GUYANA CIVIL AVIATION AUTHORITY

AIRCRAFT ACCIDENT INVESTIGATION REPORT

RUNWAY EXCURSION ON LANDING

CARIBBEAN AIRLINES

FLIGHT BW 523

BOEING 737-800

TRINIDAD AND TOBAGO REGISTRATION 9Y-PBM

CHEDDI JAGAN INTERNATIONAL AIRPORT,

TIMEHRI GUYANA

062956.1490N 0581515.670 W

30th July, 2011

REPORT # GCAA: 2/5/1/63

The Guyana Civil Aviation Authority (GCAA) investigated this occurrence in accordance with Annex 13 to the Convention on International Civil Aviation. The investigation is intended neither to apportion blame, nor to assess individual or collective liability. Its sole objective is to draw lessons from the occurrence which may help to prevent future accidents

Accredited Representatives: the National Transportation Safety Board (NTSB), Trinidad and Tobago Civil Aviation Authority (TTCAA), the Boeing Company, Caribbean Airlines Limited and the Caribbean Safety and Security Oversight System (CASSOS).

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SYNOPSIS

On 30thJuly, 2011 Caribbean Airlines Flight BW523, a Boeing 737-800 aircraft, with 157 passengers and a crew of six, departed Piarco International Airport, (TTPP), Port of Spain Trinidad at 04:36hrs Universal Coordinated Time (UTC) on an instrument flight rules (IFR) flight plan on a scheduled flight to the Cheddi Jagan International Airport (CJIA), ICAO identifier: (SYCJ), Timehri, Guyana.

The aircraft landed at CJIA on runway 06 (RWY06) in the hours of darkness at 05:32hrs UTC, following an RNAV (GPS) approach. The reported aerodrome weather conditions were at 05:00hrs - wind calm, visibility 9km, light rain, few clouds 1400ft in cumulonimbus clouds, broken at 1500ft, QNH 1009hPA.

The aircraft touched down at approximately 4700 feet of the 7448 feet long runway, some 1700 feet beyond the runway touchdown zone. The runway was wet. The crew was unable to stop the aircraft on the remaining runway surface and it exited the end of the runway approximately 20ft left of the center line, breaking through a fence and coming to rest on the bottom of a 20ft high earth embankment.

The final position of the aircraft was approximately 130ft from the end of the paved surface of RWY06 and 64ft off the extended runway center line.

The aircraft suffered damage beyond economic repair. It broke into two sections in the vicinity of the first class bulkhead. Both engines were destroyed by the impact and foreign object debris (FOD) ingestion. There was no post-crash fire.

There were no fatalities. One passenger suffered a broken leg which resulted in an amputation. Several other passengers and crew suffered minor injuries during the accident and evacuation.

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ABBREVIATIONS AND GLOSSARY

AC – Advisory Circular

AFTN - Aeronautical Fixed Telecommunication Network – This is a worldwide system of aeronautical fixed circuits provided as part of the Aeronautical Fixed Service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics. The AFTN comprises aviation entities including Air Navigation Services providers, aviation service providers, airport authorities and government agencies. It exchanges vital information with aircraft operations such as distress messages, urgency messages, flight safety messages, meteorological messages, flight regularity messages and aeronautical administrative messages.

AGL – Above Ground Level

AIP – Aeronautical Information Publication – The AIP is defined by ICAO, as a publication issued by or with the authority of a State and contains aeronautical information of a lasting character essential to air navigation. It is designed to be a manual containing thorough details of regulations, procedures and other information pertinent to flying aircraft in the particular country to which it relates. It is usually issued by or on behalf of the respective civil aviation administration.

AMSL – Above Mean Sea Level

AOM – Aerodrome Operating Minima

AP – Auto Pilot

APU – Auxiliary power unit

ARFFS – Aircraft Rescue and Fire Fighting Service

ASAP –	As soon as possible
ASL –	Above Sea Level
AT –	Auto Throttle
ATC –	Air Traffic Control
ATIS –	Automatic Terminal Information Service
ATS –	Air Traffic Services
AWOS–	Automated Weather Observation System
BS –	Body station
°C–	Degrees Centigrade
CAM –	Cockpit Area Microphone
CVR –	Cockpit Voice Recorder
CRM–	Crew Resource Management
DA –	Decision Altitude
dBz -	decibels
DH–	Decision Height
DME –	Distance Measuring Equipment
EEC –	Electronic Engine Control
EFB –	Electronic Flight Bag
EMAS–	Engineered Materials Arresting System
ELT –	Emergency Locator Transmitter
°F –	Degrees Fahrenheit
FA –	Flight Attendant
FAA –	Federal Aviation Administration (United States)
FAF –	Final Approach Fix
FCOM –	Flight Crew Operations Manual
FL –	Flight Level

FDR – Flight Data Recorder

FMC – Flight Management Computer

FMS – Flight Management System

FO - First Officer

FOD – Foreign Object Damage/Debris

FPM – feet per minute

FRMS – Fatigue Risk Management System

GCAA – Guyana Civil Aviation Authority

GMT – Greenwich Mean Time

GPS – Global Positioning System

HF – High Frequency

hPa - HectoPascals

ICAO – International Civil Aviation Organization

IFR – Instrument Flight Rules

IIC – Investigator in Charge (used synonymously with Accident Investigator)

ILS – Instrument Landing System

IR – Instrument Rated

ITCZ – Inter Tropical Convergence Zone

KIAS – Knots indicated airspeed

LH – Left hand

LNAV/VNAV – Lateral/Vertical Navigation

LOSA – Line Operations Safety Audit

LST – Local Standard Time

m– Meters

mb – Millibars

MDA – Minimum Descent Altitude

MEL – Minimum Equipment List

METAR – Meteorological Aerodrome Report (aviation routine weather report)

N1 – Engine rotation speed

NLG – Nose Landing Gear

NTSB – National Transportation Safety Board (United States)

NOTAM – Notice to Airmen

NWS – National Weather Service

PA – Passenger Address system

PAPI – Precision Approach Path Indicator – The PAPI is a visual aid that provides guidance information to help a pilot acquire and maintain the correct approach path in the vertical plane to an aerodrome or airport. It is generally located beside the runway approximately 300 meters beyond the landing threshold of the runway.

PF - Pilot Flying

PNF - Pilot Not Flying

PM – Pilot Monitoring

P/N – Part Number

POS – Port of Spain

PSU – Passenger Service Unit

PSI – pounds per square inch

QRH – Quick Reference Handbook – a convenient sized notebook, in the possession of the flight crew, that contains tabular charts of aircraft performance that are intended to guide the crew in efficient and safe management of non-normal conditions and to support standardized crew performance in the aircraft. It also provides a single-source reference document for guiding non-normal tasks and supports the range of flight crew competencies and skills world-wide.

RA – Radio Altimeter

REIL - Runway End Identifier Lights

RESA – Runway End Safety Area

RH – Right hand

RNAV – Area Navigation

RPM – Revolutions per minute

RVR – Runway Visual Range

RWY - Runway

SMS - Safety Management System

S/N – Serial Number

SOPs – Standard Operating Procedures

SPECI – Special meteorological report

SRN – Sub-frame reference number

SYCJ – Cheddi Jagan International Airport (ICAO 4-letter Code)

T&T ATPL – Trinidad and Tobago Airline Transport Pilot License

T&T CPL – Trinidad and Tobago Commercial Pilot License

TAF – Terminal Aerodrome Forecast

TEM – Threat and Error Management

TLA – Thrust Lever Angle

TTPP – Piarco International Airport (ICAO 4-letter code)

UTC – Coordinated Universal Time

VFR – Visual Flight Rules

VHF – Very High Frequency

VOR – VHF Omni-directional Radio Range

V-Speeds – Standard term used to define airspeeds that are important or useful for aircraft operations. Using appropriate v-speeds is considered best practice to maximize aviation safety and aircraft performance.

VREF– Reference landing speed or threshold crossing speed

WP – Way point. A specified geographical location used to define an area navigation route or the flight path of an aircraft employing area navigation. Waypoints on the SYCJ GPS-RNAV Approach RWY06 are OLVIK and ASKIN.

Wx – Weather

1. FACTUAL INFORMATION

1.1. HISTORY OF THE FLIGHT

The flight originated in New York as BW 523, and made a passenger and fuel stop in Port-of-Spain, Trinidad where there was also a change of crew comprising two pilots and four flight attendants before proceeding to Georgetown, Guyana. The flight departed Piarco at 04:36UTC. The aircraft proceeded to Georgetown from Port of Spain at Flight Level (FL) 330, was given descent clearance and was cleared for an RNAV (GPS) approach to RWY 06, landing at 05:32 UTC. There were no reported anomalies in the en-route profile, although during the transition from cruise to approach to RWY 06 the aircraft deviated to avoid some thunderstorm cells north and east of the Airport. The reported visibility was 9,000m. Light rain was encountered during the approach.

The pilot reported that after visual contact was made and after crossing the Final Approach Fix (FAF), he disengaged the auto pilot and configured the aircraft for landing. The Flight Data Recorder (FDR) indicated that the flight was normal until the aircraft was approaching the runway. Even before the aircraft was over the threshold, the captain commented that he was not landing here.

