by Massey University School of Aviation, was conducted in 2001.

The findings taken from the observations of 323 flights involving Boeing 737 and Airbus A330, and 30 instructional observations, included:

- Situational awareness and decision making were weak
- Very steep cockpit gradient
- Crew coordination was poor
- Captains very often ignoring First Officer input.

The T-LOA team recommended that due to the frequency of unstable approaches, (in particular high and fast approaches) Approach Safety Window should be included in Type Recurrent training program in 2002. The training was repeated during Type Recurrent training in 2005 and 2006.

Garuda's Type Recurrent Ground training program, to be completed in the first 6 months of 2006, included:

Flight procedures covering Approach and Landing (ALAR) toolkit

Controlled flight into terrain (CFIT)

Constant angle non-precision approach (CANPA) Situational awareness

Case studies on Garuda's previous serious incident involving a Boeing 737 unstabilized approach resulting in a runway overrun.

Human performance limitation

Communication

Situational awareness

Threat and error management

Case study a major accident involving one of Garuda's Airbus A300-B4 aircraft.

Garuda's training program, to be completed in the second 6 months of 2006, included simulator type recurrent training covering:

- Adverse weather operations
- Weather minima for takeoff and landing
- Stabilized approach procedures.

Garuda's training program, to be completed in the first 6 months of 2007, included:

- CANPA and CFIT
- Crosswind takeoffs and landings, and bounced landing recovery technique.

1.16.2 Garuda stabilized approach procedure

The Garuda stabilized approach procedure, published in the Aircraft Operation's Manual, Flight Techniques, Approach and Landing section, part 2.3.5, page 2. Issue 3 dated 14 January 2004, was current at the time of the accident. It stated:

STABILIZED APPROACH RECOMMENDATIONS

Maintaining a stable speed, descent rate, and vertical/lateral flight path in landing configuration is commonly referred to as the stabilized approach concept.

Any significant deviation from planned flight path, airspeed, or descent rate should be announced. The decision to execute a go-around is no indication of poor performance.

NOTE: Do not attempt to land from an unstable approach.

Recommended Elements of a Stabilized Approach

All approaches should be stabilized by 1000 feet HAA in instrument meteorological condition (IMC) and by 500 feet HAA in visual meteorological conditions (VMC). An approach is considered stabilized when all of 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 VREF +20 knots indicated airspeed and not less than VREF.
- the aircraft is in the correct landing configuration.
- sink rate is no greater than 1,000 fpm; if an approach require a sink rate greater than 1,000 fpm, a special briefing should be conducted.
- power setting is appropriate for the aircraft configuration.
- all briefing and checklist have been conducted.

Specific types of approaches are stabilized if they also fulfill the following:

- ILS approaches should be flown within one dot of the glideslope and localizer
- During a circling approach, wings should be level on final when the aircraft reaches 300 feet HAA.

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

NOTE: An approach above elements of a stabilized approach require a special briefing that becomes unstabilized below 1,000 feet HAA in IMC or below 500 feet HAA in VMC requires an immediate go-around.

These conditions should be maintained throughout the rest of the approach for it to be considered a stabilized approach. If the above criteria cannot be established and maintained at and below 500 HAA, initiate a go-around.

At 100 feet HAT for all visual approaches, the aircraft should be positioned so the flight deck is within, and tracking so as to remain within, the lateral confines of the runway extended.

As the aircraft crosses the runway threshold it should be:

- Stabilized on target airspeed to within +10 knots until arresting the rate of flare.
- On a stabilized flight path using normal maneuvering.
- Positioned to make a normal landing in the touchdown zone (i.e., first 3,000 feet or first third of the runway, whichever is the less).

Initiate a go-around if the above criteria cannot be maintained.

The Garuda Basic Operation Manual, Part 2.2 Crew Descriptions, Section 2.1.2 Duties and Responsibilities, Sub-section 04 Copilot, paragraph 2, issue 6, dated 22 December 2006, stated:

Duties and responsibilities of a Co-Pilot are to carefully follow the progress of the flight and to give inputs to the PIC, to ask the PIC to take accurate action. In such extraordinary conditions, where the PIC is acting outside of normal circumstances (or incapacitated), jeopardizing the Safety or endanger the Flight, she/he can take needed action to avoid the condition worsening.

1.16.3 Civil Aviation Safety Regulation

The Indonesian Civil Aviation Safety Regulation 121.360 effective 1 April 2001, Ground Proximity Warning/Glideslope Deviation Alerting System (GPWS) stated that:

The Airplane Flight Manual shall contain:

Appropriate procedures for-

- (i) The use of the equipment;
- (ii) Proper flight crew action with respect to the equipment;
- (iii) Deactivation for planned abnormal and emergency conditions;
- (iv) Inhibition of Mode 4 warnings based on flaps being in other than the landing configuration if the system incorporates a Mode 4 flap warning inhibition control.

1.16.4 Garuda GPWS procedures

The flight techniques for terrain avoidance described in the Garuda AOM part 2.3.8 page 8, stated that:

The GPWS 'PULL-UP' warning occurs for an un-safe closure rate with the terrain. Immediately accomplish the following recall, disconnect the auto pilot and auto throttles. Aggressively apply maximum thrust. Roll wing level and rotate to an initial pitch attitude of 20 degrees. retract the speed brakes if extended.

121.360 Ground Proximity Warning/Glideslope Deviation Alerting System (GPWS)

- (a) No person may operate a turbine-powered airplane after April 1, 2001 unless it is equipped with a ground proximity warning system (GPWS).
- (b) The ground proximity warning system required by this section shall provide as a minimum warnings of the following circumstances:
 - (1) Excessive descent rate
 - (2) Excessive terrain closure rate
 - (3) Excessive altitude loss after take-off or go-around
 - (4) Unsafe terrain clearance while not in landing configuration
 - (i) gear not locked down
 - (ii) flaps not in landing position
 - (5) Excessive descent below the instrument glide path
- (c) For the ground proximity warning system required by this section, the Airplane Flight Manual shall contain-
 - (1) Appropriate procedures for-
 - (i) The use of the equipment;
 - (ii) Proper flight crew action with respect to the equipment;
 - (iii) Deactivation for planned abnormal and emergency conditions;
 - (iv) Inhibition of Mode 4 warnings based on flaps being in other than the landing configuration if the system incorporates a Mode 4 flap warning inhibition control...
 - (2) An outline of all input sources that must be operating.
- (d) No person may deactivate a ground proximity warning system required by this section, except in accordance with the procedures contained in the Airplane Flight Manual.
- (e) Whenever a ground proximity warning system required by this section is deactivated, an entry shall be made in the airplane maintenance record that includes the date and time of deactivation.

1.16.5 Garuda GPWS training policy

CASR 121 sub-part N did not require GPWS or EGPWS simulator training for flight crews. However, the Garuda Flight Crew Training Manual Part 4.3 Simulator Training Curriculum stated:

A. GENERAL

Simulator training GPWS/EGPWS will focus on the CFIT and will address the avoidance and escape maneuver of GPWS/EGPWS alert and warning as standard operating policy in Garuda Indonesia.

This training should consist of module

- (a) GPWS/EGPWS alerts and warning
- (b) Avoidance of Controlled Flight Into Terrain (CFIT).

B. TRAINING OBJECTIVE

Satisfactory completion of this curriculum segment, a flight crew member properly trained and fulfils the requirement of CASR Part 121.360 – GPWS/EGPWS, CFIT.

1.16.6 Garuda implementation of GPWS training policy

The Recurrent Ground Training Record and the Pilot – Proficiency Check (Simulator) record for the pilots of GA200 showed that in the two years prior to the accident they had completed:

- recurrent ground training courses, which included computer based training (CBT) and general systems knowledge training, including ‘situational awareness CFIT/ALAR’ and ‘windshear’.
- simulator pilot proficiency checks covered ‘windshear during Take-off After Vr’ and ‘Approach’.

The records showed no evidence that the pilots had been checked or received simulator training in appropriate vital actions and responses (escape maneuver) with respect to GPWS or EGPWS alerts and warnings, such as ‘TOO LOW TERRAIN’ and ‘WHOO, WHOO, PULL UP’.

Interviews and discussions with other Garuda Boeing 737 pilots revealed that they had not received this training and had not been checked on these aspects in the simulator.

1.16.7 Garuda Flight Operations Quality Assurance (FOQA) program

On 8 May 2006, Garuda approved the implementation of a FOQA program with scheduled operation of the FOQA program planned for August 2007. Although Garuda did not have an operating FOQA program at the time of the accident, it had been reviewing incidents and accidents as they were deemed necessary to maintain safety. At the time of finalising this report, a FOQA program had not commenced.

On 5 March 2007 (2 days before the accident), Garuda issued a Flight Operation's Notice to Flight Crew number 008/2007, covering the subject, *Serious Incident and Accident*. The notice, signed by the VP Flight Operations, reminded crews of the need for vigilance and to comply with procedures to ensure continued safe operations. It stated that crews were:

1. To obey all procedures and limits, stay cautious during flight duty.
2. To calculate correctly the runway length required for takeoff and landing based on the last reported weather conditions.
3. To perform a -around and/or rejected landing, any time approach stability criteria were not met.
4. To file a written report in the Trip Report and/or Operational Hazard Report when operational deviation is encountered during duty.
5. To file a written report in the air safety report, when an incident, serious incident or accident occurs.

1.16.8 CFIT and ALAR training

The DGCA introduced the CFIT ALAR training program using the United States Flight Safety Foundation' CFIT and ALAR material (Appendices G and H), to all Indonesian operators between 18 and 21 July 2005. The training for operators' training instructors and some line pilots was jointly conducted by the DGCA and International Civil Aviation Organization.

The PIC and Copilot involved in this occurrence had completed CFIT and ALAR training conducted by Garuda instructors in February 2006.

1.16.9 DGCA Surveillance of Garuda flight operations

Review of Garuda records of safety and security audits carried out by Garuda or external agencies indicated that from 1998 the DGCA performed two activities:

- safety inspection audit February 2003, but the results were not provided to Garuda; and
- safety and airworthiness surveillance conducted between 9 March (2 days after the accident) and 18 April 2007. All findings of that surveillance were closed on DGCA files on 30 June 2007.

Surveillance of operators by DGCA is required in accordance with Civil Aviation Safety Regulations. However, the DGCA does not have adequate resources, as well as the detailed guidance of how appropriately the flight operations surveillance should be conducted regularly'. Additionally, the Director advised the investigation that the DGCA had planned to commence a program of en-route checks in 2007, but that had not been commenced.

1.17 Additional information¹⁵

1.17.1 Circumstances leading to flap setting for the landing

At interview, the PIC stated that he continued to call for flap fifteen because he was committed to land from the approach, and was aware that he would not be able to use flaps 40 as planned. He knew the risks, but believed that he could safely land using flaps 15, even with the higher airspeed required for a flap 15 approach.

At interview the copilot stated that he did not extend the flaps to 15 degrees as instructed by the PIC, because the airspeed exceeded the maximum operating speed for flaps 15.

The PIC stated that he was unaware of the actual airspeed, and expected that the copilot would inform him of any speed concerns.

1.17.2 Maximum Flaps Operating speed (IAS)

Flaps 1	250 knots
Flaps 5	250 knots
Flaps 10	215 knots
Flaps 15	205 knots
Flaps 25	190 knots
Flaps 30	185 knots
Flaps 40	162 knots

1.17.3 Landing gear limit speed (indicated airspeed)

Maximum gear extension speed	270 knots
Maximum speed with gear down and locked	320 knots

1.17.4 Maximum tire speed

Maximum tire speed	195 knots (groundspeed)
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1.17.5 Eye witnesses

Eyewitnesses informed the NTSC investigation team that the aircraft landed at an unusually fast speed. They said that the fire fighting team was moving fast, but they could not reach the aircraft, and they took about 15 minutes to install the flexible hose extension. One eyewitness reported seeing foam leaking from the fire vehicle connection and the flexible hoses on the first shoot, and it was fixed by a fireman from Angkasa Pura I. The witness helped to move the flexible hose to the target and took some photos of the process of extinguishing the fire.

¹⁵ Limitations listed in paragraphs 1.18.2 to 1.18.4 are from the Garuda Aircraft Operations Manual Part 2, Chapter 2.8 Operating Limitations, Section 2.8.2 Speed Limitations.

1.17.6 Airport Emergency Plan Manual

The AEP manual was distributed among the rescue and fire fighting units within the airport and the surrounding area. The distributed copy was an uncontrolled copy of the manual. The manual should have been a controlled document. The purpose of maintaining a controlled copy of a manual is to make sure that it is kept up to date through revisions.

The manual did not have a procedure for the appointment of personnel to ensure the manual was appropriate for purpose and updated. The manual did not contain a revision control page or a distribution list.

The AEP manual's procedures were inadequate for use in an emergency operation, especially during a rescue operation involving an aircraft accident. The last emergency exercise conducted was in August 2005, and was within the airport perimeter. People involved in the 2005 rescue exercise were interviewed. They reported that the exercise was ineffective to handle an actual emergency situation that might occur outside the airport perimeter.

The AEP manual did not contain a grid map covering up to 5 NM from the airport perimeter, as required by Transport Minister Decree 47. The manual was only available in Bahasa Indonesia.

ICAO Annex 14 contains Standards and Recommended Practices with respect to Airport Emergency Planning. (Appendix B)

Paragraph 9.1.12;

The plan shall contain procedures for periodic testing of the adequacy of the plan and for reviewing the results in order to improve its effectiveness.

Note.— The plan includes all participating agencies and associated equipment.

Paragraph 9.1.13

The plan shall be tested by conducting:

- a) a full-scale aerodrome emergency exercise at intervals not exceeding two years; and
- b) partial emergency exercises in the intervening year to ensure that any deficiencies found during the full-scale aerodrome emergency exercise have been corrected; and reviewed thereafter, or after an actual emergency, so as to correct any deficiency found during such exercises or actual emergency.

The uninjured passengers and their families were handled directly by the airline. However, the Yogyakarta AEP manual did not contain details of where an appropriate meet and greet room for relatives and injured passengers would be located.

ICAO Annex 14, paragraph 9.1.14 states that:

The airport rescue and fire fighting services shall have a plan that shall include ready availability of coordination with appropriate specialist rescue services to be able to respond to emergencies where an aerodrome is located close to water/or swampy areas and where a significant portion of approach or departure operations takes place over these areas.

Paragraph 9.2.2 states that:

Where an aerodrome is located close to water/or swampy areas and where a significant portion of approach or departure operations takes place over these areas, specialist rescue services and fire fighting equipment appropriate to the hazards and risks shall be available.

Paragraph 9.2.9 recommends that:

The principal extinguishing agent should be a foam meeting the minimum performance level B for a Category 3 aerodrome.

Paragraph 9.2.10 recommends that:

The complementary extinguishing agent should be a dry chemical powder suitable for extinguishing hydrocarbon fires.

Paragraph 9.2.11 recommends that:

The amount of water specified for foam production are predicated on an application rate of 5.5 liters/minute/meters squared for a foam meeting performance level B.

ICAO Annex 14, Table 9.2 (Appendix D) shows that the minimum usable amounts of extinguishing agents for performance level B, at a Category 3 aerodromes, are 1200 liters of water and a discharge rate of foam solution/minute of 900 liters.

1.17.7 Garuda's response to the accident

Garuda reported that when it received the notification about the accident, it sent personnel and buses to the accident site. At the accident site, the airline staff became confused due to many people giving commands/instructions. This situation made Garuda's response to the rescue operation less than effective, because there was no guidance or appropriately trained personnel handling the accident site.