As the flight continued over the runway, comments on the Cockpit Voice Recorder (CVR), revealed that the captain indicated to the First Officer (FO) that the aircraft was not touching down. A go-around call was made by the Captain and acknowledged by the First Officer, however three seconds elapsed and the aircraft subsequently touched down approximately 4700ft from the threshold of RWY06, leaving just over 2700 feet of runway surface remaining.

Upon touchdown, brake pressure was gradually increased and maximum brake pressure of 3000psi was not achieved until the aircraft was 250ft from the end of the runway or 450ft from the end of the paved area. The ground spoilers were extended on touchdown. The thrust reversers were partially deployed after touchdown. The aircraft did not stop and overran the runway. It then assumed a downward trajectory followed by a loud impact.

1.2. INJURIES TO PERSONS

Table: 1 – Personnel Injuries

	Crew	**Passengers**	**Others**	**Total**
Fatal	0	0	0	**0**
Serious	0	1	0	**1**
Minor/None	6	156	0	**162**
Total	**6**	**157**	**0**	**163**

During the evacuation one passenger suffered a broken leg which subsequently resulted in amputation.

Minor injuries included cuts, bruises, scrapes, sprains, strains, soft tissue injuries and whip lash to the neck. One passenger also suffered burns to her hands as a result of them coming into contact with the engine cowling. Injuries occurred both on impact and during evacuation.

1.3. DAMAGE TO AIRCRAFT

The aircraft suffered damage beyond economic repair. It was fractured at the first class bulkhead, with the cockpit portion resting at a 30° angle to the rest of the fuselage which was resting angled up at about a 10º angle from horizontal. The nose landing gear had collapsed underneath the cockpit and was pushed backwards into the fuselage where the avionics and electronics are typically housed. The fuselage, from the radar dome to about ten feet aft of the nose, was damaged and crumpled from impact. The thrust reverser doors were partially deployed on both engines which were severely damaged by impact and FOD ingestion.

1.4. OTHER DAMAGE

The boundary fence of the airport was damaged where the aircraft went through it. The area where the aircraft came to rest was ploughed up and there were several gouge marks in the area.

1.5. PERSONNEL INFORMATION

1.5.1. Flight Crew

Item	Captain	First Officer
Pilot License	T&T ATPL	T&T CPL
Type Ratings	B737-800, MD83	DHC-8, B737
Date Of Birth	6th Jan, 1959	15 Sept, 1987
Age	52 years	23 years
Type of Medical	1st Class	1st Class
Medical Expiry Date	31st August 2011	23rd Oct, 2011
Total Flying Hours	9600hrs	1400hrs
Hours on Type	5000hrs	350hrs
Duty Hours in last 24 hours	0hrs	7hrs reserve duty
Last Proficiency Check	28th May 2011	20th Feb. 2011
IR Check on Type to Cat II Specs.	28th May 2011	20th Feb. 2011
Hours on duty prior to landing	2.5hrs	2.5hrs
Hours off duty prior to work period	24hrs	11hrs
GPS Approach qualified	Yes	Not Applicable

Limitations on the Captain's medical indicated that he needed to wear spectacles that correct for near vision. Limitations on the First Officer's medical indicated that he needed to wear lenses that correct for distant vision. Both pilots were required to have a second pair of spectacles available while flying.

Records indicate that the flight and duty times for both flight crew members were within acceptable limits. However, the captain reported that he had attended an all-day union meeting and rested for 2½ hours prior to preparing for the flight. He considered his rest to be adequate as he usually retired late.

Both pilots are employees of Caribbean Airlines Ltd. and were appropriately qualified. The Captain has 25 years of service, having started with BWIA and continuing with CAL. The first officer has three years of service with CAL. This was the first flight on which the flight crew was rostered to fly together, but they had done previous flights into Guyana with other crew. The First Officer said that he knew the Captain, "by reputation to be a good, honest person, who knew how to boost people's morale".

Training records indicate that both the Captain and First officer had completed the standard CAL training for the B737 aircraft. This included ground school, simulator and flight training. Regularly scheduled Proficiency Checks are a standard requirement for all flight crew. The First Officer commenced conversion training in January 2011 and did his Proficiency Check in February 2011. All simulator, ground school and flight training were satisfactorily completed.

1.5.2. Cabin Crew

The cabin crew consisted of four females with experience on the job ranging from thirty-two years to seven months. All Cabin Crew were trained and qualified for their assigned duties on the aircraft.

1.5.3. Flight Dispatcher

The responsibilities of the flight dispatcher are listed in the CAL Operations Manual. Duties include, but are not limited to; "Planning, in co-operation with Flight Captains, all flights to maximize payload available through efficient planning and use of fuel, weather information, ATC requirements etc. and obtaining the best route for aircraft, and obtaining air traffic clearances for same."

1.6. AIRCRAFT INFORMATION

1.6.1 General

Manufacturer	Boeing Company
Aircraft Registration	9Y-PBM
Type and Model	B737-800
Year of Manufacture	2007
Serial Number	29635
Certificate of Airworthiness	Valid to August 10, 2011
Total Airframe Time	14861:2hrs
Next Inspection	A2 due at 15238:6hrs
No. & Type of engines:	Two CFM56–7B26/3 – Port-s/n-894748, Starboard-s/n-894767
Maximum allowable takeoff weight	79015kgs (174200lbs)

Maximum allowable landing weight	66360kgs (146300lbs)
Recommended fuel type	Jet A1
Fuel Type used	Jet A1

1.6.2. Maintenance

Examination of the aircraft maintenance records indicates that there were no significant maintenance issues recorded in the aircraft technical log. All required and scheduled maintenance had been performed and all Airworthiness Directives had been complied with. All major repairs and alterations were documented as required. There were two MEL items in the aircraft technical logbook, the HF radio and the pilots' Electronic Flight Bag (EFB), both of which were not necessary for this flight. There were no deferred defects neither was there any history of recurring defects on this aircraft. The total time on the aircraft prior to the accident flight was 14861:2hrs. The next scheduled inspection was an A2 inspection due at 15238:6hrs.

1.6.3. Mass and Balance

Dispatch of the flight was in keeping with the requirements of the CAL Operations Manual – Part A General, which states that a company mass and balance document must be completed in quadruplicate for each flight. The final mass and balance document must contain details of the disposition of all loaded items including fuel. The ground supervisor is required to confirm by signature that the load and its distribution are as stated on the document.

This document must be acceptable to and countersigned by the aircraft commander. Last minute changes must be notified to the commander.

The data from the dispatch package included aircraft weight parameters, loading for the flight and sufficient fuel for the use of Grantley Adams International Airport, Barbados, as the alternate aerodrome. Load sheet documentation shows that the aircraft departed Port of Spain with a payload of 17875kg and actual takeoff weight of 68337kg. The fuel burn for the trip was 2910kg and actual landing weight was stated as 65427kg. The published maximum takeoff and landing weight is 79015kg and 66360kg respectively.

1.6.4. Brake System

Each main gear wheel has a multi-disc hydraulic powered brake. The brake pedals provide independent control of the left and right brakes. The nose wheels do not have brakes. The brake system includes a normal brake system, alternate brake system, brake accumulator, antiskid protection, auto-brake system, parking brake and brake temperature indication. The entire system is powered by two hydraulic systems and even if pressure is lost in both, trapped hydraulic pressure in the brake accumulator can still provide several braking applications or parking brake application. The auto brake system provides automatic braking at preselected deceleration rates immediately after touchdown. The auto brake system operates only when the normal brake system is functioning.

1.6.5. Ground Spoilers

The aircraft is fitted with four electro-hydraulically operated ground spoilers which are located, two each on the upper surface of each wing. The speed brake lever controls the spoilers. When the speed brake lever is actuated all spoilers are deployed when the aircraft is on the ground, where the spoilers act to induce drag and increase braking efficiency.

1.6.6. Flaps and Slats

Flaps and slats are high lift devices that increase wing lift and decrease stall speed during takeoff, low speed manoeuvring and landing. The leading edge devices consist of four leading edge flaps and eight slats. Two leading edge flaps are located inboard and four slats are located outboard of each of the two engines. Slats extend to form a sealed or slotted leading edge, depending on the trailing edge flap setting. The trailing edge devices consist of double slotted flaps inboard and outboard of each engine. Flap positions 15º to 40º provide increased lift and drag. Flaps 15º, 30º and 40° are normal landing flap positions. The auto-slat system is designed to enhance aircraft stall characteristics at high angles of attack during takeoff or approach to landing.

1.6.7. Engine Controls

The aircraft is powered by two dual-rotors, axial-flow turbofan, CFM56-7B26/3 engines that are each regulated by a dual-channel electronic engine control (EEC) that is interconnected to the Flight Management System (FMS). The EEC monitors auto-throttle and flight crew inputs to automatically set engine thrust. Each engine has individual flight deck controls. The thrust levers can be positioned automatically by the auto throttle system or manually by the flight crew. The forward thrust levers control forward thrust from idle to maximum and the reverse thrust levers control thrust from reverse idle to maximum reverse.

The EEC automatically selects ground idle minimum for ground operations and approach idle is selected in flight if the flaps are in landing configuration. At the same airspeed and altitude, N1 and N2 RPM will be higher for approach idle than for flight minimum idle. This higher RPM improves engine acceleration time in event of a go-around. Approach idle is maintained until after touch-down, when minimum idle is selected.