About one hour after the accident, Garuda personnel provided a passenger list to the crisis center and police. The cargo manifest was sent to Yogyakarta from the Garuda office in Jakarta, arriving 33 hours after the accident. A cargo manifest contains vitally important information needed by rescuers and aviation safety investigators in order to know what dangerous goods might be on board an aircraft. The DGCA approved Garuda Emergency Response Plan requires that the aircraft operator must supply a copy of the aircraft passenger and cargo manifests as soon as possible after an accident.

1.17.8 Ground proximity warning system (GPWS)

GPWS provides flight crew with aural and visual alerts and warnings when the aircraft is not configured for a landing, and one of the following thresholds are exceeded between 50 and 2,450 ft radio altitude:

- excessive descent rate
- excessive terrain closure rate
- altitude loss after take-off or go-around
- unsafe terrain clearance while not in the landing configuration
- below glideslope deviation

ICAO standards and recommended practices with respect to fitment of GPWS are contained in Annex 6, Operation of Aircraft.

The function of GPWS is to prevent approach and landing accidents and controlled flight into terrain (CFIT) accidents.

1.17.9 Media reporting

A number of news media reported that Garuda had a fuel conservation policy that may have influenced Garuda pilots, encouraging them to conserve fuel. The media reports sought to convey the meaning that the PIC was influenced by that policy, to continue the landing and not go around.

On 28 February 2007, Garuda issued a Flight Operations, Flight Crew Notice, number 07/07, signed by the VP Flight Operations, covering the subject 'Fuel efficiency incentive'. The document encouraged crews to conserve fuel, and every 3 months the crews would receive a bonus based on a formulae, which would consider the difference between planned fuel and actual fuel consumed. The document indicated that the incentive program was to commence on 1 March 2007.

At interview, the PIC informed the investigation that his decision to continue to land the aircraft was not in any way influenced by that incentive program.

2 ANALYSIS

2.1 Introduction

The fundamental tenet of the model of the organizational accident is that organizational factors, such as decisions by a regulator, and senior management decisions, can combine with local workplace factors such as poorly trained staff, and unsafe acts, such as maintenance staff applying the incorrect torque to a bolt, or a flight crew not adhering to standard operating procedures. The combination of these factors can then penetrate the organization's defenses and potentially result in a catastrophic event. From this concept, contemporary investigations look not just at the actions of the individual operators sitting at the controls such as flight crew, but also at the broader actions of the organizations that support those individuals to do their job in a professional and safe manner. What defenses does an organization have? Are the organizations aware of the risks they face? How do organizations manage their risks? Does an organization have goals that conflict with their safety management activities?¹⁶ These are just some of the issues that the NTSC investigation asked.

The pilot in command and the copilot were appropriately licensed to operate the Boeing 737-497 in accordance with applicable Indonesian regulations and Garuda's requirements.

The aircraft was certified in accordance with Indonesian regulations and maintained in accordance with approved procedures. There was no evidence to indicate any pre-existing engine, system, or structural defects to affect the performance of the aircraft.

The surface wind was north easterly at 9 knots, and visual meteorological conditions prevailed at the time of the accident.

2.2 Flight crew actions

The PIC and copilot were communicating effectively during the cruise and initial descent phases of the flight. When the PIC assessed the flight profile and realized that the aircraft was above the planned profile, he attempted to regain the planned profile and lose 4,032 feet. Over a 2 minute and 8 second period, the speed increased from 288 knots to 293 knots before reducing to 243 knots. The height loss achieved was 2,912 feet. The aircraft was below 10,000 feet and a speed above 250 knots required air traffic control approval. The speed brake was not deployed at this time and the crew did not inform the controller, and did not seek approval to exceed 250 knots.

When passing 4,064 feet pressure altitude, the PIC said 'Aduh anginnya keras' (Oops strong wind). The comment at that time was interesting considering that the PIC had been aware of the actual tail wind component for at least 8 minutes prior to making the comment. He had apparently not observed the strong wind at the higher altitudes, and in fact the wind had decreased at the lower altitudes.

¹⁶ Adapted from Adams. (2006). *A Layman's Introduction to Human Factors in Aircraft Accident and Incident Investigation*. Canberra: Australian Transport Safety Bureau.

The copilot did not provide effective monitoring and operational support to the PIC, and showed no evidence that he was aware of the wind and its effect on the flight.

The PIC subsequently assessed the situation by calculating the altitude and the remaining distance to the runway, and decided that the flight profile was not as he had expected. Eleven seconds after expressing concern about the wind, the PIC said 'Target enam koma enam ILS, kagak dapat dong' (the target is 6 point 6 ILS, we will not reach it). The PIC then attempted to trade off excess airspeed and lose height, but only succeeded in flying a flight path that was erratic in pitch, causing the airspeed and altitude to vary considerably. The PIC flew an unstabilized approach.

The company Operations Manual required the aircraft to be configured for the landing, with the landing gear extended, flaps 15, and the airspeed 150 knots, when approaching the final approach point (FAP), one dot up on the glideslope instrument. When GA200 passed the FAP, the speed was 254 knots (groundspeed 286 knots), and it was in the clean configuration, meaning that the landing gear and flaps were not extended.

The PIC, realizing the situation, commenced flap extension to the one degree position. Twenty seconds after expressing concern about not being able to reach the target, the aircraft was at 3,680 feet, 1180 feet above the approach profile for the ILS. Although the crew had been cleared for a visual approach, they executed the ILS approach, but they did not inform Yogya Approach.

The PIC again expressed concern that the vertical flight path was not proceeding normally, when at 23:56:49 he commented 'Wah nggak beres nih' (oh there is something not right). Between 23:56:49 and 23:57:20 the aircraft was in an unstabilized approach condition with the speed varying between 229 and 244 knots, pitch varying between 3.5 degrees up and 3.8 degrees down, and the rate of descent reached 3,520 feet per minute at 23:57:20. The PIC's actions to regain the glideslope resulted in an excessively steep approach path, which was not in accordance with Garuda's standard operating procedures contained in the Aircraft Operating Manual. The manual stated that to achieve a stabilized approach, 'only small changes in heading/pitch are required to maintain the correct flight path'.

The Basic Operations Manual. 4.4 Approach and landing, 4.4.1 Crew Coordination stated:

During the descent phase of the flight, at altitudes below approx. 10,000 ft above terrain, and during taxi, all cockpit crewmembers shall concentrate on cockpit procedures, and adhere to monitoring or lookout procedures. They shall refrain from any non-essential activities.

During the flight below 10,000 feet, there was evidence to demonstrate that the PIC was not following Garuda's standard operating procedures, and many instances to demonstrate that the pilot was not situationally aware, and his attention was channelized. Their actions, particularly those of the PIC indicated that he was fixated on a particular thing, rather than flying the aircraft correctly. The PIC stated at interview that he was focused on landing the aircraft.

The copilot did not select flaps 15 when instructed by the PIC. At 23:57:17, after receiving six GPWS 'sink rate' alerts, the copilot read back the aircraft configuration of 'flaps 5'.

He did not inform the PIC that the reason he only selected flap 5 was that the airspeed of 240.5 knots and increasing, exceeded the flap 15 degrees maximum operating speed by 35.5 knots.

The PIC did not reduce the aircraft's speed to the target airspeed of 141 knots for the approach. The actual speed was 245 knots. The aircraft was not in the landing configuration, and the actual sink rate of 3,520 fpm exceeded the Operations Manual requirement of not greater than 1,000 fpm. The landing checklist was not completed.

The manual stated that:

An approach that becomes unstabilized below 1,000 feet HAA [height above aerodrome] in IMC or below 500 feet HAA in VMC requires an immediate go around.

The aircraft was never in a stabilized approach and so a go around should have been conducted.

Further, the ground proximity warning system (GPWS) sink rate alert sounded several times during the approach as did the alert 'too low terrain'.

The Garuda Aircraft Operation Manual paragraph 2.3.8 on page 6 with reference to terrain avoidance stated:

GPWS 'PULL UP' warning occurs for an unsafe closure rate with the terrain. Immediately accomplish by recall

Disconnect the autopilot and auto throttles. Aggressively apply maximum thrust. Roll wings level and rotate to an initial pitch attitude of 20 degrees. Retract the speed brakes if extended.

NOTE: if an alert occurs when flying under daylight VMC conditions, and positive visual verification is made that no hazard exist, the alert may be regarded as cautionary. If no corrective action is necessary, the approach may be continued.

At 23:57:42, when the aircraft was 217 feet above the aerodrome elevation, the copilot said 'Wah Capt, go around Capt'. The PIC continued the approach.

Even after another GPWS 'WHOOOP, WHOOOP, PULL UP' hard warning, and a 'go-around' call with high intonation from the copilot, the PIC did not change his plan to complete the landing. The GPWS warnings should have given the pilots a strong indication that the approach was unstabilized. Although visual flight rules conditions existed, and therefore the approach could have been continued after visual verification that no hazard existed, there was ample information available to the flight crew to alert them that the approach was unstabilized and therefore a hazard existed. While the PIC was aware of the risk, he did not have the same appreciation of the extent of the impending hazardous situation as the copilot.

The PIC's intention to continue the landing was reinforced when he asked the copilot if the landing checklist had been completed. The copilot did not give the confirmation that the landing checklist had been completed. The PIC also asked the copilot a number of times to select the next stage of flaps in the pre-landing sequence; flaps 15 degrees. The normal landing flap setting was flaps 30 or flaps 40.

The PIC had briefed the copilot for a flaps 40 degrees landing. The PIC informed the investigation that he had decided to land the aircraft from the approach, despite the aircraft being in an unstabilized condition; specifically, not being configured for the landing; the flaps at 5 degree position; the GPWS sounding alerts and warnings; and the copilot not confirming the completion of the landing checklist; rather, calling for a go around. The PIC persisted with the approach and landing.

The copilot did not attempt to take control of the aircraft from the PIC and execute a go around, in accordance with company instructions that require taking over when an unsafe condition exists.

The Garuda Simulator Pilot – Proficiency Check records showed no evidence that the copilot had been checked or received simulator training in the appropriate vital actions and responses required to retrieve a perceived or real situation that might compromise the safe operation of the aircraft.

Seventeen seconds before touchdown, the copilot instructed the cabin crew ‘flight attendant, landing position’. That was insufficient time for the flight attendants to comply with the company requirement to sit quietly for 1 minute to recall the emergency memory items. However, the flight attendants were able to sit and fasten their seat belts before the landing.

The PIC’s actions were consistent with him being trapped in the condition called ‘fixated on one task’ or ‘one view of a situation even as evidence accumulates’. He intended to land the aircraft, so that the other tasks and warnings (GPWS ‘PULL UP’ and calls from the copilot) were either not heard or were disregarded. His attention was channelized and focused on landing the aircraft from the approach. Stressful situations, such as being excessively high on an approach, but determined to land from the approach, may induce actions such as approaching ‘high and hot”, meaning higher/steeper and faster than prescribed.

The Garuda Boeing 737 simulator training did not include training or proficiency checks in the vital actions and responses to be taken in the event of GPWS or EGPWS alerts and warnings, such as ‘TOO LOW TERRAIN’ AND ‘WHOO, WHOO PULL UP’.

Because the aircraft was not configured for the landing (flaps less than 30 degrees) and was 98 knots too fast as the aircraft crossed the runway 09 threshold, a go-around maneuver should have been performed. The touchdown should have occurred around 300 meters from the landing threshold. Garuda 200 landed about 860 meters from the runway 09 threshold, further indicating that the aircraft was not in the proper approach path to effect a safe landing.

The approach to Yogyakarta was unstabilized and not conducted in accordance with Garuda’s operating procedures.

Inattention, or decreased vigilance has been a contributor to operational errors, incidents, and accidents worldwide. Decreased vigilance manifests itself in several ways, which can be referred to as hazardous states of awareness.

These include:

1. *Absorption*. A state of being so focused on a specific task that other tasks are disregarded.
2. *Fixation*: A state of being locked onto one task, or one view of a situation, even as evidence accumulates that attention is necessary elsewhere, or that the particular view is incorrect.
3. The '*tunneling or channelizing*' that can occur during stressful situations, which is an example of fixation.

Note: The term 'fixation' has been chosen to describe the PIC's state of alertness, which provides a clearer idea of 'being locked onto one task', than 'absorption'. Several 'findings' support this 'tunneling or channelized' condition, for example:

- The PIC's attention became fixated on landing the aircraft. The concept of fixation is reinforced because he asked the copilot a number of times to select flaps 15 and asked if the landing checklist had been completed.
- The PIC did not respond to the 15 GPWS alerts and warnings and the two calls from the pilot monitoring to go-around. The PIC did not change his plan to land the aircraft, although the aircraft being in unstabilized condition. The other tasks that needed his attention were either not heard or disregarded. The auditory information about other important things did not reach his conscious awareness.
- The PIC said 'The target is 6.6 ILS, we will not reach it'. The PIC flew an unstabilized approach. He also realized the abnormal situation when he commented 'Wah, nggak beres nih!' ('Oh, there is something not right'). So, the PIC's intention to continue to land the aircraft, from an excessively high and fast approach, was a sign that his attention was channelized during a stressful time.
- The PIC also asked several times for the copilot to select flaps 15. During interview he said to investigator that 'his goal was to reach the runway and to avoid severe damage'. He 'heard, but did not listen to the other voice (GPWS), and flaps 15 and speed 205 was enough to land'. The PIC experienced a heightened sense of urgency, and was motivated to escape from what he perceived to be a looming catastrophe, being too high to reach the runway (09 threshold). He fixated on an escape route, 'which seem most obvious', aiming to get the aircraft on the ground by making a steep descent. His decision was flawed, and in choosing the landing option rather than the go around, fixated on a dangerous option.
- The PIC was probably emotionally aroused, because his conscious awareness moved from the relaxed mode 'singing' to the heightened stressfulness of the desire to reach the runway by making an excessively steep and fast, unstabilized approach.

2.3 Directorate General of Civil Aviation regulatory oversight of Garuda

Following receipt of its Air Operator's Certificate (AOC) by the DGCA, Garuda was required to comply with all DGCA requirements and DGCA would conduct 'complementary' surveillance.

However, the records showed that between 1998 and July 2007, surveillance of safety and airworthiness had been conducted by DGCA on two occasions. One safety inspection audit was conducted during February 2003. The most recent surveillance was conducted 2 days after the accident at Yogyakarta.

The deficiencies in Garuda's training and checking procedures with respect to pilots' actions and response to GPWS alerts and warnings, and procedures for a copilot to take over in the event of a PIC operating in an unsafe manner or becoming incapacitated, went unnoticed by the DGCA.

2.4 Rescue and Fire Fighting

The fire fighting units were dispatched in a timely manner to the crash site, but they stopped just behind the airport perimeter fencing which was about 120 m from the departure end of runway 09. After the fence, there was a slope or embankment and a ditch between the road and the runway extension. Foam was sprayed from the vehicles from a position near the airport perimeter fence, just inside the airport.

They could not reach the aircraft, because their position was still about 130 m away from the center of the crash site. The foam sprayer from that position was also unable to reach the crash site. The absence of an access road and the difficult/ uneven terrain caused the fire vehicle unable to approach the crash site.

It took more than 2 hours to extinguish the fire. Had the fire service been equipped in accordance with the ICAO Annex 14 Standards, the injury mitigation and survival aspects may have been enhanced.

The Rescue and fire fighting services did not meet ICAO Annex 14 requirements for the following:

- Vehicles were unable to traverse the terrain between the end of the runway due to the slope, ditch, and the swampy conditions of the rice field.
- There was insufficient foam/fire suppressant agent and the off-airport fire vehicles did not have foam to meet the minimum performance level B requirements for Yogyakarta, a Category 3 aerodrome.
- There was no evidence that a dry chemical powder, suitable for extinguishing hydrocarbon fires, was available as a complementary extinguishing agent.
- The inadequate AEP and lack of coordination during the emergency outside the airport perimeter, resulted in an ineffective fire fighting operation. There was no appropriate rescue coordination at the crash site, and too many unqualified people giving instructions resulting in ineffective fire suppression.

- The lack of an access road resulted in the fire fighting and rescue vehicles being unable to reach the wreckage and fight the fire in a timely and effective manner.
- The lack of an access road, coupled with a lack of appropriate equipment, as well as not enough qualified personnel, and the lack of coordination with other rescue participants (others than Angkasa Pura I), led to delaying extinguishing the fire.
- The fire became uncontrollable and consumed the aircraft.
- The ineffective fire fighting operation may have resulted in increasing the number of fatalities and injuries.

2.5 Passenger and cargo manifests

The passenger list was given to the crisis center and the police an hour after the accident, and the cargo manifest was received 33 hours after the accident. Garuda complied with the DGCA approved Garuda Emergency Response Plan, which requires that the aircraft operator must supply a copy of the aircraft passenger and cargo manifests as soon as possible after an accident. However, because the cargo manifest was not received until 33 hours after the accident, rescuers and investigators were deprived of adequate information of potential hazards or dangerous goods in the aircraft's cargo.

2.6 Runway end safety area (RESA)

The runway 09 RESA at Yogyakarta was 60 meters long, and therefore did not meet the ICAO Annex 14 Standard of a 90 meter RESA. Given the aircraft's speed at touchdown and the fact that from the point of touchdown there was approximately 1390 meters of runway remaining, it is probable that the extra 30 meters would not have prevented the accident.

However, ICAO requires a difference to be filed by signatory States that are unable to comply with Standards. The DGCA had not filed a difference with ICAO with respect to the RESA being shorter than the Annex 14 Standard.

2.7 Failure of the nose landing gear

The SSFDR data shows that the aircraft's touchdown speed was 221 knots; 87 knots faster than the landing speed (V_{ref} for 40 degrees flap, 134 knots) specified for a landing at the aircraft weight of 53,366 kilograms. The aircraft bounced twice and the g force at the third (final) touchdown was about 2.9 g, and the aircraft's pitch angle was about -1 degree (nose down), which caused the nose landing gear to touchdown heavily before the main landing gear.

The left nose wheel tire failed due to high rotational forces applied during the initial landing roll. The subsequent bending load on the left nose wheel axle was above the material's ultimate strength and caused the left axle to fail.

Metal from the failed left nose wheel slashed the right nose wheel tire, causing deep cuts to the tire's crown. The outer hub of the right nose wheel separated, leaving pieces on the runway. The inboard hub of the right nose wheel remained attached to the right axle and was scoring the runway during the high speed landing roll.

There was no evidence of nose-wheel shimmy. The nose landing gear torque link failed due to the lower fitting, which is attached to the inner oleo, being damaged by scoring on the runway.

There was no evidence of foreign object damage (FOD) on the left nose wheel tire. The tire damage was due to overspeed. The right nose wheel tire had evidence of FOD, which caused the cuts to the crown, probably due to pieces of the failed left nose wheel assembly (metal) striking the rotating tire. The inner walls of both tires revealed no evidence of overload or under inflation.

2.8 Solid State Flight Data Recorder (SSFDR)

The examination of the SSFDR revealed that data for the following engine parameters were not being recorded: N1; N2; fuel flow; EGT; oil pressure; oil temperature. Glideslope, localizer, and radio altimeter data were also not recorded.

The fitment of an inappropriate Digital Flight Data Acquisition Unit (DFDAU), which was unable to process Electronic Flight Instrument System (EFIS) and Engine Indicating System (EIS) data sources, resulted in a system looking to non-existent analogue sources of data for many parameters that were normally supplied by EFIS and EIS. Consequently, engine, glideslope, localizer, and radio altitude data were not recorded.

While the SSFDR recorded well in excess of 32 parameters, it did not record all of the specific mandatory 32 parameters listed in ICAO Annex 6, Part 1, Table D-1. The mandatory parameters that were not recorded on the SSFDR were: radio altitude; glide path deviation; and localizer deviation.

2.9 Summary

Deviations from recommended practice and standard operating procedures are a potential hazard, particularly during the approach and landing phase of a flight, and increase the risk of approach and landing accidents. Crew coordination is less than effective, if crew members do not work together as an integrated team. Support crew members have a duty and responsibility to ensure that the safety of a flight is not compromised, by non-compliance with standard operating procedures and recommended practices.

Support from regulators and all levels of airline management, including appropriate policies, procedures, training and checking, and oversight and surveillance, is essential to ensure that pilots are appropriately trained and equipped conduct safe flying operations.

3 CONCLUSIONS

3.1 Findings¹⁷

3.1.1 Operations related issues

1. The pilots were appropriately licensed and qualified to operate the Boeing 737-400 series aircraft.
2. There was no evidence that the pilots were not medically fit.
3. The pilots complied with the Directorate General Civil Aviation (DGCA) and company flight and duty limitations.
4. The aircraft was being flown by the pilot in command at the time of the accident.
5. The aircraft was being operated within the approved weight and balance limitations.
6. The aircraft was flown at an excessively high airspeed and steep descent during the approach and landing, resulting in an unstabilized approach.
7. The pilot in command (PIC) did not follow company procedures that required him to fly a stabilized approach, and he did not abort the landing and go around when the approach was not stabilized.
8. The copilot did not follow company instructions and take control of the aircraft from the PIC when he saw that the PIC repeatedly ignored warnings to go around.
9. The Garuda Simulator Pilot – Proficiency Check records showed no evidence that the copilot had been checked or received simulator training in the appropriate vital actions and responses required to retrieve a perceived or real situation that might compromise the safe operation of the aircraft.
10. Flight crew communication and coordination complied with company standard operating procedures until passing 2,336 feet on descent after flap 1 degree was selected, when it became less than effective and compromised the safety of the flight.
11. The pilot in command's attention became channelized and was fixated on landing the aircraft.
12. The pilot in command did not respond to the 15 Ground Proximity Warning System (GPWS) alerts and warnings and the two calls from the copilot to go around.
13. The flight crew did not complete the landing checklist.

¹⁷ The finding numbers in this chapter do not denote a level of importance

14. Both engines' thrust reversers were deployed for 7 seconds during the landing roll, but were stowed 7 seconds before the aircraft left the sealed runway.
15. The wing flaps were in the 5 degree position.
16. The PIC informed the investigation that his decision to continue to land the aircraft was not in any way influenced by the airline's fuel conservation incentive program.
17. The engine damage was consistent with low RPM at the time of impact.
18. There was no evidence of in-flight fire.
19. The Garuda Simulator Pilot – Proficiency Check records showed no evidence that Garuda provided Boeing 737 simulator training for its flight crews covering vital actions and required responses to GPWS and Enhanced Ground Proximity Warning System (EGPWS) alerts and warnings.
20. The cargo manifest was supplied to the crisis center on the day after the accident. This resulted in rescue and investigation activities at the accident site being conducted during the first 33 hours without adequate information of potential hazards or dangerous goods in the aircraft's cargo.

3.1.2 Regulatory oversight

1. Between 1998 and July 2007, surveillance of safety and airworthiness had been conducted by DGCA on two occasions. One safety inspection audit was conducted during February 2003. The most recent surveillance was conducted 2 days after the accident at Yogyakarta.
2. The DGCA program of flight operation's surveillance of all Indonesian airline operators, planned for 2007, had not commenced by July 2007.
3. The DGCA lacked a mechanism for ensuring the continued safety standard of Garuda's flight operations.
4. The deficiencies in Garuda's training and checking procedures with respect to pilots' actions and response to GPWS alerts and warnings, and procedures for a copilot to take over in the event of a PIC operating in an unsafe manner or becoming incapacitated, went unnoticed by the DGCA.
5. The DGCA had not filed a difference with ICAO with respect to its inability to comply with the Standard for the runway end safety area.

3.1.3 Airport related issues

- 1 Fire fighting units responded quickly and arrived at the end of runway 09 about 1 minute after the accident.
- 2 The absence of an access road at the departure end runway 09 resulted in the fire fighting units being unable to reach the accident site in timely manner.
- 3 The Airport Emergency Plan (AEP) was not approved by the DGCA at the time of accident.
- 4 The AEP was inadequate to cover an accident emergency occurring outside the airport perimeter.
- 5 The grid map in the AEP did not cover the area up to 5 NM (8 km) from airport perimeter as stated in the Transport Ministry Decree 47 (KM47).
- 6 The AEP did require a full-scale emergency exercise to determine the effectiveness of the manual and emergency response.
- 7 The AEP did not identify holding facilities for the collection and care of victims and their families.
- 8 No person was responsible for ensuring that the AEP manual was fit for purpose. It was an uncontrolled document that did not have a revision control page or distribution list.
- 9 The airport rescue services' personnel were not familiar with the area surrounding the airport, and the airport fire service vehicles were not suitable for, or capable of, traversing swampy or soft ground such as the rice field.
- 10 It took more than 2 hours to extinguish the fire. The delay in extinguishing the fire, and the lack of appropriate fire suppressant agents, may have significantly reduced survivability.
- 11 The labeling of the victims in the care area was not carried out in accordance with the AEP, in order to identify those needing immediate treatment in hospital and afford them an appropriate level of priority.
- 12 The airport did not meet the ICAO Annex 14 Standard with respect to the runway end safety areas.

3.1.4 Maintenance Related Issues

1. The aircraft's certificates of airworthiness and registration were current.
2. There was no evidence of airframe failure or system malfunction that could have affected the performance or handling characteristics of the aircraft.
3. The Solid State Digital Flight Data Recorder (SSFDR) provided good quality data, but the Digital Flight Data Acquisition Unit that supplied the data to the SSFDR was not the correct model for the Boeing 737-497 aircraft and accordingly some parameters, required by ICAO Annex 6, Part 1, Table D1, were not recorded.
4. The Solid State Cockpit Voice Recorder provided good quality data.

3.2 Causes

- 1 Flight crew communication and coordination was less than effective after the aircraft passed 2,336 feet on descent after flap 1 was selected. Therefore the safety of the flight was compromised.
- 2 The PIC flew the aircraft at an excessively high airspeed and steep descent during the approach. The crew did not abort the approach when stabilized approach criteria were not met.
- 3 The pilot in command did not act on the 15 GPWS alerts and warnings, and the two calls from the copilot to go around.
- 4 The copilot did not follow company instructions and take control of the aircraft from the pilot in command when he saw that the pilot in command repeatedly ignored warnings to go around.
- 5 Garuda did not provide simulator training for its Boeing 737 flight crews covering vital actions and required responses to GPWS and EGPWS alerts and warnings such as 'TOO LOW TERRAIN' and 'WHOOOP, WHOOOP PULL UP'.

3.3 Other Factors

- 1 The airport did not meet the ICAO Standard with respect to runway end safety areas.
- 2 The airport did not meet the ICAO Standard with respect to rescue and fire fighting equipment and services for operation outside the airport perimeter and in swampy terrain.

4 SAFETY RECOMMENDATIONS¹⁸

As result of this investigation, the NTSC issues the following recommendations to address the safety deficiencies identified in this report.

4.1 Recommendation to Garuda Indonesia

The National Transportation Safety Committee recommends that Garuda Indonesia review its fuel conservation incentive program policy to ensure that flight crews are in no doubt about its intent, and that there is no perception that such a policy could compromise the safe operation of aircraft.

4.2 Recommendation to Indonesian airline operators

The National Transportation Safety Committee recommends that airline operators ensure that their flight crews are trained and checked, in ‘GPWS specific’ simulator training sessions, for the vital actions and required responses to Ground Proximity Warning System (GPWS) and Enhanced Ground Proximity Warning System (EGPWS) warnings.

4.3 Recommendation to Indonesian airline operators

The National Transportation Safety Committee recommends that airline operators review the procedures used by their maintenance organizations for ensuring that flight recorders meet the relevant manufacturers’ specifications with respect to specific aircraft systems such as Electronic Flight Instrument Systems (EFIS) or non-EFIS systems.

The annual inspection procedures for flight recorders, including functional checks, should also be reviewed to ensure that all parameters are being recorded in accordance with CASR 121.343 and ICAO Annex 6, Part I. 3. 4., Table D-1. The method of inspection should follow the manufacturer specification.

4.4 Recommendation to Indonesian airline operators

The National Transportation Safety Committee recommends that airline operators ensure that published procedures take into consideration the runway end safety area (RESA) requirement when calculating performance specifications for operations into airports with runways having a RESA that does not meet the ICAO Annex 14 Standard.

¹⁸ The recommendation numbers in this chapter do not denote a level of importance

4.5 Recommendation to Indonesian airline operators

The National Transportation Safety Committee encourages the use of the Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) and Controlled Flight Into Terrain (CFIT) awareness training material by Indonesian airlines. The NTSC recommends that airline operators include ALAR and CFIT awareness modules in their recurrency training programs, and conduct initial ALAR and CFIT training for flight crew members who have not yet completed such training.

4.6 Recommendation to Indonesian airline operators

The National Transportation Safety Committee recommends that airline operators ensure that published procedures provide for:

- a. the passenger lists to be sent to the crisis center, within 1 hour of an accident, to assist in identification of victims and survivors, and notification to next of kin
- b. the cargo manifest to be sent to the crisis center, rescue and fire fighting services and the National Transportation Safety Committee, within 1 hour, to enable hazard mitigation at the accident site.

4.7 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) ensure that airline operators train and check their crews, in the simulator, for the vital actions and required responses to GPWS and EGPWS warnings.

4.8 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) ensure that airline operators have published procedures that take into consideration the runway end safety area (RESA) requirement when calculating performance specifications for operations into airports with runways having a RESA that does not meet the ICAO Annex 14 Standard.

4.9 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) review its policy, procedures and implementation of flight operation's surveillance, to ensure that DGCA achieves and maintains, adequate and appropriate regulatory oversight.

4.10 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) ensure that airline operators have procedures to provide:

- c. the passenger lists to the crisis center, within 1 hour of an accident, to assist in identification of victims and survivors, and notification to next of kin
- d. the cargo manifest to the crisis center, rescue and fire fighting services and the National Transportation Safety Committee, within 1 hour, to enable hazard mitigation at the accident site.

4.11 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) review the procedures used by airline maintenance organizations for ensuring that flight recorders meet the relevant manufacturers' specifications with respect to specific aircraft systems such as EFIS or non-EFIS systems.

The annual inspection procedures for flight recorders, including functional checks, should also be reviewed to ensure that all parameters are being recorded in accordance with CASR 121.343 and ICAO Annex 6, Part I. 3. 4., Table D-1. The method of inspection should follow the manufacturer specification.

4.12 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) review the Yogyakarta runway complex to ensure that the runway end safety areas (RESA) meet the dimension Standards prescribed in the International Civil Aviation Organization (ICAO) Annex 14.

Particular attention should be given to:

- a. ICAO Annex 14 Paragraph 3.5.2 (Standard) that a runway end safety area (RESA) shall extend from the end of a runway strip to a distance of at least 90 meters.
- b. ICAO Annex 14 Paragraph 3.5.3 (Recommendation) that for a Code number 3 airport a runway end safety area (RESA) should, as far as practicable, extend from the end of a runway strip to a distance of at least 240 meters.

If the DGCA is unable to meet the RESA Standard in accordance with ICAO Annex 14, it should file a difference with ICAO as soon as possible.

4.13 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) review the procedures and equipment used by airport Rescue and Fire Fighting Services to ensure that they:

- a. meet the minimum requirements specified in the International Civil Aviation Organization's Annex 14; and
- b. meet the requirements to cover the area up to 5 NM (8 Km) from the airport perimeter, as stated in the Transport Ministry Decree 47 (KM47).