1.6.8. Rain Removal System

The aircraft is equipped with wind screen wipers and a permanent rain repellant coating on the windows.

1.6.9. Weather Radar

The weather radar system detects and locates various types of precipitation bearing clouds along the flight path of the aircraft and gives a visual indication in colour of the clouds intensity. The antenna sweeps a forward arc of 180°. The rainfall intensity is indicated by contrasting colours against a black background. Heaviest rainfall appears in red, the next level in yellow and the lowest in green. The aircraft weather radar turbulence mode displays normal precipitation and precipitation associated with turbulence. When a horizontal flow of precipitation with velocities of 5 meters per second or more, toward or away from the radar antenna is detected, that target display becomes magenta. This magenta area is associated with heavy turbulence.

1.6.10. Passenger Address System

The passenger address system allows flight deck crew members and flight attendants to make announcements to the passengers. Announcements are heard through speakers located in the cabin and lavatories.

1.6.11. GPS Navigation Equipment

The GPS is part of the Flight Management System (FMS). It can function either independently or in various combinations with other components of the FMS. The aircraft is equipped with two GPS receivers that receive GPS satellite positioning signals and each provides an accurate aircraft geographical position to the Flight Management Computer (FMC) and other aircraft systems. GPS operation is automatic.

The aircraft was cleared for and flew the RNAV (GPS) approach to Runway 06.

1.6.12. Cockpit

The flight deck accommodates two adjustable pilots' seats and two observer seats. The cockpit seats are standard, manufactured by IPECO.

Control systems for the aircraft are located on panels and control stands in the cockpit.

The emergency evacuation signal and the emergency lights switch are located on the forward overhead panel and flashes when any activation switch is moved to the ON position.

1.6.13. The Cabin

The Boeing 737-800 is a single aisle passenger jet transport aircraft. The passenger cabin is configured for 154 passenger seats. There are16 first class seats, arranged in four rows, two seats on either side of the aisle. In the economy section, there are 138 coach class seats, arranged in twenty-three rows with three seats on either side of the aisle.

Normal entrance to and exit from the cabin is achieved via four doors located fore and aft on both sides of the cabin. These are referred to as L1, L2, R1 and R2.

Aft-facing, double-occupancy, retractable flight attendant seats are mounted on the left side of the forward monument, adjacent to the L1 door, another aft-facing, double-occupancy, retractable flight attendant seat is mounted on the left side of the aft monument adjacent to the L2 door and a double-occupancy retractable flight attendant seat is mounted on the right side of the aft monument, adjacent to the R2 door.

Stow bins are attached to the structure above and outboard of the ceiling. Bin doors are designed to remain open unless latched closed.

Passenger Service Units (PSUs) are located on the bottom of the stow bins, within reach of the passengers from their seats. Each PSU contains dropdown oxygen masks, fresh air/cooling regulators, reading lights and flight attendant call button.

1.6.14. Emergency Exits– Cabin

In the cabin, there are four over wing emergency exits. Two each are located at Rows 11 and 12 on either side of the aircraft. These doors are held in the fuselage by mechanical latches and locks. In the pressurized condition, the doors are additionally held in place against the fuselage stops. On the ground, the doors can be opened from inside via a spring loaded operating handle and from the outside by pushing on the vent panel at the top of the door. Additionally, a flight lock system operates automatically and prevents handle operation during flight and will unlock automatically on the ground to allow for opening the door.

In an emergency the regular aircraft doors, located forward and aft of the cabin can also be used as emergency exits.

1.6.15. Emergency Exits – Cockpit

Two windows, one on each side of the cockpit, can be opened by the flight crew on the ground and can be used for emergency evacuation. The flight deck door is equipped with release pins and two blow-out panels. Removal of the release pins facilitates easy removal of the blow-out panels, which allows egress in event of an emergency.

1.6.16. Evacuation

Passenger emergency evacuation can be accomplished through the four entry/service doors and four over-wing escape hatches.

The aircraft is equipped with four escape slides that are located at the four cabin doors. They are stowed in the lower half of each door and inflate automatically when they are deployed. There are no escape slides at the over-wing exits.

1.6.17. Emergency Lighting

1.6.17.1. General

Exit lights are located throughout the passenger cabin to indicate the approved emergency exit routes. The system is controlled by a switch on the overhead panel in the cockpit. If electrical power to the DC bus bar No.1 fails or if the AC power has been turned off, the emergency exit lights will automatically illuminate. The emergency exit lights may also be illuminated by a switch on the aft flight attendants panel.

The flight deck dome light contains a separate bulb that is powered by the emergency lighting system to facilitate flight deck evacuation.

1.6.17.2 Interior Emergency Lighting

Interior emergency exit lights are:

- In the lower inboard panel of stowage bins, to illuminate the aisle.

- Over the passenger and service doors and over-wing emergency hatches to indicate the door and hatch exits.
- In the ceiling to identify the exits and provide general illumination in the area of the exits.
- Lighted exit locator signs, installed at the forward, middle, and aft end of the passenger cabin.
- Seat mounted emergency escape path lighting consisting of locator lights spaced at regular intervals down one side of the aisle.
- A lighted 'EXIT' indicator near the floor by each door and over-wing exit.
- Escape path markings that provide visual guidance for emergency cabin evacuation when other sources of cabin lighting are obscured.
- At the exit, electrically operated lights and markers provide exit identification.

1.6.17.3. Exterior Emergency Lighting

Exterior emergency lights illuminate the escape slides. The fuselage installed escape slide lights are adjacent to the forward and aft service and entry doors. Lights are also installed on the fuselage to illuminate the over-wing escape routes and ground contact area.

1.6.18. Emergency Equipment

The aircraft is equipped with various emergency equipment including flashlights, life vests, life rafts, first aid kits, megaphones and a crash axe. These are stowed at convenient locations, throughout the aircraft, to facilitate easy access by passengers and flight and cabin crew as appropriate. The aircraft is also equipped with two Emergency Locator Transmitters (ELTs).The fixed ELT should normally activate on impact when there is a crash landing. The Portable one is manually activated. When activated the ELTs transmit on frequencies 121.5, 243.0 and 406.0MHZ simultaneously.

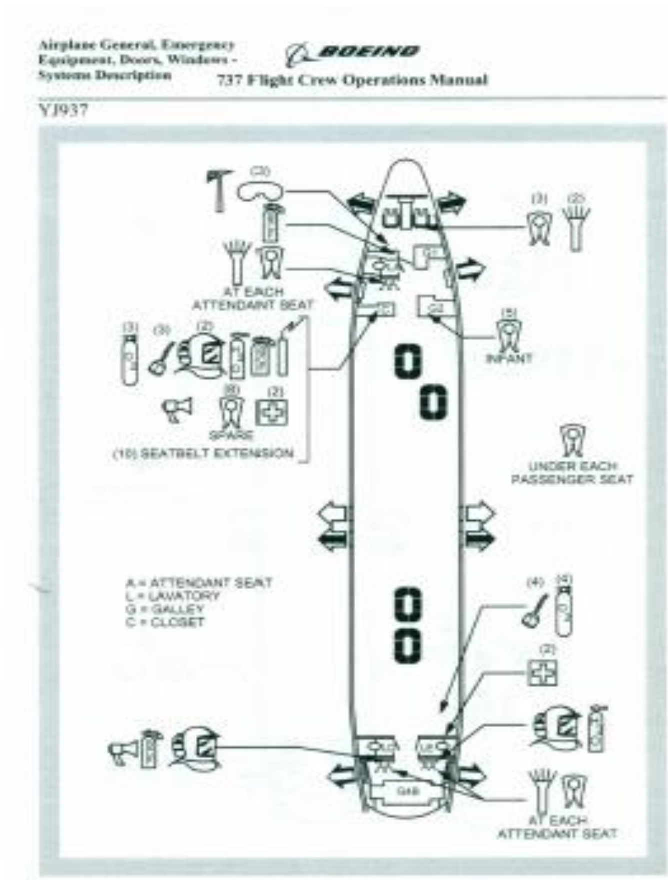

Figure 1:- Showing location of emergency equipment on aircraft

1.7. METEOROLOGICAL INFORMATION

1.7.1 General

Meteorological data was gathered from the Guyana Hydro-meteorological Service, the Piarco International Airport Weather Centre and the US National Weather Service.

1.7.2 Synoptic

The synoptic or large scale migratory weather systems influencing the area were documented using NWS charts, (FIGs.2&3), issued by the National Centre for Environmental Prediction, United States of America. The charts showed a low pressure system with a central pressure of 1008hPa located in the Central Atlantic Ocean east of the Leeward Islands and north east of the accident site. The monsoon trough[1] stretched eastward from the low pressure system toward western Africa. The Inter-Tropical Convergence Zone (ITCZ)[2] stretched southwestward from the low pressure system over the accident site, then westward over northern South America. Station models near the accident site depicted calm winds, partly cloudy skies with

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[1] Trough - An elongated area of relatively low atmospheric pressure or heights.

[2] Inter-Tropical Convergence Zone (ITCZ) – A zone of surface convergence of the trade winds from the northern and southern hemispheres. It is often marked by an area of convective clouds, rising air, and light surface winds.

haze, and temperatures in the mid to upper 70's°F and temperature-dew point depressions of 1°F-3ºF indicated a moist tropical atmosphere.