4.14 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) ensure that airport operators:

- a. publish a procedure for the appointment of a suitably qualified person, and appoint such a person, to ensure that the Airport Emergency Plan (AEP) manual is updated and is fit for purpose; and
- b. have published procedures for emergency response to an aircraft accident outside the airport perimeter to a minimum of distance of 5 NM in accordance with the Transport Minister Decree 47, also noting the ICAO Annex 14 Standard; and
- c. review the AEP to ensure holding facilities for the collecting and care of victims and their families are available; and
- d. exercise the AEP for response to full-scale emergencies, within and outside the airport perimeter, at intervals not exceeding two years; and
- e. review the results of any actual or exercised emergencies, with the aim of correcting any identified deficiencies; and
- f. ensure that any identified deficiencies are corrected.

4.15 Recommendation to the Directorate General Civil Aviation (DGCA)

The National Transportation Safety Committee recommends that the Directorate General Civil Aviation (DGCA) ensure that airport operators having water or swampy terrain along the departure and arrival paths are equipped, in accordance with the ICAO Annex 14, Paragraph 9.2.2 Standard, with specialist rescue services and fire fighting equipment appropriate to the hazards and risks.

4.16 Recommendation to airport operators

The National Transportation Safety Committee recommends that the Yogyakarta airport operator review the Yogyakarta runway complex to ensure that the runway end safety area (RESA) meets the dimension Standards prescribed in the International Civil Aviation Organization (ICAO) Annex 14.

Particular attention should be given to:

- a. ICAO Annex 14 Paragraph 3.5.2 (Standard), that a runway end safety area (RESA) shall extend from the end of a runway strip to a distance of at least 90 meters.
- b. ICAO Annex 14 Paragraph 3.5.3 (Recommendation) that for a Code number 3 airport, a runway end safety area (RESA) should, as far as practicable, extend from the end of a runway strip to a distance of at least 240 meters.

4.17 Recommendation to airport operators

The National Transportation Safety Committee recommends that airport operators review the procedures and equipment used by airport Rescue and Fire Fighting Services to ensure that they:

- a. meet the minimum requirements specified in the International Civil Aviation Organization's Annex 14; and
- b. meet the requirements to cover the area up to 5 NM (8 Km) from airport perimeter, as stated in the Transport Ministry Decree 47 (KM47).

4.18 Recommendation to airport operators

The National Transportation Safety Committee recommends that airport operators having water or swampy terrain along the departure and arrival paths are equipped, in accordance with the ICAO Annex 14, Paragraph 9.2.2 Standard, with specialist rescue services and fire fighting equipment appropriate to the hazards and risks.

4.19 Recommendation to airport operators

The National Transportation Safety Committee recommends that airport operators:

- a. publish a procedure for the appointment of a suitably qualified person, and appoint such a person, to ensure that the Airport Emergency Plan (AEP) manual is updated and is fit for purpose; and
- b. have published procedures for emergency response to an aircraft accident outside the airport perimeter to a minimum of distance of 5 NM in accordance with the Transport Minister Decree 47, also noting the ICAO Annex 14 Standard; and

- c. review the AEP to ensure holding facilities for the collecting and care of victims and their families are available; and
- d. exercise the AEP for response to full-scale emergencies, within and outside the airport perimeter, at intervals not exceeding two years, in accordance with ICAO Annex 14 Paragraph 9.1.13 Standard; and
- e. review the results of any actual or exercised emergencies, with the aim of correcting any identified deficiencies, in accordance with ICAO Annex 14 Paragraph 9.1.13 Standard; and
- f. ensure that any identified deficiencies are corrected.

5 SAFETY ACTION ¹⁹

5.1 Airport operator, access road

Since the accident on 7 March 2007, the Yogyakarta airport operator constructed an access road between the airport perimeter and the rice field where the accident occurred. The road is along the flight path of arriving and departing aircraft using the Yogyakarta runway and crosses an urban road. It covers two ditches and passes through a median strip on the road (Figure 22 and Figure 23).



Figure 22: Access road from runway across urban road. View towards the runway



Figure 23: Access road from urban road to rice field. The rice field and accident site are to the left of the picture

¹⁹ Where safety action has been proposed, or has commenced but has been not completed, the NTSC will continue to monitor the progress of implementation of the safety action.

5.2 Garuda Indonesia, Flight Operations policy

On 2 April 2007 Garuda issued a Flight Operations, Notice to Flight Crew, number 14/07, which reinforced its mandatory policy relating to a pilot monitoring to take control of an aircraft and execute a go around in instances of unstabilized approach, when the pilot flying does not make an appropriate response. The notice assures pilots that ‘the company will not take disciplinary measures for a go around executed under any unsafe or unstabilized approach’ (Appendix F).

5.3 Garuda Indonesia GPWS and EGPWS training

On 14 September 2007, Garuda Indonesia informed the NTSC that:

‘On July 6, 2007, Garuda Indonesia implemented additional GPWS training for B737 flight crews, which includes both ground and simulator training. Each member of the B737 flight crew will complete both phases of this new training program on an annual basis.’

5.4 Garuda Indonesia compatibility of Digital Flight Data Acquisition Unit (DFDAU) and Digital Flight Data Recorder (DFDR)²⁰

On 31 August 2007, Garuda Indonesia informed the NTSC that it had taken the following safety action with respect to DFDAUs and DFDRs in its Boeing 737 fleet:

1. All non-effective DFDAUs were documented, and DFDAUs and DFDRs were correctly matched to ensure correct configuration.
2. The Component Control System has been improved to ensure that incorrect Part Number DFDAUs cannot be requested by engineers to be installed in the aircraft.
3. All certifying staff have been trained and briefed.
4. Reviewed procedures for evaluating and reporting on all DFDR downloaded data in accordance with the existing regulations.

An inventory check conducted by Garuda Indonesia engineering has found that DFDAUs Part Number 2227000-45 are no longer held in the material store or installed in Garuda Boeing 737 aircraft. The remaining DFDAUs Part Number 2227000-45 were removed from the Garuda system when the aircraft PK-GWV, PK-GWW and PK-GWX were returned to the lessor. The possibility of installing a DFDAU with incorrect configuration has been eliminated.

²⁰ Digital Flight Data Recorder (DFDR) referred to by Garuda is the Solid State Flight Data Recorder

5.5 PT. Angkasa Pura I follow up, safety action

On 27 September 2007, PT (Persero) Angkasa Pura I informed the NTSC that it had taken the following safety action with respect to the recommendations made by the NTSC during the accident investigation:

No	RECOMMENDATION	FOLLOW UP
4.15	Review the Yogyakarta runway complex to ensure that the runway end safety area (RESA) meets the dimension standards prescribed in the ICAO Annex 14.	The requirement of RESA at the airports operated by Angkasa Pura I will be met step by step. First in 2008 will be at Denpasar, Surabaya, and Makassar. Yogyakarta has been reviewed and the airport does not have land to build the 90 meter RESA while keeping the existing runway length. Angkasa Pura I will study appropriate engineering alternatives to RESA by June 2008.
4.16	Review the procedures and equipment used by Airport Rescue and Fire Fighting Services to ensure that they: <ul style="list-style-type: none"> • Meet minimum requirement in the ICAO Annex 14 • Meet the requirement to cover the area up to 5 Nm (8Km) from airport perimeter, as stated in the Transport Ministry Decree 47 (KM 47) 	Angkasa Pura I has commenced a review of the procedures and equipment and is taking the following actions: <ul style="list-style-type: none"> – Amend procedures to meet the ICAO Annex 14 and KM 47 requirements; targeted for completion December 2007 – Equipment will be installed to meet the ICAO Annex 14 requirement (Cat 7) targeted for completion March 2008 – Facilities and equipment will be available to ensure they meet the ICAO Annex 14 requirement; targeted for completion March 2008. A further study will be conducted to assess the facilities and equipment available to meet the KM 47 requirements; targeted for completion March 2008.
4.17	Having water or swampy terrain along the departure and arrival paths are equipped with specialist rescue services and fire fighting equipment appropriate to the hazards and risks.	The requirements are being evaluated; targeted for completion March 2008.
4.18a	Publish a procedure for the appointment of a suitably qualified person, and appoint such a person, to ensure that the Airport Emergency Plan (AEP) manual is updated and is fit for purpose.	Procedures are currently being amended; target for completion December 2007.

4.18b	Have published procedures for emergency response to an aircraft accident outside the airport perimeter to a minimum of distance 5 Nm in accordance with the Transport Ministry Decree 47, also noting the ICAO Annex 14 Standard.	Procedures are currently being amended; target for completion December 2007.
4.18c	Review the AEP to ensure holding facilities for the collection and care of victims and their families are available.	Procedures are currently being amended; target for completion December 2007.
4.18d	Exercise the AEP for response to full-scale emergencies, within and outside the airport perimeter, at intervals not exceeding two years, in accordance with ICAO Annex 14 Paragraph 9.1.13 Standard.	Angkasa Pura I will file a difference with ICAO, through DGCA, to state that a full-scale response exercise will be conducted, at intervals not exceeding 3 years, and each year will conduct an “airport internal-scale (desk-top) emergency exercise”.
4.18e	Review the result of any actual or exercised emergencies, with the aim of correcting any identified deficiencies, in accordance with ICAO Annex 14 Paragraph 9.1.13 Standard.	All emergency response exercises conducted by Angkasa Pura I will be evaluated.
4.18f	Ensure that any identified deficiencies are corrected.	All deficiencies identified during emergency response exercises will be corrected.

APPENDICES

Appendix A: Human Factors

Hazardous States of Awareness

Inattention, or decreased vigilance, is often cited in ASRS reports, and has been a contributor to operational errors, incidents, and accidents. Decreased vigilance manifests itself in several ways, which can be referred to as hazardous states of awareness. These states include:

- *Absorption* is a state of being so focused on a specific task that other tasks are disregarded. Programming the FMS to the exclusion of other tasks, such as monitoring other instruments, would be an example of absorption. The potential for absorption is one reason some operators discourage their flight crews from programming the FMS during certain flight phases or conditions (e.g., altitude below 10,000 feet).
- *Fixation* is a state of being locked onto one task or one view of a situation even as evidence accumulates that attention is necessary elsewhere, or that the particular view is incorrect. The ‘tunneling’ that can occur during stressful situations is an example of fixation.

For example, a pilot may be convinced that a high, unstabilized approach to landing is salvageable even when other flight crew members, air traffic control, and cockpit instrument strongly suggest that the approach cannot be completed within acceptable parameters.

The pilot will typically be unaware of these other inputs and appear to be unresponsive until the fixation is broken. Fixation is difficult to self-diagnose, but it may be recognizable in someone else.

- *Preoccupation* is a state where one’s attention is elsewhere (e.g., daydreaming).

Decreased vigilance can be caused or fostered by a number of factors, including:

- *Fatigue*, which has been the subject of extensive research and is well recognized as a cause of decreased vigilance.
- *Underload*, which is increasingly being recognized as a concern. Sustained attention is difficult to maintain when workload is very low.
- *Complacency*. Automated systems have become very reliable and perform most tasks extremely well. As a result, flight crews increasingly rely on the automation. Although high system reliability is desired, these high reliability effects flight crew monitoring strategies in a potentially troublesome way.

When a failure occurs, or when the automation behavior violates expectations, the flightcrew may miss the failure, misunderstand the situation, or take longer to assess the information and respond appropriately.

In other words, over reliance on automation can breed complacency, which hampers the flight crew’s ability to recognize a failure or unexpected automation behavior.

*Federal Aviation Administration Human Factors Team Report on:
The Interfaces Between Flight-crews and Modern Flight Decks System
June 18, 1996*

Kinds of attention failure

There are occasions in flying when 'too many stimuli' are presented and 'too many responses' are required. Attention is overload (Cognitive saturation?; editor).

- **FIXATION** of attention occurs when a pilot concentrates one set of stimuli to the exclusion of others which also require his attention.

Fixation can result from inadequate training in the control of attention. It is most apt to occur when the pilot is emotionally aroused. It has been observed times and again in emergencies which precede accidents.

In these situation there is a strong motive to escape from the threatened catastrophe and the pilot may fixate on the escape route 'which seem most obvious' at the moment, but which may in fact be the least desirable.

Aviation Psychology: Nicholas A. Bond et al.; University of Southern California. Los Angeles 7, California, March 1968.

Single channel of attention

The model described indicates that man has a filter system and that most of incoming signals impinging on man's sense do not reach the level of conscious awareness.

The single channel hypothesis, state that, in complex tasks human beings can consciously attend only to one thing at a time. This limitation can lead to errors and subsequent accidents. In such accidents the pilot attention may have been 'locked on' to one channel, and auditory information about the position of the aircraft being on another channel, has not reached conscious awareness.

Aviation Medicine: Human Errors and Some Aspects of Stress. R.C. Humphrey, London 1978

Appendix B: ICAO Annex 14, Rescue and Fire fighting

CHAPTER 9. AERODROME OPERATIONAL SERVICES, EQUIPMENT AND INSTALLATIONS

9.1 Aerodrome emergency planning

General

Introductory Note.— Aerodrome emergency planning is the process of preparing an aerodrome to cope with an emergency occurring at the aerodrome or in its vicinity. The objective of aerodrome emergency planning is to minimize the effects of an emergency, particularly in respect of saving lives and maintaining aircraft operations. The aerodrome emergency plan sets forth the procedures for coordinating the response of different aerodrome agencies (or services) and of those agencies in the surrounding community that could be of assistance in responding to the emergency. Guidance material to assist the appropriate authority in establishing aerodrome emergency planning is given in the Airport Services Manual, Part 7.

9.1.1 An aerodrome emergency plan shall be established at an aerodrome, commensurate with the aircraft operations and other activities conducted at the aerodrome.

9.1.2 The aerodrome emergency plan shall provide for the coordination of the actions to be taken in an emergency occurring at an aerodrome or in its vicinity.

Note.— Examples of emergencies are: aircraft emergencies, sabotage including bomb threats, unlawfully seized aircraft, dangerous goods occurrences, building fires and natural disasters.

9.1.3 The plan shall coordinate the response or participation of all existing agencies which, in the opinion of the appropriate authority, could be of assistance in responding to an emergency.

Note.— Examples of agencies are:

— on the aerodrome: air traffic control unit, rescue and fire fighting services, aerodrome administration, medical and ambulance services, aircraft operators, security services, and police;

— off the aerodrome: fire departments, police, medical and ambulance services, hospitals, military, and harbour patrol or coast guard.

9.1.4 **Recommendation.**— *The plan should provide for cooperation and coordination with the rescue coordination centre, as necessary.*

9.1.5 **Recommendation.**— *The aerodrome emergency plan document should include at least the following:*

- a) types of emergencies planned for;
- b) agencies involved in the plan;
- c) responsibility and role of each agency, the emergency operations centre and the command post, for each type of emergency;
- d) information on names and telephone numbers of offices or people to be contacted in the case of a particular emergency; and
- e) a grid map of the aerodrome and its immediate vicinity.

9.1.6 The plan shall observe Human Factors principles to ensure optimum response by all existing agencies participating in emergency operations.

Note.— Guidance material on Human Factors principles can be found in the Human Factors Training Manual.

Emergency operations centre and command post

9.1.7 **Recommendation.**— *A fixed emergency operations centre and a mobile command post should be available for use during an emergency.*

9.1.8 **Recommendation.**— *The emergency operations centre should be a part of the aerodrome facilities and should be responsible for the overall coordination and general direction of the response to an emergency.*

9.1.9 **Recommendation.**— *The command post should be a facility capable of being moved rapidly to the site of an emergency, when required, and should undertake the local coordination of those agencies responding to the emergency.*

9.1.10 **Recommendation.**— *A person should be assigned to assume control of the emergency operations centre and, when appropriate, another person the command post.*

Communication system

9.1.11 **Recommendation.**— *Adequate communication systems linking the command post and the emergency*

operations centre with each other and with the participating agencies should be provided in accordance with the plan and consistent with the particular requirements of the aerodrome.

Aerodrome emergency exercise

9.1.12 The plan shall contain procedures for periodic testing of the adequacy of the plan and for reviewing the results in order to improve its effectiveness.

Note.— The plan includes all participating agencies and associated equipment.

9.1.13 The plan shall be tested by conducting:

- a) a full-scale aerodrome emergency exercise at intervals not exceeding two years; and
- b) partial emergency exercises in the intervening year to ensure that any deficiencies found during the full-scale aerodrome emergency exercise have been corrected; and

reviewed thereafter, or after an actual emergency, so as to correct any deficiency found during such exercises or actual emergency.

Note.— The purpose of a full-scale exercise is to ensure the adequacy of the plan to cope with different types of emergencies. The purpose of a partial exercise is to ensure the adequacy of the response to individual participating agencies and components of the plan, such as the communications system.

Emergencies in difficult environments

9.1.14 The plan shall include the ready availability of and coordination with appropriate specialist rescue services to be able to respond to emergencies where an aerodrome is located close to water and/or swampy areas and where a significant portion of approach or departure operations takes place over these areas.

9.1.15 **Recommendation.**— At those aerodromes located close to water and/or swampy areas, or difficult terrain, the aerodrome emergency plan should include the establishment, testing and assessment at regular intervals of a pre-determined response for the specialist rescue services.

9.2 Rescue and fire fighting

General

Introductory Note.— The principal objective of a rescue and fire fighting service is to save lives. For this reason, the

provision of means of dealing with an aircraft accident or incident occurring at, or in the immediate vicinity of, an aerodrome assumes primary importance because it is within this area that there are the greatest opportunities of saving lives. This must assume at all times the possibility of, and need for, extinguishing a fire which may occur either immediately following an aircraft accident or incident, or at any time during rescue operations.

The most important factors bearing on effective rescue in a survivable aircraft accident are: the training received, the effectiveness of the equipment and the speed with which personnel and equipment designated for rescue and fire fighting purposes can be put into use.

Requirements to combat building and fuel farm fires, or to deal with foaming of runways, are not taken into account.

Application

9.2.1 Rescue and fire fighting equipment and services shall be provided at an aerodrome.

Note.— Public or private organizations, suitably located and equipped, may be designated to provide the rescue and fire fighting service. It is intended that the fire station housing these organizations be normally located on the aerodrome, although an off-aerodrome location is not precluded provided the response time can be met.

9.2.2 Where an aerodrome is located close to water/swampy areas, or difficult terrain, and where a significant portion of approach or departure operations takes place over these areas, specialist rescue services and fire fighting equipment appropriate to the hazard and risk shall be available.

Note 1.— Special fire fighting equipment need not be provided for water areas; this does not prevent the provision of such equipment if it would be of practical use, such as when the areas concerned include reefs or islands.

Note 2.— The objective is to plan and deploy the necessary life-saving flotation equipment as expeditiously as possible in a number commensurate with the largest aeroplane normally using the aerodrome.

Note 3.— Additional guidance is available in Chapter 13 of the Airport Services Manual, Part 1.

Level of protection to be provided

9.2.3 The level of protection provided at an aerodrome for rescue and fire fighting shall be appropriate to the aerodrome category determined using the principles in 9.2.5 and 9.2.6, except that, where the number of movements of the aeroplanes in the highest category normally using the aerodrome is less than 700 in the busiest consecutive three months, the level of protection provided shall be not less than one category below the determined category.

Note.— Either a take-off or a landing constitutes a movement.

9.2.4 Recommendation.— From 1 January 2005, the level of protection provided at an aerodrome for rescue and fire fighting should be equal to the aerodrome category determined using the principles in 9.2.5 and 9.2.6.

9.2.5 The aerodrome category shall be determined from Table 9-1 and shall be based on the longest aeroplanes normally using the aerodrome and their fuselage width.

Note.— To categorize the aeroplanes using the aerodrome, first evaluate their overall length and second, their fuselage width.

9.2.6 If, after selecting the category appropriate to the longest aeroplane's overall length, that aeroplane's fuselage width is greater than the maximum width in Table 9-1, column 3 for that category, then the category for that aeroplane shall actually be one category higher.

Note.— Guidance on categorizing aerodromes for rescue and fire fighting purposes and on providing rescue and fire fighting equipment and services is given in Attachment A, Section 17 and in the Airport Services Manual, Part 1.

9.2.7 During anticipated periods of reduced activity, the level of protection available shall be no less than that needed for the highest category of aeroplane planned to use the aerodrome during that time irrespective of the number of movements.

Extinguishing agents

9.2.8 Recommendation.— Both principal and complementary agents should normally be provided at an aerodrome.

Note.— Descriptions of the agents may be found in the Airport Services Manual, Part 1.

9.2.9 Recommendation.— The principal extinguishing agent should be:

- a) a foam meeting the minimum performance level A; or
- b) a foam meeting the minimum performance level B; or
- c) a combination of these agents;

except that the principal extinguishing agent for aerodromes in categories 1 to 3 should preferably meet the minimum performance level B.

Note.— Information on the required physical properties and fire extinguishing performance criteria needed for a foam to achieve an acceptable performance level A or B rating is given in the Airport Services Manual, Part 1.

9.2.10 Recommendation.— The complementary extinguishing agent should be a dry chemical powder suitable for extinguishing hydrocarbon fires.

Note 1.— When selecting dry chemical powders for use with foam, care must be exercised to ensure compatibility.

Note 2.— Alternate complementary agents having equivalent fire fighting capability may be utilized. Additional information on extinguishing agents is given in the Airport Services Manual, Part 1.

9.2.11 The amounts of water for foam production and the complementary agents to be provided on the rescue and fire fighting vehicles shall be in accordance with the aerodrome category determined under 9.2.3, 9.2.4, 9.2.5, 9.2.6 and Table 9-2, except that these amounts may be modified as follows:

- a) for aerodrome categories 1 and 2 up to 100 per cent of the water may be replaced by complementary agent; or
- b) for aerodrome categories 3 to 10 when a foam meeting performance level A is used, up to 30 per cent of the water may be replaced by complementary agent.

For the purpose of agent substitution, the following equivalents shall be used:

1 kg complementary agent = 1.0 L water for production of a foam meeting performance level A

1 kg complementary agent = 0.66 L water for production of a foam meeting performance level B

Note 1.— The amounts of water specified for foam production are predicated on an application rate of 8.2 L/min/m² for a foam meeting performance level A, and 5.5 L/min/m² for a foam meeting performance level B.

Note 2.— When any other complementary agent is used, the substitution ratios need to be checked.

9.2.12 The quantity of foam concentrates separately provided on vehicles for foam production shall be in proportion to the quantity of water provided and the foam concentrate selected.

9.2.13 Recommendation.— The amount of foam concentrate provided on a vehicle should be sufficient to produce at least two loads of foam solution.

9.2.14 Recommendation.— Supplementary water supplies, for the expeditious replenishment of rescue and fire fighting vehicles at the scene of an aircraft accident, should be provided.

9.2.15 Recommendation.— When both a foam meeting performance level A and a foam meeting performance level B

Appendix C: ICAO Annex 14, Runway end Safety Area (RESA)

Slopes on runway strips

3.4.12 Longitudinal slopes

Recommendation.— *A longitudinal slope along that portion of a strip to be graded should not exceed:*

- 1.5 per cent where the code number is 4;
- 1.75 per cent where the code number is 3; and
- 2 per cent where the code number is 1 or 2.

3.4.13 Longitudinal slope changes

Recommendation.— *Slope changes on that portion of a strip to be graded should be as gradual as practicable and abrupt changes or sudden reversals of slopes avoided.*

3.4.14 Transverse slopes

Recommendation.— *Transverse slopes on that portion of a strip to be graded should be adequate to prevent the accumulation of water on the surface but should not exceed:*

- 2.5 per cent where the code number is 3 or 4; and
- 3 per cent where the code number is 1 or 2;

except that to facilitate drainage the slope for the first 3 m outward from the runway, shoulder or stopway edge should be negative as measured in the direction away from the runway and may be as great as 5 per cent.

3.4.15 Recommendation.— *The transverse slopes of any portion of a strip beyond that to be graded should not exceed an upward slope of 5 per cent as measured in the direction away from the runway.*

Strength of runway strips

3.4.16 Recommendation.— *That portion of a strip of an instrument runway within a distance of at least:*

- 75 m where the code number is 3 or 4; and
- 40 m where the code number is 1 or 2;

from the centre line of the runway and its extended centre line should be so prepared or constructed as to minimize hazards arising from differences in load bearing capacity to aeroplanes which the runway is intended to serve in the event of an aeroplane running off the runway.

Note.— *Guidance on preparation of runway strips is given in the Aerodrome Design Manual, Part 1.*

3.4.17 Recommendation.— *That portion of a strip containing a non-instrument runway within a distance of at least:*

- 75 m where the code number is 3 or 4;
- 40 m where the code number is 2; and
- 30 m where the code number is 1;

from the centre line of the runway and its extended centre line should be so prepared or constructed as to minimize hazards arising from differences in load bearing capacity to aeroplanes which the runway is intended to serve in the event of an aeroplane running off the runway.

3.5 Runway end safety areas

General

3.5.1 A runway end safety area shall be provided at each end of a runway strip where:

- the code number is 3 or 4; and
- the code number is 1 or 2 and the runway is an instrument one.

Note.— *Guidance on runway end safety areas is given in Attachment A, Section 9.*

Dimensions of runway end safety areas

3.5.2 A runway end safety area shall extend from the end of a runway strip to a distance of at least 90 m.

3.5.3 Recommendation.— *A runway end safety area should, as far as practicable, extend from the end of a runway strip to a distance of at least:*

- 240 m where the code number is 3 or 4; and
- 120 m where the code number is 1 or 2.

3.5.4 The width of a runway end safety area shall be at least twice that of the associated runway.

3.5.5 Recommendation.— *The width of a runway end safety area should, wherever practicable, be equal to that of the graded portion of the associated runway strip.*

Appendix D: ICAO Annex 14, Aerodrome category for rescue and fire fighting

Table 9-1. Aerodrome category for rescue and fire fighting

Aerodrome category (1)	Aeroplane overall length (2)	Maximum fuselage width (3)
1	0 m up to but not including 9 m	2 m
2	9 m up to but not including 12 m	2 m
3	12 m up to but not including 18 m	3 m
4	18 m up to but not including 24 m	4 m
5	24 m up to but not including 28 m	4 m
6	28 m up to but not including 39 m	5 m
7	39 m up to but not including 49 m	5 m
8	49 m up to but not including 61 m	7 m
9	61 m up to but not including 76 m	7 m
10	76 m up to but not including 90 m	8 m

Table 9-2. Minimum usable amounts of extinguishing agents

Aerodrome category (1)	Foam meeting performance level A		Foam meeting performance level B		Complementary agents Dry ² chemical powders (kg) (6)
	Water ¹ (L) (2)	Discharge rate foam solution/ minute (L) (3)	Water ¹ (L) (4)	Discharge rate foam solution/ minute (L) (5)	
1	350	350	230	230	45
2	1 000	800	670	550	90
3	1 800	1 300	1 200	900	135
4	3 600	2 600	2 400	1 800	135
5	8 100	4 500	5 400	3 000	180
6	11 800	6 000	7 900	4 000	225
7	18 200	7 900	12 100	5 300	225
8	27 300	10 800	18 200	7 200	450
9	36 400	13 500	24 300	9 000	450
10	48 200	16 600	32 300	11 200	450

Note 1.— The quantities of water shown in columns 2 and 4 are based on the average overall length of aeroplanes in a given category. Where operations of an aeroplane larger than the average size are expected, the quantities of water would need to be recalculated. See the Airport Services Manual, Part 1 for additional guidance.

Note 2.— Any other complementary agent having equivalent fire fighting capability may be used.

Appendix E: Illustrated Parts Catalog


737-300/400/500
PARTS CATALOG (MAINTENANCE)

FIG ITEM	PART NUMBER	1 2 3 4 5 6 7	NOMENCLATURE	EFFECT FROM TO	UNITS PER ASSY
1B 30	2233000-3A		.UNIT-DIGITAL FLIGHT DATA ACQUISITION SUPPLIER CODE: V98571 MISCELLANEOUS DATA: 2233000-3A HAS ACMS CAPABILITY WITH BUILT-IN FLOPPY DRIVE ELECTRICAL EQUIP NUMBER: M00675 COMPONENT MAINT MANUAL REF: 31-32-80	401407 412412 415418 421500	1
30	2233000-4A		.UNIT-DIGITAL FLIGHT DATA ACQUISITION SUPPLIER CODE: V98571 MISCELLANEOUS DATA: 2233000-4A HAS ACMS CAPABILITY WITH BUILT-IN FLOPPY DRIVE ELECTRICAL EQUIP NUMBER: M00675 SOFTWARE DRAWING REF: 31-24-22-01B	401407 412412 <u>415418</u> 421500	1
30	967-0202-001		.UNIT-DIGITAL FLIGHT DATA ACQUISITION SUPPLIER CODE: V97896 MISCELLANEOUS DATA: 967-0202-001 HAS ACMS CAPABILITY ELECTRICAL EQUIP NUMBER: M00675 COMPONENT MAINT MANUAL REF: 31-31-17 SOFTWARE DRAWING REF: 31-24-22-01B	401407 412412 <u>415418</u> 421500	1
30	2227000-45		.UNIT-DIGITAL FLIGHT DATA ACQUISITION (CUSTOMER FURNISHED) SUPPLIER CODE: V98571 ELECTRICAL EQUIP NUMBER: M00675 COMPONENT MAINT MANUAL REF: 31-32-45	408410	1

MISSING ITEM NO. NOT APPLICABLE

- ITEM NOT ILLUSTRATED

31-24-22-01B

31-24-22
FIG. 1B
PAGE 2
JAN 12/05

GIA

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Appendix F: Garuda Flight Operation Manual



FLIGHT OPERATIONS

04 APR 2007

Notice To : Flight Crew
Nr : 14 / 07
Subject : New Procedure of 1000/ 500 feet
Call During Approach & Landing

Date : 02 April 2007

Flight Crew Yth.

Untuk mencegah terjadinya kecelakaan khususnya pada fase Approach dan Landing, kami sampaikan kepada seluruh flight crew untuk melaksanakan perubahan/tambahan terhadap Policy (ditulis dengan bold) dan SOP sebagai berikut:

1. BOM 4.4.4-05: 500 Feet Call

A 500 feet call must be included in the final part of each approach, to protect against subtle incapacitation and to serve as an awareness call for the approach stability and the landing clearance.

If there is no automatic 500 ft call, the Pilot Monitoring must give this call.

The PF must respond: 'CLEARED / NOT CLEARED', followed by a 'CHECKED' call from the Pilot Monitoring, which means that he/she agrees with the response from the PF.

If no landing clearance : Obtain Landing Clearance
If the aircraft is not stabilize : Go Around

If disagreement to the objective of 500 feet call (and stabilized approach criteria) exists or when doubt exists to the awareness of, or no appropriate response from the PF, the PM shall consider him/her in the subtle incapacitation state (BOM 5.2.1-C). The PM shall take over control and execute Go Around.

File an incident report on ASR as soon as possible.