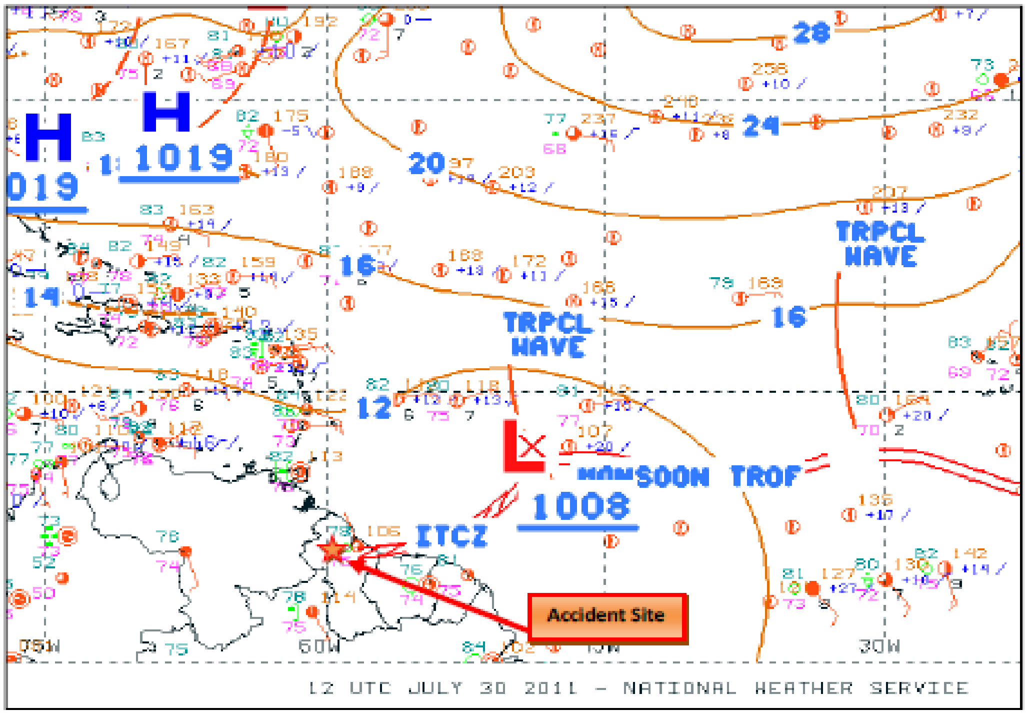

Figure 2 – NWS Surface Analysis Chart for 12:00UTC

The United States National Hurricane Centre (NHC) North Atlantic Surface Analysis for the same period (Fig. 3) is a larger scale chart that shows the approximate accident site. It depicts a low pressure system with a central pressure of 1008hPa east of the Leeward Islands and north east of the accident site in the Central Atlantic Ocean. The ITCZ stretches southwest from the low pressure system over the accident site. A tropical wave extends northward from the low pressure system northeast of the accident site.

These findings were supported by other observations from the Rawinsinde Observation from Piarco International Airport, Trinidad and Tobago and by Satellite data from the Geostationary Operational Environmental Satellite (GOES) #13 from the NTSB Man-computer Interactive Data Access System (McIDAS) work station.

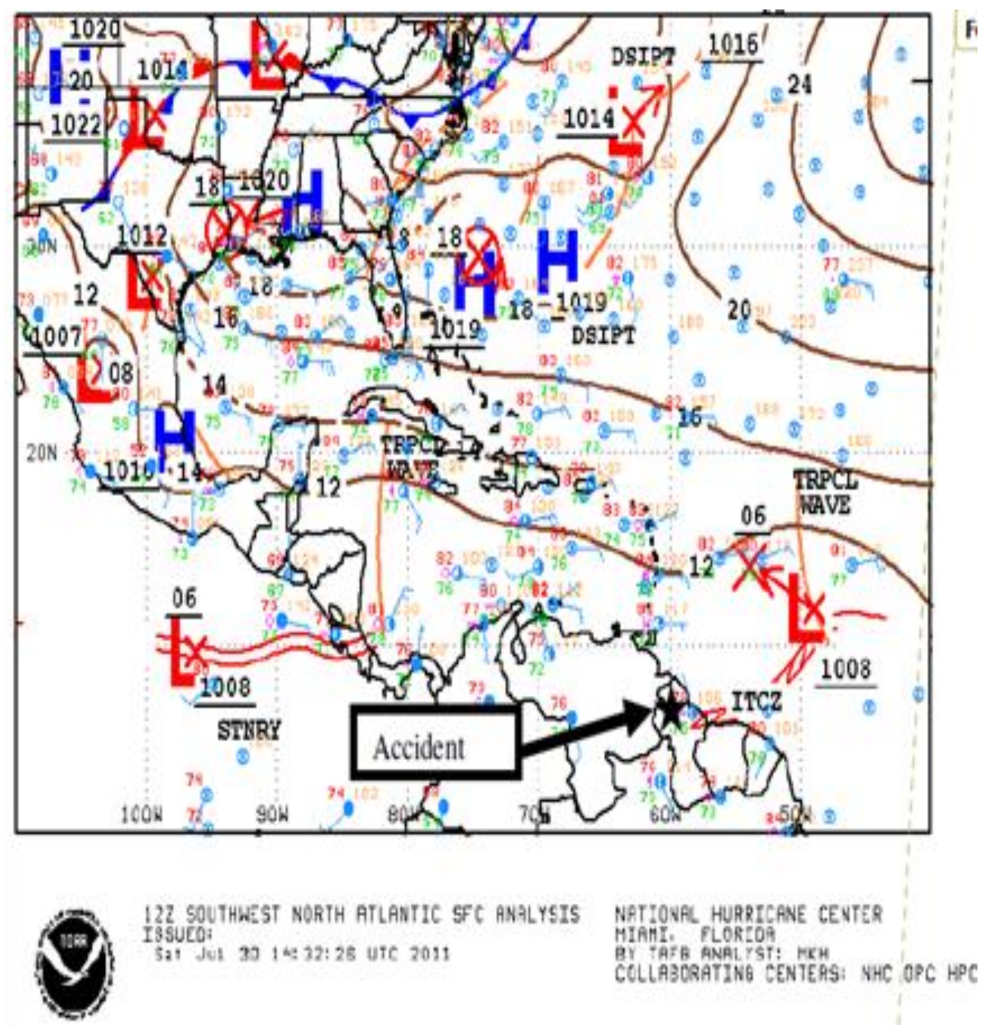

Figure 3 – National Hurricane Centre North Atlantic Surface Analysis for 12:00UTC

1.7.3 Local Observations

At the Cheddi Jagan International Airport, weather observations are taken by a human observer located approximately one mile south of the accident site. The following observations were reported during the times surrounding the accident:

SYCJ weather at 04:23UTC– wind calm, visibility 10km or more with thunderstorm, few clouds at 1500ft in cumulonimbus clouds, scattered clouds at 1600ft, cumulonimbus northeast and east northeast.

SYCJ weather at 05:00UTC – wind calm, visibility 9km in light rain showers, few clouds at 1500ft in cumulonimbus clouds, ceiling broken at 1500ft, temperature 25°C, dew point 24ºC, QNH- 1009hPa, cumulonimbus clouds northeast through east northeast, no significant change expected.

SYCJ weather at 06:00UTC– wind calm, visibility 9km, ceiling broken at 1500ft, temperature and dew-point 24°C, QNH- 1008hPa, no significant change expected.

The raw observations or Meteorological Aerodrome Reports (METARs) surrounding the accident period were as follows:

METAR SYCJ 300200Z 00000KT 9999 FEW017 SCT300 25/24 Q1010 NOSIG=

METAR SYCJ 300300Z 00000KT 9999 FEW016 25/24 Q1010 NOSIG=

METAR SYCJ 300400Z 00000KT 9999 FEW016 24/24 Q1009 NOSIG=

SPECISYCJ 300423Z 00000KT 9999 TS FEW015CB SCT016 CB-NE-ENE NOSIG=

METAR SYCJ 300500Z 00000KT 9000 -SHRA FEW014CB BKN015 25/24 Q1009 CB-NE-ENE NOSIG=

Accident 05:32Z

METAR SYCJ 300600Z 00000KT 9000 BKN015 24/24 Q1008 NOSIG=
METAR SYCJ 300700Z 00000KT 9000 BKN015 24/24 Q1008 NOSIG=
METAR SYCJ 300800Z 00000KT 9000 SCT015 24/24 Q1008 NOSIG=

A review of the Guyana Hydrometeorological Services station observation log indicated that the thunderstorm began at 04:23UTC and ended at 04:31UTC based on observing lightning and hearing thunder. The rain began at 04:57UTC and ended at 05:43UTC. The total recorded precipitation during the period was 1.8mm or 0.07 inches. The ceiling, based on the temperature and dew-point and adiabatic lapse rates, was 1500ft with 5/8ths sky coverage or broken.

1.7.4 Weather Radar Data

The closest Doppler weather radar was located 1 mile south of the accident site. Archived radar data for the accident time was obtained from the Guyana Hydrometeorological Service National Weather Watch Centre.