It is mandatory to execute go around and /or reject the landing at any time when the safety of the flight is jeopardized.

The company will not initiate disciplinary measures for a go around executed under any unsafe or unstabilize approach.

2. BOM 4.4.4-06: APPROACH STABILITY

" If the aircraft is not stabilized below 1000 feet above airport elevation in IMC and by 500 feet in VMC in accordance with the stabilized criteria, the PIC or PF SHALL Go Around" (see BOM 4.4.4-05)

3. Perubahan ini berlaku effective mulai tanggal 09 April 2007. „BOM dan AOM seluruh type akan direvisi.

Demikian disampaikan atas perhatiannya diucapkan terima kasih dan selamat terbang.

PT GARUDA INDONESIA (PERSERO)
VP FLIGHT OPERATIONS

CAPT. S SAMAD

00070263

Appendix G: Report on Solid State Flight Data Recorder (SSFDR) replay and analysis

This appendix contains an excerpt from Australian Transport Safety Bureau report on the replay and analysis of the flight recorders

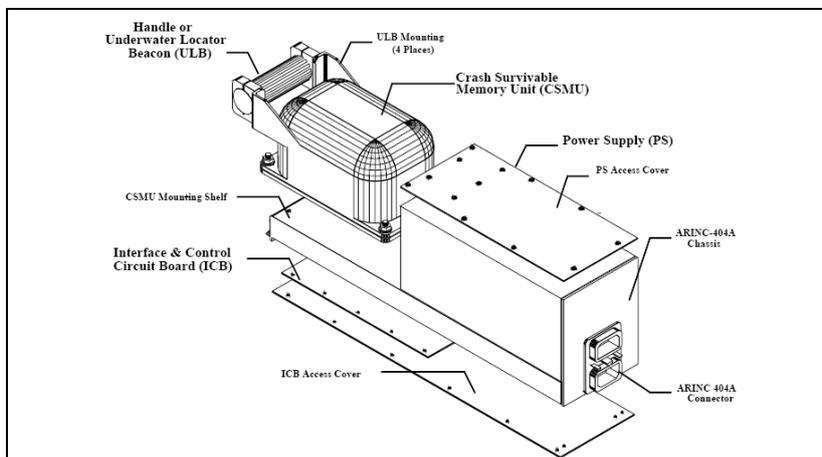


Figure 1: SSFDR exploded view showing major shop replaceable items (Honeywell)



Figure 2: PK-GZC flight data recorder as received at the ATSB on 9 March 2007

The memory board was carefully removed from the CSMU on 09 March 2007 (Figure 3).



Figure 3: Memory board from PK-GZC SSFDR

The memory board connector pins were cleaned and the flex cable replaced (Figure 4 and Figure 5)

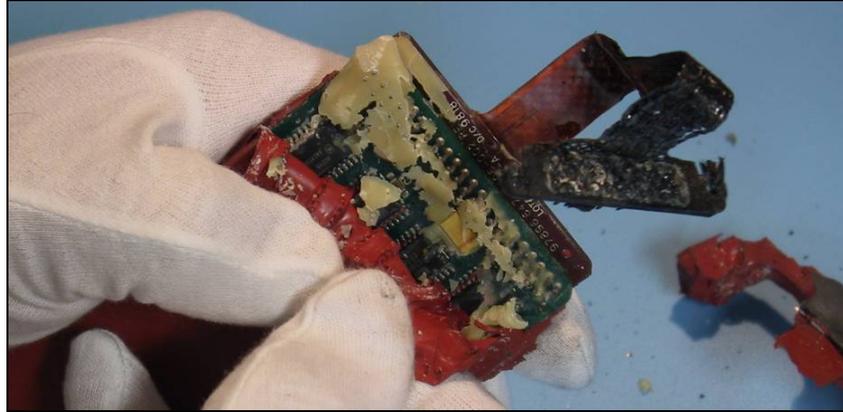


Figure 4: SSFDR memory board connector pins and damaged flex cable

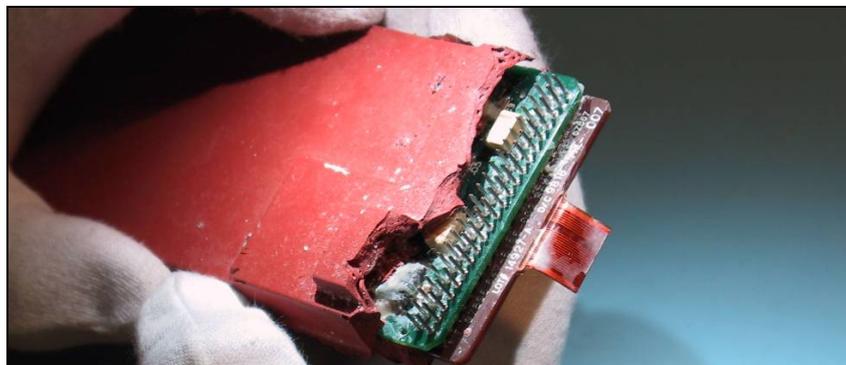


Figure 5: Connector pins and cable prior to download

The PK-GZC memory board was connected to the ATSB slave SSFDR chassis and downloaded using Honeywell Ruggedized Portable Ground Support Equipment (RPGSE) (Figure 6).



Figure 6: PK-GZC memory board connected to ATSB SSFDR and RPGSE

The SSFDR contained approximately 53 hours of flight data that comprised thirty-two flights including the accident flight.

SSFDR data frame layout

On 09 March 2007, the aircraft manufacturer advised that PK-GZC was an Electronic Flight Instrumentation System (EFIS) and Engine Indicating System (EIS) equipped aircraft. Records indicated that the aircraft was delivered with a Teledyne digital flight data acquisition unit (DFDAU), part number 2233000-4A. They advised that the data frame layout used for decoding the SSFDR would consequently be a 737-1EE frame format.

The SSFDR data downloaded from PK-GZC was subsequently confirmed to be in the 737-I (eye) non-EFIS data frame format. This was not the data frame the aircraft was intended to operate with, since it was an EFIS/ EIS aircraft. The data frame/ aircraft mismatch resulted in the DFDAU looking to non-existent analogue sources of data for many parameters normally supplied by EFIS and EIS. This resulted in some parameters not being recorded.

Information received from the operator indicated that the original Teledyne DFDAU part number 2233000-4A had been removed and replaced with Teledyne DFDAU part number 2227000-45 at some time before June 2004.

As a result of the mismatch, engine parameters (N1, N2, EGT, fuel flow, oil pressure and temperature), Instrument Landing System (ILS) parameters (glideslope and localiser deviation,) and radio altitude, were not available.

Aircraft attitude parameters (pitch, roll, etc), sourced from the inertial reference unit (IRU) were recorded correctly.

Flight data parameters

Examination and analysis of the SSFDR data were carried out using Flightscape Insight software and the 737-I (eye) data frame. Tables and plots of relevant engineering parameters (Table 1 and Table 2) recorded during the accident flight were prepared and provided to the NTSC to assist in analysis of the accident.

Table 1: Key engineering parameters examined

Parameter	Units	Sampling interval (seconds)
GMT (Greenwich Mean Time)	hh:mm:ss	4
Altitude – pressure ²¹	feet	1
Altitude - corrected ²²	feet	1
Magnetic Heading	degrees	1
Airspeed - Computed	knots	1
Groundspeed	knots	1
Drift Angle	degrees	1
Wind Speed	knots	4
Wind Direction True	degrees	4
Lateral Acceleration	g	0.25
Longitudinal Acceleration	g	0.25

²¹ Altitude measured relative to standard atmospheric pressure 29.92 in Hg or 1013.25 mb

²² Altitude corrected to the pressure of the day at Yogyakarta on 07 March 2007 - 1003.6 mb

Vertical Acceleration	G	0.125
Pitch Angle	degrees	0.25
Roll Angle	degrees	0.5
Angle of Attack	degrees	0.5
T.E. Flaps Position (left and right)	degrees	1
Speed Brake Handle Position	degrees	1
Throttle Lever Angle (left and right)	degrees	1
DME Distance (left and right)	NM	4
VOR/ILS Freq (left and right)	MHz	4

Table 2: Key discrete parameters

Parameter	Units	Sampling interval (seconds)
Air /Ground Switch	AIR /GROUND	1
Auto Throttle (A/T) engaged.	ENGAGED /NOT ENGAGED	1
Auto Pilot	ON /OFF	1
Master Caution	WARNING /NO WARNING	1
GPWS Alert ²³	TRUE /FALSE	1
VHF Keying (left and right)	KEYED /NOT KEYED	1
Gear Down (left, right and nose)	UP /DOWN	1
Thrust Reversers Deployed (inboard and outboard) (left and right)	DEPLOYED /NOT DEPLOYED	2
VOR/ILS Select (left and right)	VOR /ILS	4
VOR/LOC Engage.	ENGAGED /NOT ENGAGED	4

Aircraft brake data was not a parameter recorded on this SSFDR.

SSFDR data synchronization with cockpit voice recorder audio

Following download and transcription of the SSCVR information by NTSC investigators at the ATSB's flight recorder laboratory in Canberra, Australia, synchronisation of the SSCVR audio to SSFDR data was achieved by correlating VHF keying events. The NTSC was provided with a table correlating the SSFDR and SSCVR data to SSFDR recorded GMT. This information is provided from the time that PK-GZC enters the ILS approach. The SSFDR data ended at precisely the same time as the SSCVR audio.

²³ The GPWS discrete parameter incorporated all GPWS warning into one bit so the different GPWS annunciations were not available from the FDR. Specific warnings were obtained from the SSCVR recording.

SSFDR data frame layout

The aircraft manufacturer advised that when an inappropriate older DFDAU is installed on the aircraft such as part number 2227000-45 (as per PK-GZC) that the DFDAU will select the older 737-I (eye) data frame in lieu of the newer data frame 737-1. The data frame mismatch resulted in the DFDAU looking to non-existent analogue sources of data for parameters normally supplied by EFIS and EIS as seen on PK-GZC.

A previous download of PK-GZC flight data by the operator in 2006 was also examined. The data frame mismatch and non-recording of EFIS and EIS parameters existed at this time.

Approach distance from VOR (DME) versus altitude

The Garuda Yogyakarta (JOG) Route Manual Charts and Jeppesen ILS DME Rwy 09 chart were used to conduct a distance versus altitude comparison of the PK-GZC approach profile. The altitudes and distances relating to the approach profiles are identical between both chart presentations. The recorded values of DME DISTANCE-LEFT transmitted on ILS DME 109.1 MHz IJOG were plotted against corrected pressure altitude (aerodrome QNH at Yogyakarta was 1003.6 mb). The approach plate elevation profiles from the charts (Figure 7) were compared to the elevation approach profile of PK-GZC during the accident flight.

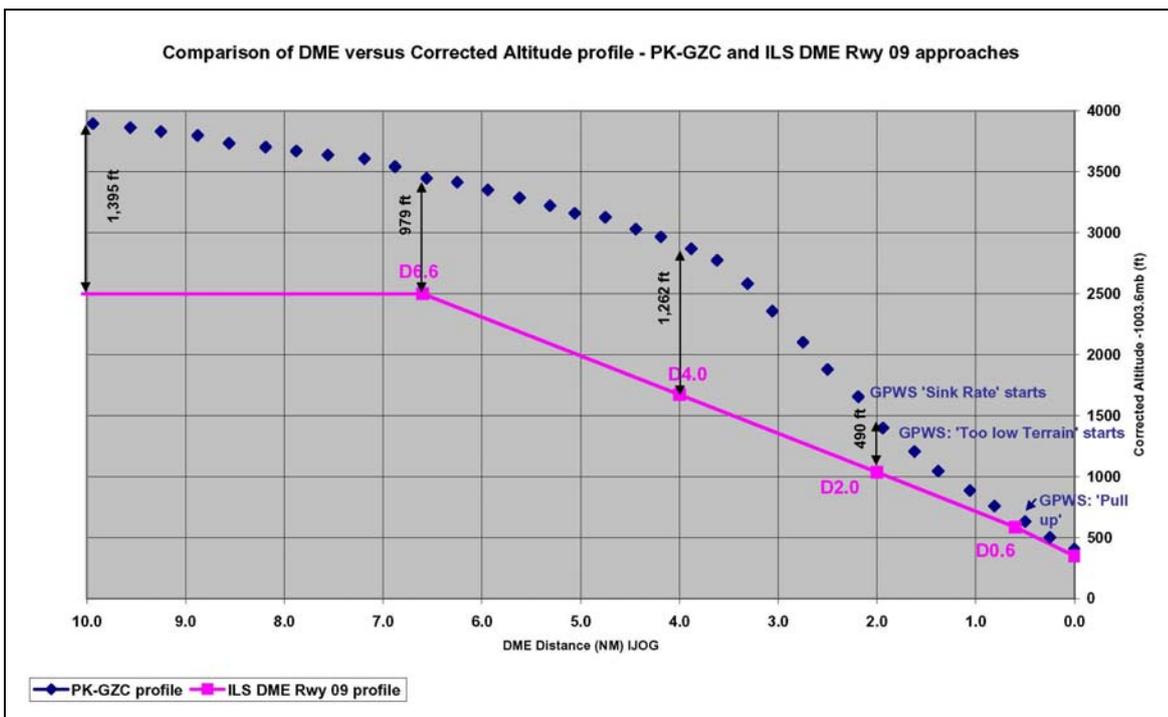


Figure 7: Yogyakarta runway 09 approach showing DME vs corrected altitude profile of PK-GZC and ILS DME approach plates

At the intermediate fix (IF) 10.1 DME IJOG (3.5 DME JOG) PK-GZC corrected altitude was 3,927 feet. The aircraft passed the final approach point (FAP), 6.6 DME IJOG, passing JOG VOR, approximately 950 feet above the approach plate altitude (2,500 feet) to commence the 3 degree glideslope. At D4.0 IJOG, PK-GZC was at 2,935 feet, 1,262 feet above the glideslope (1,673 feet). At D2.0 IJOG, PK-GZC was at 1,527 feet, 490 feet above the glideslope (1,037 feet). PK-GZC attained the glideslope at approximately 0.5 DME IJOG.

The approach flight path was derived using the groundspeed, drift angle, heading and corrected altitude. An elevation profile view of the flight path was overlaid on the Garuda JOG approach plate using Insight animation (Figure 8). The PK-GZC approach profile was considerably higher than the 3 degree glideslope approach profile.

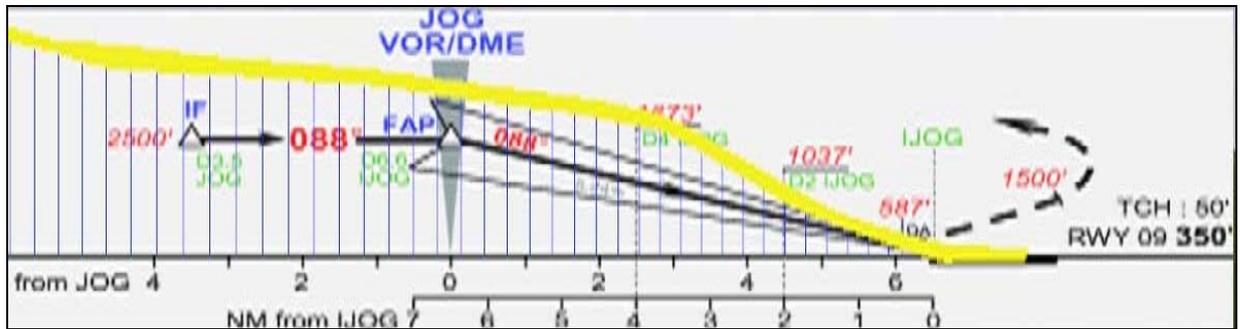


Figure 8: Screenshot of the animated PK-GZC flight path (blue) over the Garuda Yogyakarta approach plate (elevation view)

Ground track

The plan view of Garuda’s approach plate was also applied to the animated flight path (Figure 9) for comparison.