1.7.5 Terminal Aerodrome Forecast (TAF)

The Terminal Aerodrome Forecast (TAF) issued for SYCJ at 21:30UTC on July 29th, 2011 and current for the period was as follows:

TAF SYCJ 292130Z 3000/3024 00000KT 9000 SCT018 TEMPO 3006/3011 4000 VCFG SCT006 SCT011 TEMPO 3008/3012 9000 SHRA BKN016 BECMG 3012/3014 08010KT 9999 FEW019CB SCT020 PROB30 TEMPO 3015/3020 9000 SHRA FEW016CB BKN017

The forecast expected calm wind, visibility 9km with scattered clouds at 1800ft AGL, with temporary conditions, between 06:00UTC and 11:00UTC, of visibility 4000m with fog in the vicinity, scattered clouds at 600ft, and at 1100 feet. Rain showers were expected after 04:00LST through12:00UTC.

The forecast issued prior to the accident at 03:30UTC on July 30, 2011 and valid from 06:00UTCwas as follows:

TAF 300330Z 3006/3106 00000KT 9000 SCT015 SCT038 TEMPO 3006/3011 8000 SHRA BKN014 SCT036PROB30 TEMPO 3008/3011 0800 FG SCT001BECMG 3012/3014 08012KT 9999 FEW018CB BKN020

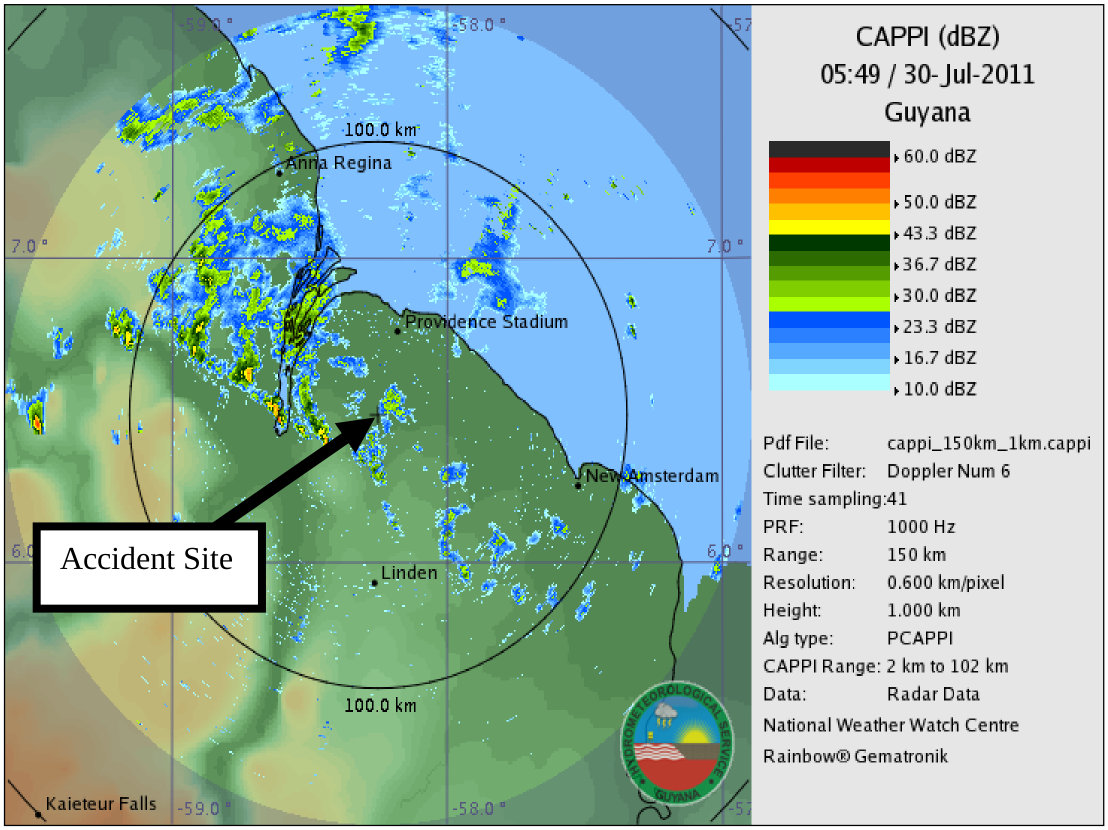

Figure 4 – Weather radar image for 05:49UTC with the accident site identified.

1.7.6 Meteorological Information from Interviews

In relation to meteorological conditions, interviews were conducted with the Met Observer from the Guyana Hydrometeorological Service, the Air Traffic Controller who was on duty in the Aerodrome Control Tower at the time of the accident and the Flight Crew.

1.7.6.1 Met Observer

The duty Met Observer has over 35 years' experience as an observer and forecaster for the Guyana Hydrometeorological Service. On the evening of the accident he was working the midnight shift, between 22:00UTC to 12:00UTC, which consisted of an observer, forecaster, and a trainee, for whom he was providing training and oversight. He indicated he was well rested prior to his shift and had experienced a normal workload during the period. He indicated that on the evening surrounding the time of the accident he observed thunderstorms northeast through east-northeast of the airport and recorded a thunderstorm beginning at 04:23UTC and ending at 04:31UTC, with light rain starting at 04:57UTC and ending at 05:43UTC, with 1.8mm of rainfall being recorded between 00:00UTC on July 30th and 06:00UTCon July 30th. No strong winds were recorded at the station and no other reports of severe weather were recorded in the area during the period.

The Observer indicated that the weather agency enters the latest weather observations and Terminal Aerodrome Forecasts into the AFTN system. The observations are telephoned to the Control Tower and the latest TAFs are faxed to them. He indicated that he became aware of the accident when he called the tower to provide them with the 06:00UTC observation.

He was asked to give more details about the weather conditions recorded during the period. He indicated that the precipitation was very light with no significant reduction in visibility during the period until early in the morning when mist and fog formed near sunrise. He also indicated that being off airport does not allow the observer to accurately report low visibility events in fog and heavy rain situations; however, he assured that during this period, visibility was not restricted below 6000m for reporting or weather coding purposes.

During a subsequent tour of the weather office the location of equipment was identified. The visibility markers used, and the weather observers' log during the period of the accident were reviewed. Based on that log, the weather conditions at the time of the accident were identified as being wind calm, visibility 9km in light rain showers, ceiling broken at 1500ft AGL, temperature and dew point 24°C, with rain ending at 05:43UTC. The total rainfall recorded during the period was 1.8mm or 0.07 inches.

1.7.6.2. Air Traffic Controller

The Air Traffic Controller on duty at the time of the accident was interviewed on August 2, 2011. She indicated that she received the latest weather observation from the weather agency and estimated the visibility to be 8km in light rain at the time the aircraft made contact with the tower. She observed no lightning nor heard any thunder at that time and did not observe any water spray from the aircraft at touchdown, but indicated it was dark with no Moon visible. She stated the wind was calm during the period.

Review of the recording from the Control Tower indicates that just before the aircraft was cleared to land the Controller issued wind information and a caution; "caution runway surface wet".

1.7.6.3 Flight Crew

The First Officer related that they were cleared for the RNAV approach to runway 06. The reported visibility was 8000m which was sufficient to commence the approach. They descended in rain during the approach and had the runway in sight before the FAF, and configured for landing before the FAF. At 500ft above airport elevation, airspeed was at Vref plus wind correction, done using LNAV/VNAV modes and with auto-throttle on in FMC mode. The captain disengaged the Autopilot, but he was not sure where or at what altitude. They continued visually below decision altitude because they had all the required lights and the runway in sight.

The Captain advised that other than a track deviation to the left around some weather en-route, the flight was very smooth. He briefed the FO for the RNAV approach to RWY06 and was cleared by ATC to AKSIN. He stated that 400ft was set as minimum Decision Height (DH) on the FMC as it is rounded up from the published 384ft. A Missed Approach Procedure (MAP) is required if visual contact is not established at 400ft. During the transition they deviated again, paralleling right of track due to some weather.

The Pilot decided to establish early on speed with Flaps 30° and completed the landing checklist due to the weather in the area. He had no concerns about the approach. He stated that he was just thinking about the weather and conditions of dry and wet, and did not want to float due to runway length. He said he felt very comfortable coming into Guyana, it was not bumpy, the whole flight was smooth and he flew a stable approach.

He disengaged the autopilot and hand flew the aircraft from 1000ft, seeing 2+2 on the PAPI and he verbally briefed the FO that he would go below to 3+1[3]. He described weather as still raining at the threshold when he arrived there on profile 3+1 and on speed and that the rain stopped just past the threshold of RWY06. He did not consider holding to wait for the shower at the field to abate, as the weather radar was not showing magenta or yellow returns, and he could see the full length of the runway. He said they had used the weather radar all the way from Piarco and there was quite a bit of weather en-route, he had gone left of track then right of track on descent then direct to AKSIN. He said that during the en-route segment of the flight the weather was heavy enough to be avoided.

1.7.7. Astronomical Data

Data from the United States Naval Observatory indicated that Sunset occurred at 22:12UTC and the end of civil twilight occurred at 22:34UTC on July 29th, 2011. The Moon set at 21:17UTC on July 29th, 2011 and rose at 09:29UTC on July 30th, 2011. At the time of the accident the Moon was more than 15° below the horizon and provided no illumination. The phase of the Moon was a waning crescent with only 2% of the Moon's visible disk illuminated.

[3] Seeing 2+2 on the PAPI indicates that the aircraft is on the correct approach slope with two white lights and two red lights visible; 3+1 indicates a low approach with three red lights and one white light visible.

1.8 AIDS TO NAVIGATION

1.8.1 General

The only ground based navigation aid at the airport was the Timehri VOR, which was functioning normally at the time of the accident. The Timehri VOR serves as both an en-route and approach navigation aid.

Neither Distance Measuring Equipment (DME) nor Instrument Landing System (ILS) was available at the time of the accident.

1.8.2 Instrument Approaches at SYCJ

SYCJ is served by four instrument approaches, namely,

- SYCJ VOR RWY 06(045/180 PT);
- SYCJ VOR RWY 06 (BASE TURN);
- CHEDDI JAGAN INT'L RNAV (GPS) RWY 06;
- CHEDDI JAGAN INT'L RNAV (GPS) RWY 24.

All approaches were designed in accordance with ICAO Document 8168 – Procedures for Air Navigation Services. The instrument approach charts are published in the Guyana AIP. (See charts at Appendix 1.)

1.8.2.1. The Timehri VOR Approach

The approach procedure for the VOR has been flight tested and has been published for operational use for several years. The procedure was revised on July 31st 2008. It allows the pilot to do a let-down from 2000ft on a pre-defined track to 520ft above the airport's elevation of 96ft, approximately aligned with the extended center line of runway 06. Upon reaching 520ft, the approach and landing is completed by visual reference to the ground or a MAP is carried out. The VOR and this procedure were inspected and recertified on 2nd February, 2011 by ASECNA.

1.8.2.2. The Timehri (SYCJ) RNAV RWY06 Approach

The RNAV-GPS approach procedure aligns the aircraft on the RWY06 extended center line at position AKSIN, 11.2nm from the threshold at an altitude of 3000ft AMSL. The aircraft will continue the approach to cross the Final Approach Fix, position OLVIK, located 5.2nm from the threshold, at 1800ft. Thereafter the aircraft will make a continuous descent on a 3^{o} slope to a Minimum Decision Altitude of 380ft AMSL. After this, approach and landing is completed by visual reference to the ground. If visual reference is not acquired when the aircraft reaches 380ft AMSL a MAP is carried out.

1.9. COMMUNICATIONS

No malfunctions of ground or aircraft radio communications systems were reported between the time BW523 first made contact with the Georgetown Area Control Centre and the time the aircraft ran off the runway. At the time of the incident the aircraft was in contact with the Timehri Control Tower on VHF 118.3MHz.

1.10 AERODROME INFORMATION

The accident occurred at the Cheddi Jagan International Airport, Timehri, Guyana. The ICAO location indicator is SYCJ, position – North 6 29 56.149, West 058 15 15.67; magnetic variation –16° West, elevation – 96ft ASL. SYCJ is located 39km south of the city of Georgetown on the eastern bank of the Demerara River.

SYCJ is operated by the Cheddi Jagan International Airport Corporation. The Airport is governed by the Cheddi Jagan International Airport Act: Chapter 52:01 of the Laws of Guyana and the Cheddi Jagan International Airport Order No. 20 of 2001. The Order establishes the airport as a public corporation. Among the functions of the corporation is the provision of rescue and fire-fighting equipment and services at the airport. The Order also requires the corporation, through its Chief Executive Officer to ensure that physical amenities meet the Standards as established by the Guyana Civil Aviation Authority, The International Civil Aviation Organization and any other International Agreements to which the Government of Guyana is a party.

SYCJ operates 24 hours a day, with visual flight rules (VFR) and instrument flight rules (IFR) operations during daylight and IFR operations only during hours of darkness.

Runway 06/24 was closed immediately after the accident, and reopened ten hours later with modified Declared Distances to allow for the protrusion of the tail of the wreckage into the airspace at the end of runway 06.

At sunrise, approximately four hours after the accident, the runway was inspected by the Chief Accident Investigator and representatives of the SYCJ. The runway surface, lights and markings were found to be satisfactory and in keeping with ICAO Standards. There was no FOD on the runway.

1.10.1 Certification

At the time of the accident SYCJ was certified. The last certification inspection was done on June 28 & 29, 2011 and the Certificate was valid from July 1, 2011 to June 30, 2012.

The regulatory authority is the Guyana Civil Aviation Authority which provides oversight for safety and security compliance.

1.10.2 Runway Description

1.10.2.1 Runway 06

The following information regarding runway 06 was extracted from the Guyana Aeronautical Information Publication (AIP), and by observation.

- Runway 06 is 2270m (7448ft.) long by 46m (150ft.) wide.
- Orientation is 061° magnetic; 045º true.
- Take-off run available (TORA), take-off distance available (TODA), accelerate stop distance available (ASDA); landing distance available (LDA) are all 2270m (7448ft.).

- Information on the slope of runway is not provided. It is however noted that the elevation of the threshold of runway 06 is 96ft while the elevation at the end of the runway is 71ft.
- Along the entire length of the runway there are transverse grooves providing improved friction characteristics for landing aircraft. These grooves also aid in drainage of the runway. On average, the grooves are 3/16” wide and 1/4” deep and the grooves’ center lines are 1½” apart.
- Due to terrain, there is no runway end safety area (RESA). However, for both ends of the runway, beyond the marked runway there is an additional 200ft of usable paved surface. The 200ft overrun area of runway 06 is not grooved.

1.10.2.2. Runway 06 Lighting

The following information was gathered from the 4th edition of the Guyana AIP and SYCJ Corporation.

- The runway is equipped with red runway end lights, green threshold lights and white edge lights. The runway edge lights are spaced 60m apart.

It has been noted that the SYCJ Aerodrome Chart – ICAO indicates that RWY06 is equipped with white runway end identifier lights, REIL; however, these were not functioning at the time of the accident.

Note:-*Approach lighting is not provided due to the terrain and there is no center line lighting.*

- The runway is also equipped with a Precision Approach Path Indicator system (PAPIs). The PAPIs at SYCJ consists of four light units on the left side of the runway in the form of a horizontal bar. Aircraft preparing to land on this runway would be on the correct slope if the two units nearest the runway showed red and the two units furthest from the runway showed white; the aircraft is too high if all units shows white and too low if all units shows red.
- The PAPIs are installed in accordance with ICAO specifications. At the time of the accident, the glide slope angle of the beam projection was 2.39º and was so published in the approach charts in the Guyana AIP.

The runway lights and PAPIs are adjustable and are operated and controlled from the Control Tower by the Air Traffic Controller. The intensity can be adjusted at the request of the pilot.

1.10.2.3. Runway 06 Marking

RWY06 has white runway markings consisting of the following:

- Threshold markings - a series of vertical bars marking the threshold;
- Runway designation markings, consisting of the runway number at the threshold;
- Touchdown zone markings, consisting of repeating series of vertical bars either side of the center line;
- Aiming point markings at 1500ft from the threshold;

- Center line markings - a dashed line along the entire length indicating the center line of the runway.
- The runway side stripe markings – a solid white stripe along both edges of the runway.

All runway markings contain reflective material.

1.11 FLIGHT RECORDERS

1.11.1 Cockpit Voice Recorder (CVR)

The Cockpit Voice Recorder on the accident aircraft was located in the aft cargo hold. It was sent to, the NTSB Vehicle Recorder Division Audio Laboratory on 1stAugust, 2011. The CVR identification is as follows:

Recorder Manufacturer/Model: L-3 Communications FA2100-1020

Recorder Serial Number: 147351

1.11.1.2 CVR Description

This model CVR, the L-3 Communications FA2100-1020, is a Solid State CVR that records 2 hours of digital cockpit audio. Specifically, it contains a 2-channel recording of the last 2 hours of operation and separately contains a 4-channel recording of the last 30 minutes of operation. The 2-hour portion of the recording is comprised of one channel of audio information from the cockpit area microphone (CAM) and one channel that combines two audio sources; the Captain's audio panel information and the First Officer's audio panel information. The 30-minute portion of the recording contains 4 channels of audio data; one channel for each flight crew and one channel for the CAM audio information.

1.11.1.3 CVR Damage

Upon arrival and inspection at the audio laboratory, it was evident that the CVR had not sustained any heat or structural damage and the audio information was extracted from the recorder normally, without difficulty.

1.11.1.4 CVR Audio Recording Description

For the 2-hour portion of the CVR recording, each channel contained good quality audio information as defined by the following CVR Rating Scale.

Excellent Quality: Virtually all of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate only one or two words that were not intelligible. Any loss in the transcript is usually attributed to simultaneous cockpit/radio transmissions that obscure each other.

Good Quality: Most of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate several words or phrases that were not intelligible. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.

Fair Quality: The majority of the crew conversations were intelligible. The transcript that was developed may indicate passages where conversations were unintelligible or fragmented. This type of recording is usually caused by cockpit noise that obscures portions of the voice signals or by a minor electrical or mechanical failure of the CVR system that distorts or obscures the audio information.

Poor Quality: Extraordinary means had to be used to make some of the crew conversations intelligible. The transcript that was developed may indicate fragmented phrases and conversations and may indicate extensive passages where conversations were missing or unintelligible. This type of recording is usually caused by a combination of a high cockpit noise level with a low voice signal (poor signal-to-noise ratio) or by a mechanical or electrical failure of the CVR system that severely distorts or obscures the audio information.