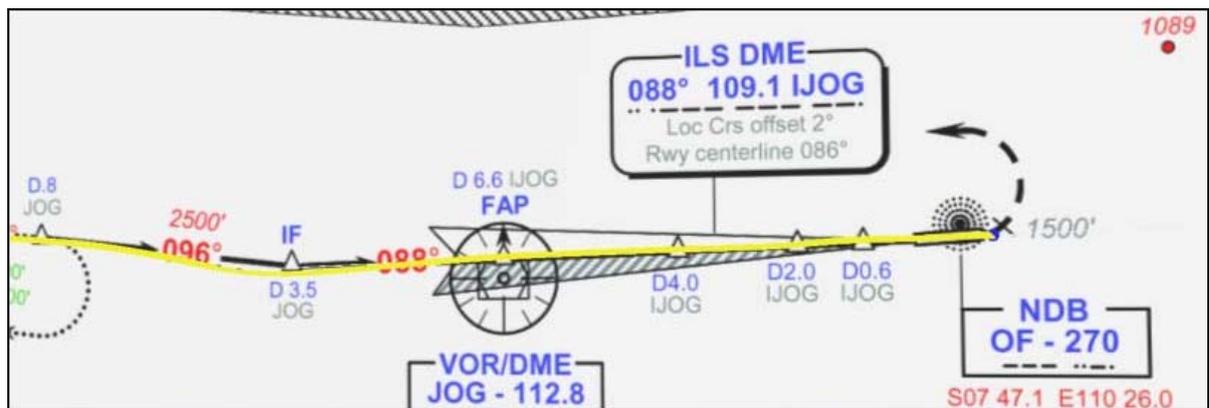


Figure 9: Screenshot of the animated PK-GZC flight path (blue) over the Garuda Yogyakarta approach plate (plan view)

The PK-GZC approach ground track approximately followed the published approach track on the Garuda plate.

Three vertical acceleration spikes of increasing magnitude (+1.86g, +2.26g, +2.91g respectively) were recorded over a four-second period from 23:57:54.

The final two spikes resulted in activation of the air/ground parameter to GROUND (initially for one sample and finally for the duration of the recording).

The initial vertical acceleration peak of 1.86g although not resulting in a GROUND activation, was consistent with a sudden roll direction change of eight degrees over two samples (Figure 12). The vertical acceleration spike corresponding with a roll rate greater than 8 degrees/second and direction change indicated that a touchdown had occurred at this time.

The final touchdown time was considered to be coincident with the +2.91 g vertical acceleration peak at 23:57:57. At this time the aircraft pitch angle was recorded as 3.5 degrees and decreased to -1.1 degree over the following second. This was considered to be the time when the nose wheel of the aircraft separated and the nose gear commenced contact with the runway surface (nose wheel separation section 2.9). The physical evidence/damage, attributed to the landing of PK-GZC, was noted during the inspection of Yogyakarta runway 09 on 10 March 2007. The nose landing gear scrape mark commenced at chainage marking 222 (1,100m from runway 09 threshold).

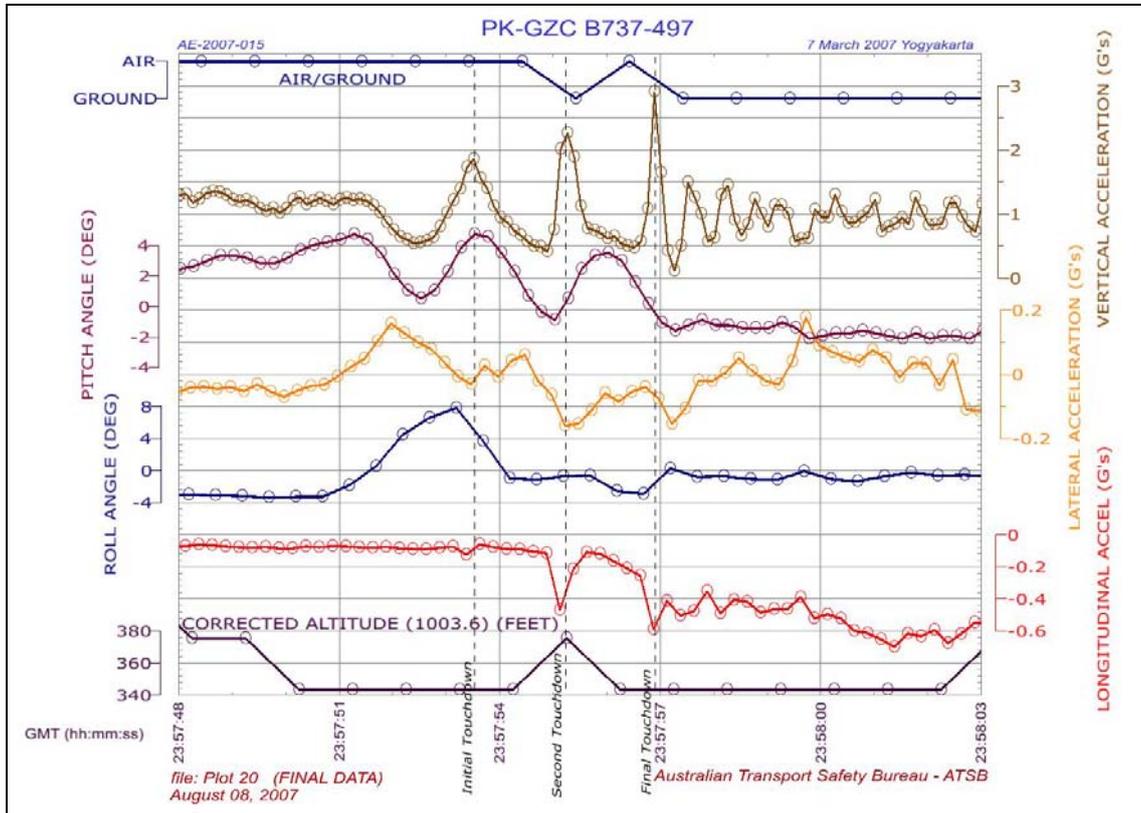


Figure 10: Graphical representation of 15-second touchdown period

Flight path animation

A flight path was calculated from the recorded flight data using groundspeed, magnetic heading, drift, corrected altitude, pitch and roll. A satellite image of the Yogyakarta airport was imported into the Flightscape software and scaled against a known runway length model. The flight path was positioned with the final touchdown point (resulting in nose wheel separation and nose landing gear axle and strut runway contact) coinciding with the commencement of the strut scrape found as physical evidence on-site. Consideration was given to the pitch angle of the aircraft for more precise positioning.

The flight path animation was then used to check correlation with the location of the three touchdown points identified from the touchdown calculation; section 2.7). The calculated touchdown locations correlated closely with the location of physical evidence observed on the runway and the position of the aircraft depicted in the animation, (Figure 15, Figure 16 and Figure 17).



Figure 11: Initial touchdown location (+1.86G)

The initial touchdown was further along the runway than the touchdown zone for runway 09. The animation touchdown locations matched both the calculated touchdown points and physical evidence observed on the runway considered to be associated with PK-GZC accident landing.



Figure 12: Second touchdown location (+2.26G)



Figure 13: Final touchdown location (+2.91G)



Figure 14: Flight path animation showing start of nose gear scrape



Figure 15: Flight path animation of aircraft leaving paved runway landing roll distance

The flight path animation showed the aircraft passing over the runway threshold line marking at 23:57:47. Calculation of landing roll and runway distances were made using groundspeed (Table 4).

GMT (hh:mm:ss)	GROUNDSPEED (KNOTS)	GROUNDSPEED (m/sec)	DISTANCE TRAVELLED (m)	COMMENT
23:57:47	236	121	0	
	235	121	121	
	233	120	241	
	232	119	360	
23:57:51	230	118	478	
	228	117	596	
	226	116	712	Initial touchdown
	224	115	827	
23:57:55	222	114	941	Second touchdown
	219	113	1054	
	215	111	1165	Final touchdown
	207	106	1271	

23:57:59	199	102	1374	
	192	99	1472	
	183	94	1566	
	172	88	1655	
23:58:03	163	84	1739	
	155	80	1819	
	147	76	1894	
	140	72	1966	
23:58:07	133	68	2035	
	126	65	2099	
	120	62	2161	
	114	59	2220	Crossing rwy 27 threshold
	107	55	2275	

The flight path animation indicated that the aircraft passed the threshold line marking of runway 27 at 23:58:10 (Figure 16). Table 4 gives a distance of approximately 2,220 meters to this point which equates closely to the published runway length of 2,200 m between threshold marks. Jeppesen Chart relating to Yogyakarta, JOG ADI SUTJIPTO²⁴, shows a stopway distance of 60 meters on the far end of runway 09 giving a total distance from the 09 threshold to the end of the stopway of 2260 meters.



Figure 16: Flight path animation of aircraft passing over runway 27 threshold line

²⁴ Yogyakarta Adi Sucipto Airport is spelt JOG ADI SUTJIPTO on the Jeppesen chart.

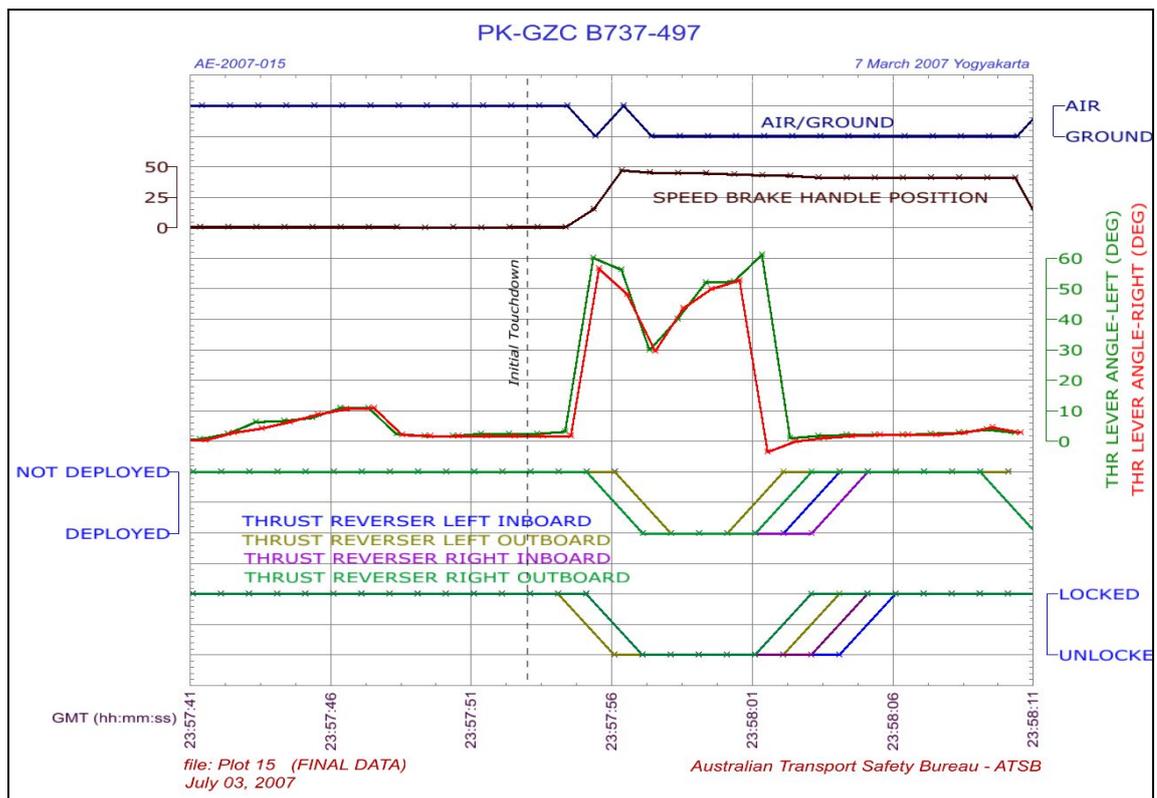


Figure 17: Snapshot of initial, second and final touchdowns

Thrust reversers

The recorded flight data indicated that only the right thrust reverser was used on the previous two landings. Further examination found that only the right thrust reverser had been used for the previous 27 sectors. This indicated that the left thrust reverser was unserviceable for a considerable number of flights immediately prior to the accident flight.

However the recorded data showed that both engines’ thrust reversers were deployed at 23:57:58, 4 seconds after the touchdown. They were stowed at 23:58:05 approximately seven seconds prior to the aircraft departing the paved runway.



End of recorded data

The flight recorders stopped shortly after the aircraft departed the paved runway surface, possibly indicating that the engines were shutdown while the aircraft was still on the runway. The data finished prior to the expected end of data (i.e. before the aircraft contacted the road) and coincided with the end of SSCVR audio.

This may indicate that power to the recorders was lost as a result of an engine shutdown and subsequent generator run down.

Appendix H: Flight Safety Foundation (FSF) CFIT Checklist risk reduction guide



Flight Safety Foundation

CFIT Checklist Evaluate the Risk and Take Action

Flight Safety Foundation (FSF) designed this controlled-flight-into-terrain (CFIT) risk-assessment safety tool as part of its international program to reduce CFIT accidents, which present the greatest risks to aircraft, crews and passengers. The FSF CFIT Checklist is likely to undergo further developments, but the Foundation believes that the checklist is sufficiently developed to warrant distribution to the worldwide aviation community.

Use the checklist to evaluate specific flight operations and to enhance pilot awareness of the CFIT risk. The checklist is divided into three parts. In each part, numerical values are assigned to a variety of factors that the pilot/operator will use to score his/her own situation and to calculate a numerical total.

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 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 your CFIT Risk Score. To score the checklist, use a nonpermanent marker (do not use a ballpoint pen or pencil) and erase with a soft cloth.

Part I: CFIT Risk Assessment

Section 1 – Destination CFIT Risk Factors

	Value	Score
Airport and Approach Control Capabilities:		
ATC approach radar with MSAWS	0	_____
ATC minimum radar vectoring charts	0	_____
ATC radar only	-10	_____
ATC radar coverage limited by terrain masking	-15	_____
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	0	_____
VOR/DME	-15	_____
Nonprecision approach with the approach slope from the FAF to the airport TD shallower than 2 3/4 degrees	-20	_____
NDB	-30	_____
Visual night "black-hole" approach	-30	_____
Runway Lighting:		
Complete approach lighting system	0	_____
Limited lighting system	-30	_____
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	Score
Your Company's Type of Operation (select only one value):		
Scheduled	1.0	_____
Nonscheduled	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 Commonwealth of Independent States)	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 flight crew	1.5	_____
Flight crew duty day at maximum and ending with a night nonprecision approach	1.2	_____
Flight 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		(-) _____

Part II: CFIT Risk-reduction Factors

Section 1 – Company Culture

	Value	Score
Corporate/company management:		
Places safety before schedule	20	_____
CEO signs off on flight operations manual	20	_____
Maintains a centralized 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 training	15	_____
Places no negative connotation on a diversion or missed approach	20	_____
115-130 points	Tops in company culture	Company Culture Total (+) _____ *
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	Score
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 positions	10	_____
Checking crossing altitudes at FAF and glideslope centering	10	_____
Independent verification by PNF of minimum altitude during stepdown DME (VOR/DME or LOC/DME) approach	20	_____
Requiring approach/departure procedure charts with terrain in color, 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	_____
Use of 500-foot 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 familiarization aids, such as audiovisual aids	10	_____
First officer 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	_____
<hr/>		
300-335 points	Tops in CFIT flight standards	
270-300 points	Good, but not the best	Flight Standards Total (+) _____ *
200-270 points	Improvement needed	
Less than 200	High CFIT risk	

Section 3 – Hazard Awareness and Training

	Value	Score
Your company reviews training with the training department or training contractor	10	_____
Your 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, MOCA, MSA, MEA, etc.	15	_____
You have a trained flight safety officer who rides the jump seat occasionally	25	_____
You have flight safety periodicals that describe and analyze CFIT incidents	10	_____
You have an incident/exceedance review and reporting program	20	_____
Your organization investigates every instance in which minimum terrain clearance has been compromised	20	_____

You annually practice recoveries from terrain with GPWS in the simulator 40 _____
 You train the way that you fly 25 _____

285-315 points	Tops in CFIT training	Hazard Awareness and Training Total (+) _____ *
250-285 points	Good, but not the best	
190-250 points	Improvement needed	
Less than 190	High CFIT risk	

Section 4 – Aircraft Equipment

	Value	Score
Aircraft includes:		
Radio altimeter with cockpit display of full 2,500-foot range — captain only	20	_____
Radio altimeter with cockpit display of full 2,500-foot range — copilot	10	_____
First-generation GPWS	20	_____
Second-generation GPWS or better	30	_____
GPWS with all approved modifications, data tables and service bulletins to reduce false warnings	10	_____
Navigation display and FMS	10	_____
Limited number of automated altitude callouts	10	_____
Radio-altitude automated callouts for nonprecision approach (not heard on ILS approach) and procedure	10	_____
Preselected radio altitudes to provide automated callouts that would not be heard during normal nonprecision approach	10	_____
Barometric altitudes and radio altitudes to give automated “decision” or “minimums” callouts	10	_____
An automated excessive “bank angle” callout	10	_____
Auto flight/vertical speed mode	-10	_____
Auto flight/vertical speed mode 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	_____
175-195 points	Excellent equipment to minimize CFIT risk	Aircraft Equipment Total (+) _____ *
155-175 points	Good, but not the best	
115-155 points	Improvement needed	
Less than 115	High CFIT risk	

Company Culture _____ + Flight Standards _____ + Hazard Awareness and Training _____
+ Aircraft Equipment _____ = CFIT Risk-reduction Factors Total (+) _____

*** If any section in Part II scores less than “Good,” a thorough review is warranted of that aspect of the company’s operation.**

Part III: Your CFIT Risk

Part I CFIT Risk Factors Total (-) _____ + Part II CFIT Risk-reduction Factors Total (+) _____
= CFIT Risk Score (±) _____

A negative CFIT Risk Score indicates a significant threat; review the sections in Part II and determine what changes and improvements can be made to reduce CFIT risk.

In the interest of aviation safety, this checklist may be reprinted in whole or in part, but credit must be given to Flight Safety Foundation. To request more information or to offer comments about the FSF CFIT Checklist, contact Robert H. Vandel, director of technical projects, Flight Safety Foundation, 601 Madison Street, Suite 300, Alexandria, VA 22314 U.S., Telephone: +1 (703) 739-6700 • Fax: +1 (703) 739-6708.

FSF CFIT Checklist © 1994 Flight Safety Foundation

Appendix I: FSF Approach-and-landing Risk Reduction Guide



Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

Tool Kit

Approach-and-landing Risk Reduction Guide

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force designed this guide as part of the *FSF ALAR Tool Kit*, which is designed to help prevent ALAs, including those involving controlled flight into terrain. This guide should be used to evaluate specific flight operations and to improve crew awareness of associated risks. This guide is intended for use as a strategic tool (i.e., for long-term planning).

Part 1 of this guide should be used by the chief pilot to review flight operations policies and training. Part 2 should be used by dispatchers and schedulers. The chief pilot should provide Part 3 to flight crews for evaluating pilot understanding of company training objectives and policies. Part 4 should be used by the chief pilot and line pilots.

This guide is presented as a “check-the-box” questionnaire; boxes that are not checked may represent shortcomings and should prompt further assessment.

Part 1 — Operations: Policies and Training

Check the boxes below that apply to your specific flight operations.

Approach

Crew Resource Management

- Is risk management taught in initial training and recurrent training?
- Are crew resource management (CRM) roles defined for each crewmember?
- Are CRM roles defined for each crewmember for emergencies and/or system malfunctions?
- Are standard operating procedures (SOPs) provided for “sterile-cockpit”¹ operations?
- Are differences between domestic operations and international operations explained in CRM training?
- Is decision making taught in CRM training?

Approach Procedures

- Do detailed and mandatory approach-briefing requirements exist? (See Part 4 below.)
- Are approach risks among the required briefing items?
- Are standard calls defined for approach deviations?
- Are limits defined for approach gate² at 1,000 feet in instrument meteorological conditions (IMC) or at 500 feet in visual meteorological conditions (VMC).
- Is a missed approach/go-around recommended when stabilized approach criteria (Table 1) are exceeded?
- Is a “no fault” go-around policy established? If so, is it emphasized during training?
- Does the checklist policy require challenge-and-response for specified items?
- Does the checklist policy provide for interruptions/distractions?
- Is a go-around recommended when the appropriate checklist is not completed before reaching the approach gate?

Flight Safety Foundation Approach-and-landing Risk Reduction Guide (Rev 1.1, 11/00) 1

**Table 1
Recommended Elements of a Stabilized Approach**

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than $V_{REF} + 20$ knots indicated airspeed and not less than V_{REF} ;
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

- Are captain/first officer weather limits provided for approach (e.g., visibility, winds and runway conditions)?
- Are crewmember roles defined for approach (e.g., crewmember assigned pilot flying duties, crewmember monitoring and conducting checklist, crewmember who decides to land or go around, crewmember landing aircraft, exchange of aircraft control)?

Fuel

- Are fuel minimums defined for proceeding to the alternate airport, contingency fuel, dump-fuel limits?
- Are crews aware of when to declare "minimum fuel" or an emergency?
- When declaring an emergency for low fuel, is International Civil Aviation Organization (ICAO) phraseology required (e.g., "Mayday, Mayday, Mayday for low fuel")?

Approach Type

- Is your risk exposure greatest during precision, nonprecision, circling or visual approaches? Is the training provided appropriate for the risk?
- Are SOPs provided for constant-angle nonprecision approaches (CANPAs) using rate of descent or angle?

Environment

- Is training provided for visual illusions on approach (e.g., "black hole effect,"³ sloping terrain, etc.)?
- Is training provided for minimum-safe-altitude awareness?
- Does a policy exist to use the radio altimeter as a terrain-awareness tool?
- Are crews required to adjust altitudes during approach for lower than international standard atmosphere (ISA) standard temperatures?

- Are crews aware that most approach-and-landing accidents occur with multiple conditions present (e.g., rain and darkness, rain and crosswind)?

Airport and Air Traffic Control (ATC) Services

- Are crews aware of the increased risk at airports without radar service, approach control service or tower service?
- Is training provided for unfamiliar airports using a route check or a video?
- Is potential complacency at very familiar airports discussed?
- Are crews provided current weather at destination airfields via automatic terminal information service (ATIS), airborne communications addressing and reporting system (ACARS) and/or routine weather broadcasts for aircraft in flight (VOLMET)?

Aircraft Equipment

- Are procedures established to evaluate the accuracy and reliability of navigation/terrain databases?
- Are mechanical checklists or electronic checklists installed?
- Is a radio altimeter installed in the pilot's normal scan pattern?
- Does the radio altimeter provide visual/audio alerting?
- Is a wind shear alert system (either predictive or reactive) installed?
- Is a ground-proximity warning system (GPWS) or a terrain awareness and warning system (TAWS)⁴ installed?
- Is a traffic-alert and collision avoidance system (TCAS) installed?
- Are head-up displays (HUDs) installed with a velocity-vector indicators?
- Are angle-of-attack indicators installed?
- For aircraft with a flight management system (FMS), are lateral navigation/vertical navigation (LNAV/VNAV) approach procedures database-selected?
- Are pilots prevented from modifying specified FMS data points on approach?
- Is the FMS system "sole-means-of-navigation" capable?
- Is there a policy for appropriate automation use (e.g., "full up for Category III instrument landing system, okay to turn automation off for a daylight visual approach")?
- Is there a policy requiring standard calls by the pilot not flying for mode changes and annunciations on the mode control panel?
- Is training provided and are policies established for the use of all the equipment installed on all aircraft?
- Are current and regulator-approved navigation charts provided for each flight crewmember?

Flight Crew

- Is there a crew-pairing policy established for new captain/new first officer based on flight time or a minimum number of trip segments?
- Is the check airmen/training captain program monitored for feedback from pilots? Are additional training needs, failure rates and complaints about pilots from line operations tracked? Is it possible to trace these issues to the check airmen/training captain who trained specific pilots?
- Is there a hazard reporting system such as a captain's report? Are policies established to identify and to correct problems? Is a system set up to provide feedback to the person who reports a hazard?

Safety Programs

- Is a nonpunitive safety reporting system established?
- Is a proactive safety monitoring program such as a flight operational quality assurance (FOQA) program or an aviation safety action program (ASAP) established?

Landing

- Is training provided and are policies established for the use of visual landing aids?
- Is it recommended that crews use all available vertical guidance for approaches, especially at night?
- Is training provided and are policies established for landing on contaminated runways with adverse winds?
- Are crews knowledgeable of the differences in braking deceleration on contaminated runways and dry runways?
- Does training include performance considerations for items such as critical touchdown area, braking required, land-and-hold-short operation (LAHSO), engine-out go-around, and full-flaps/gear-extended go-around?
- Does the aircraft operating manual (AOM)/quick reference handbook (QRH) provide crosswind limitations?
- Is a policy in effect to ensure speed brake deployment and autobrake awareness?
- Does policy prohibit a go-around after reverse thrust is selected?

Part 2 — Dispatcher/Scheduler

Check the boxes below that apply to your specific flight operations.

- Does the company have a dispatch system to provide information to assist flight crews in evaluating approach-and-landing risks?

Approach and Landing

- Are dispatchers and captains familiar with each other's authority, accountability and responsibility?
- Are crews monitored for route qualifications and appropriate crew pairing?
- Are crew rest requirements defined adequately?
- Does the company monitor and provide suitable crew rest as defined by requirements?
- Are crews provided with timely and accurate aircraft performance data?
- Are crews assisted in dealing with minimum equipment list(MEL)/dispatch deviation guide (DDG)/configuration deviation list (CDL) items?
- Do dispatch-pilot communications exist for monitoring and advising crews en route about changing conditions?
- Are updates provided on weather conditions (e.g., icing, turbulence, wind shear, severe weather)?
- Are updates provided on field conditions (e.g., runway/taxiway conditions, braking-action reports)?
- Is there coordination with the captain to determine appropriate loads and fuel required for the effects of ATC flow control, weather and alternates?
- Are all the appropriate charts provided for routing and approaches to destinations and alternates?
- Is a current notice to airmen (NOTAM) file maintained for all of your operations and is the appropriate information provided to crews?

Part 3 — Flight Crew

Check the boxes below that apply to your specific flight operations.

- Do you believe that you have appropriate written guidance, training and procedures to evaluate and reduce approach-and-landing risks?

Approach

- Is the [Flight Safety Foundation Approach-and-landing Risk Awareness Tool \(RAT\)](#) provided to flight crews, and is its use required before every approach?
- Does the approach briefing consist of more than the "briefing strip" minimum? (See Part 4 below.)

- Do briefings include information about visual illusions during approach and methods to counteract them?
- Are the following briefed: setup of the FMS, autopilot, HUD, navigation radios and missed approach procedures?
- Is a discussion of missed approach/go-around details required during every approach briefing?
- Are performance minimums briefed for the approach gate?
- Are standard calls required for deviations from a stabilized approach?
- Does the briefing include execution of a missed approach/go-around if criteria for the approach gate are not met?
- Are stabilized approach criteria defined? Is a go-around recommended in the event that these criteria are not met?
- Does your company practice a no-fault go-around policy?
- Are you required to write a report to the chief pilot if you conduct a missed approach/go-around?
- Do you back up the flight plan top-of-descent point with your own calculation to monitor descent profile?
- Are approach charts current and readily available for reference during approach?
- Are policies established to determine which crewmember is assigned pilot flying duties, which crewmember is assigned checklist duties, which crewmember will land the aircraft and how to exchange aircraft control? Do these policies change based on prevailing weather?
- Do terrain-awareness procedures exist (e.g., calling "radio altimeter alive," checking radio altimeter altitudes during approach to confirm that the aircraft is above required obstacle clearance heights)?
- Do altitude-deviation-prevention policies exist (e.g., assigned altitude, minimum descent altitude/height [MDA(H)], decision altitude/height [DA(H)])?
- Are you familiar with the required obstacle clearance criteria for charting design?
- Do altimeter-setting procedures and cross-check procedures exist?
- Do temperature-compensation procedures exist for temperatures lower than ISA at the destination airport?
- Are you aware of the increased risk during night/low-visibility approaches when approach lighting/visual approach slope indicator/precision approach path indicator aids are not available? How do you compensate for these deficiencies? For example, are runways with vertical guidance requested in those conditions?
- Are you aware of the increased risk associated with nonprecision approaches compared with precision approaches?
- Is a CANPA policy established at your company? Are you aware of the increased risk associated with step-down approaches compared with constant-angle approaches?
- Is a policy established for maintaining visual look-out, and is there a requirement to call "head-down"?
- Does a look-out policy exist for approach and landing in visual flight rules (VFR) conditions?

Part 4 — Recommended Approach-and-landing Briefing Items

For the approach-risk briefing, refer to top-of-descent use of the [FSF Approach-and-landing RAT](#).

In addition to the briefing strip items (e.g., chart date, runway, approach type, glideslope angle, check altitudes), which of following items are briefed, as appropriate?

- Automation setup and usage
- Navigation equipment setup and monitoring
- Rate of descent/angle of descent

- Intermediate altitudes and standard calls
- Altitude-alert setting and acknowledgment
- MDA(H)/DA(H) calls (e.g., “landing, continue, go-around”); runway environment expected to see (offsets); lighting
- Radio-altimeter setting in the DH window, calls required (e.g., “radio altimeter alive” and “below 1,000 feet” prior to an intermediate approach fix; “below 500 feet” prior to the final approach fix [FAF]; “go around” after the FAF if “minimums” is called [with radio altimeter at 200 feet] and if visual contact with the required references is not acquired or the aircraft is not in position for a normal landing)
- Aircraft configuration
- Airspeeds
- Checklists complete
- ATC clearance
- Uncontrolled airport procedures
- Manual landing or autoland
- Missed approach procedure/go-around
- Performance data
- Contaminated runway/braking action and autobrakes
- Illusions/hazards or other airport-specific items
- Abnormals (e.g., aircraft equipment/ground facilities unserviceable, MEL/DDG items, glideslope out)
- Runway (e.g., length, width, lighting, LAHSO, planned taxiway exit)
- Procedure for simultaneous approaches (as applicable)

References

1. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: “No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight.” [The FSF ALAR Task Force says that “10,000 feet” should be height above ground level during flight operations over high terrain.]
2. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *approach gate* as “a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria.”
3. The *black-hole effect* typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot’s near vision affect depth perception and cause the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path (i.e., a low approach).
4. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. “Enhanced GPWS” and “ground collision avoidance system” are other terms used to describe TAWS equipment.

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Suite 300, 601 Madison Street • Alexandria, VA 22314-1756 U.S. • Telephone: +1 (703) 739-6700, Fax: +1 (703) 739-6708
www.flightsafety.org

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