Unusable: Crew conversations may be discerned, but neither ordinary nor extraordinary means made it possible to develop a meaningful transcript of the conversations. This type of recording is usually caused by an almost total mechanical or electrical failure of the CVR system.

As shown in Table 2 below, the 30-minute portion of the recording consisted of four channels of audio information. Each channel's audio quality is indicated. Notably, channel number one contained a Morse code station identifier.

Table 2: CVR Audio Quality

Channel Number	Content/Source	Quality
1	Observer	N/A
2	First Officer	Good
3	Captain	Good
4	CAM	Good

1.11.1.5 Timing and Correlation (CVR and FDR)

Timing on the transcript was established by correlating the CVR events to common events on the flight data recorder (FDR). Specifically, the last 11 radio transmissions that the aircraft made were correlated to the radio transmit microphone key parameter from the FDR. Each of the 11 radio transmissions acted as an anchor point for a linear interpolation between the remaining CVR events. This correlation resulted in the CVR elapsed time on the 30-minute CVR of 0027:50.789 corresponding to FDR sub-frame reference number (SRN) of 97786.8164. Once a correlation between the two recorders was established, GMT time recorded on the FDR was used to convert SRN to GMT. FDR SRN of 97975.70313 = 0532:28 GMT. The CVR and FDR times were offset to reflect the local time of the accident by adding 0501:28.324 to the 30-minute recording and 0328:15.048 to the 120-minute recording.

1.11.1.6 Description of Audio Events (CVR)

The recording began with the prior approach and landing into the Piarco International Airport in Trinidad by another crew. After power was removed from the CVR for an undetermined amount of time, at 04:31:30, the crew of flight BW523 was recorded preparing for the flight to Georgetown. At 04:32:22, the aircraft was cleared for take-off from Trinidad, and after taxiing into position, took off at 04:35:30. The aircraft climbed to FL330 and was given a clearance direct AKSIN to expect the RNAV RWY06 approach. At 04:56:35, Air Traffic Control cleared the aircraft to descend at pilot's discretion to 3000ft.

The transcript in relation to this accident began at 04:57:06 and continued until the end of the recording. The partial transcript of the CVR is attached at Appendix 2.

1.11.2. Flight Data Recorder

1.11.2.1 General Details of FDR Investigation

The Flight Data Recorder on the accident aircraft was located in the ceiling above the rear galley. It was sent to the Vehicle Recorder Division of the NTSB on August 1, 2011. The FDR was identified as follows:

FDR Type: Honeywell Solid State Flight Data Recorder (SSFDR)
Recorder Manufacturer/Model: Honeywell 4700 256wps
Recorder Serial Number: 13673

This SSFDR records aircraft flight data in a digital format using solid-state flash memory as the recording medium and can record a minimum of 25 hours of flight data. It is configured to record 256 12-bit words of digital information every second. It is designed to meet the crash-survivability requirements of TSO-C124[4].

The recorder was in good condition and the data were extracted normally. The recording contained approximately 27 hours of data. Timing of the FDR data is measured in sub-frame reference number (SRN), where each SRN equals one elapsed second. The event flight was the last flight of the recording and its duration was approximately 56 minutes.

1.11.2.2. Engineering Units Conversions

The engineering units conversions used for the data contained in this report are based on documentation from the aircraft manufacturer. Where applicable, the conversions have been changed to ensure that the parameters conform to the NTSB's standard sign convention that climbing right turns are positive (CRT=+)[5].

[4] TSO-C124 – The FAA Regulation under which FDRs are certified

[5] CRT=+ means that for any parameter recorded that indicates a climb or a right turn, the sign for that value is positive. Also, for any parameter recorded that indicates an action or deflection, if it induces a climb or right turn, the value is positive. Examples: Right Roll = +, Pitch Up = +, Elevator Trailing Edge Up = +, Right Rudder = +.

1.11.2.3. Time Correlation

Correlation of the FDR data from SRN to the UTC of the accident was derived from the recorded UTC time parameters on the FDR. Accordingly, the time offset for the event flight data from SRN to UTC is the following:

UTC = SRN - 78027.

1.11.2.4. FDR Plots and Corresponding Tabular Data

The FDR plots which are at Appendix 3 show the following data:

- Basic flight data was recorded over the entire duration of the accident flight.
- Engine related parameters recorded over the entire duration of the accident flight.
- Flaps, spoilers, and brake parameters recorded over the duration of the accident flight.
- Parameters related to the hydraulic system recorded over the entire accident flight.
- Parameters related to the lateral/directional control of the aircraft recorded over the entire accident flight.
- Parameters related to the pitch control of the aircraft recorded over the entire accident flight.
- Discrete parameters related to the operation of the leading edge slat devices recorded over the entire accident flight.
- The above listed parameters recorded for the final three minutes of the accident flight as the aircraft descended through 2000 feet.

- The same parameters as listed above recorded for the landing preceding the accident as the aircraft touched down at Port of Spain, Trinidad and Tobago.

1.12. WRECKAGE INFORMATION

1.12.1. Wreckage Site Description

The aircraft came to rest approximately 130ft off the runway paved surface and 64ft left of the extended runway center line. The final aircraft heading was approximately 10˚ left of RWY06 center line. (Figs.5&6.)

Fig.5: Location of Aircraft after accident

Figure 6: The Aircraft's Final Heading was approximately 10˚ left of Runway 06

Main and nose gear tire marks were found in the dirt, immediately off of the asphalt (Fig.7). A set of main gear tire marks were found approximately 56ft off of the asphalt and down an embankment, 39ft in front of the airport perimeter fence, and then disappeared. These were approximately 8ft long and 2ft deep. Nose gear tire marks were not found at this location.

Figure 7: Under carriage tire marks off the runway.

A 20ft wide dirt road located 15ft beyond the perimeter fence had no tire marks until its far side. A berm (i.e., dirt road shoulder) on the far side marked the final resting position of the main landing gear tires. The berm was located 74ft beyond the main gear tire marks found in the dirt. See Figures 8&9.

A section of the airport perimeter fence was destroyed, being uprooted by the aircraft.

There was no damage to the runway.

Figure 8: A Dirt Berm Marked the Final Resting Position of the Main Gear Tires

Figure 9: Final position of aircraft across a 20ft Wide Dirt Road.

In Figure 10 below, a Sworn Land Surveyor referenced a point referred to as the “airport origin”. It was located on the center line and at the threshold of runway 24. All longitudinal and lateral displacements, as well as east and north distances, are with respect to this point.

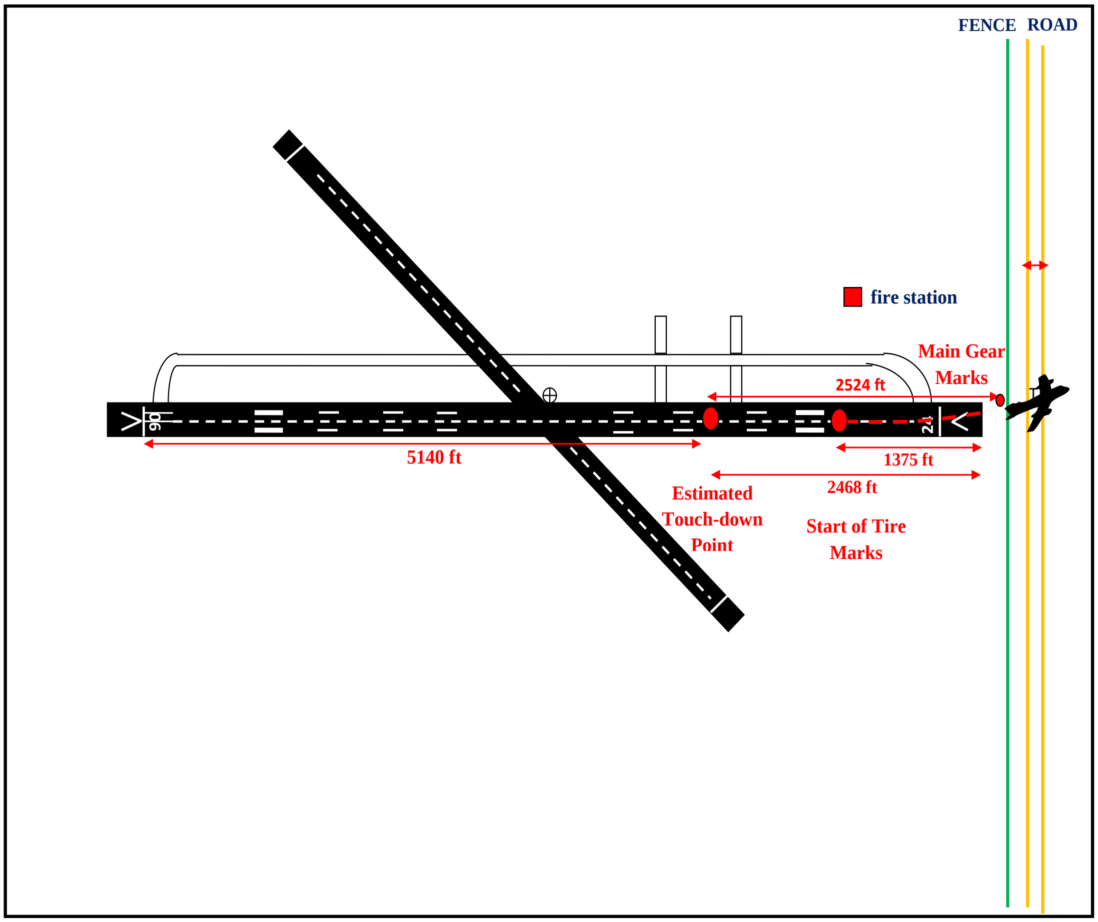

Figure 10: Estimated Main Gear Touch-down Point

Figure 10 highlights the estimated main gear touch-down point, the tire marks on the runway, and the final position of the aircraft. The figure shows that the tire marks tracked the runway center line for approximately 700ft. For the remaining 675ft of asphalt, the tire marks veered to the left. The nose wheel departed the asphalt approximately 46ft left of the runway center line.

1.12.2 Damage to Aircraft - General

The forward fuselage partially broke aft of the first class cabin, and the nose was found resting on the ground. The aircraft flaps and slats were retracted. The nose wheel gear was pushed backwards (opposite the normal retraction direction) into the fuselage where avionics and electronics are housed. The thrust reverser doors were found partially extended on both engines.

Figure 11: Showing break in first class cabin, deployed R1 slide, and open right over wing emergency exits and partially extended thrust reverser door

Barbed wire and airport perimeter fence mesh were found attached to the left engine nacelle. Mud and grass were found on both nacelles. See Figure 12. Figures 13&14 are included for additional perspective.

Figure 12: Mud and Grass were found on Both Nacelles

Figure 13: Egress Slides on Right Side Deployed

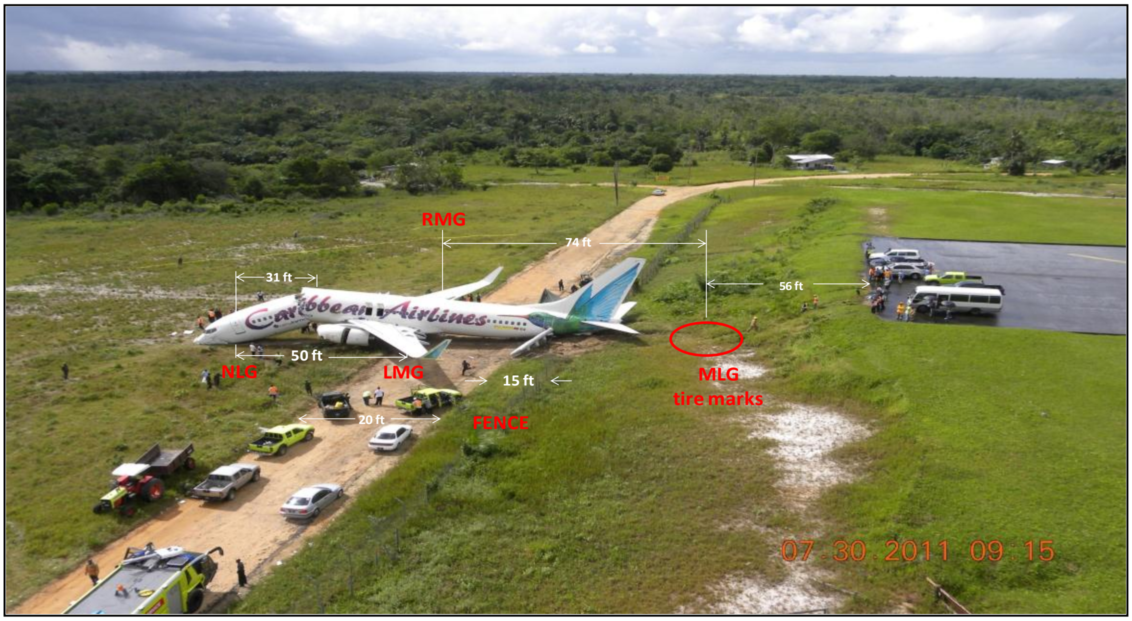

Figure 14: Final Aircraft Location Relative to Runway

1.12.3 Cabin Damage

1.12.3.1 Forward Cabin Damage (Forward of the Break)

Forward of the fuselage break, all of the overhead interior components had broken free from the support structure up to the forward monuments (G2 galley and G7 closet). The stow bins on the left side, from the fuselage break to the forward monument had collapsed. The stow bins on the right side had also collapsed forward of the fuselage break, except the forward-most stow bin, which remained attached to the structure adjacent to the G2 galley monument.

Damage to the support structure varied, and included torn metal brackets, snapped turnbuckles, and broken bushings. This damage was evident on both the stow bins and aircraft interfaces. The brackets and fasteners that attached the stow bins to one another were still intact, although, some showed evidence of bending stress in either the panels or the brackets.

The bins from the left side were resting over the aisle, supported by the open bin doors and passenger seats. The bins from the right side were resting on the seat backs on the right side of the cabin (Figure 15).

Figure15: Cabin forward of the fuselage break; left stow bins resting over the aisle (looking forward).

The G7 closet was displaced forward, blocking the forward, left door (L1), which could not be opened due to interference from the closet. The upper attachment fittings for the G7 closet, were pulled out of the honeycomb panel and the lower (aft) attach fittings were broken and pulled free from the floor. The video monitor on the aft surface of the G7 closet was hanging from the cable; the frame was still attached to the closet. None of the compartments on the forward surface of the G7 closet could be opened. The compartments facing the aisle operated normally, although the closet door could not be completely closed and latched. The measured distances from the forward surface of the G7 closet to the aft face of Lavatory A (wall) were as follows:

	Accident airplane	Exemplar airplane
-	Top inboard: 25”	38” (floor to ceiling)
-	Top Outboard: 33”	45” (floor to ceiling)

The G2 galley was not significantly damaged; there was slight buckling of the forward, inboard (aisle-side) panel, at the top and bottom.

The cabin floor in the vestibule area (between exits L1 and R1) was warped.

The forward Lavatory sustained severe floor warpage and the toilet shroud had broken free. The door was removed during the rescue operation as it was jammed in a partially open position, blocking the cockpit exit. The door was located and had significant bending at the bottom and marks consistent with the reported use of a crash axe and prying of the door.

The flight deck door had been removed prior to cabin examination. The door was not damaged, but had superficial markings consistent with attempts to pry the door open with a tool. There was a slight separation of the frame/trim from the area of the door strike. Both "blowout" panels had been removed and the release pins functioned normally. There was no damage to the panels.

1.12.3.2. Rear Cabin Damage

The cabin aft of fuselage break was in good condition. Overhead stow bins local to and forward of the fuselage break (Row 5) were detached from the support structure. Ceiling panels forward of Row 8, right side and Row 11, left side were pulled down and found hanging by wire harnesses.

No damage was found on any of the Flight Attendants seats and restraints.

PSUs on left side at rows 6 and 7 were broken at the outboard clips and were hanging from the hoses.

1.12.4. Emergency Equipment

All emergency equipment was found in their normally stowed positions, except:

- 6 flashlights missing; 4 from the aft FA jump seat and 2 from the forward FA jump seat.
- 3 first aid kits missing: 2 from aft cabin and 1 from forward cabin.

- Extra adult life vests, child life vests, and protective breathing equipment were found in an adjacent overhead bin;
- Life raft and its stowage compartment in the forward cabin were separated from the ceiling, and were found in first class area.

1.12.4.1. Emergency Locator Transmitter (ELT)

The Aircraft is equipped with two ELTs. One is fixed, attached to a mounting plate in the crown area of the ceiling above seat 24C. The other is portable and is located in the forward closet. The portable ELT was located in its correct position. The fixed ELT was found in its correct location, however the ceiling panel directly above seat 24C was missing, and the ELT mounting plate was visible in the aircraft crown area. This ELT was found in the "off," position and disconnected from its wiring harness. It was marked:

Artex
Part number: 452-0133
TSO C-91a/C-126
Expiration date 11/2014

1.12.5. Landing Gears – Tire Pressure

The main gear tire pressures were measured and found to be within normal limits in accordance with CAL Maintenance Manual. The measured pressures were:

Left Gear Outboard Tire – 200psi
Left Gear Inboard Tire – 195psi

Right Gear Inboard Tire – 195psi

Right Gear Outboard Tire – 205psi.

The nose gear tires were not measured due to inaccessibility.

1.12.5.1 Nose Gear

The shock strut was folded backwards into the lower aft wheel well bulkhead and partially into the main electronics bay. Access was very limited due to the final position of the nose of the aircraft on the ground. The shock strut appeared to be still connected to the lower drag brace at the attachment bolt. The shock strut was still attached to the sidewall trunnion fittings. The trunnion pins and torsion links appeared to be intact. The shock strut did not appear to leak any fluid. The structural element failure that caused the NLG to fold backwards was not determined due to limited access. A portion of the nose gear shock strut was smashed into the electronics equipment bay access door and belly structure between the aft nose wheel well bulkhead and the electronics equipment bay access door.

Steering System - The cable pulleys and the attach bracket at the upper shock strut were shattered and partially missing and the cables were hanging loose. The steering metering valve was still attached to the upper steering plate. The summing mechanism was severely deformed and fractured in many places; the cover was missing and was not found. The steering actuators were intact and still attached to the upper and lower steering plates which were also intact.

Nose Gear Tires - The nose gear tires were intact and showed no evidence of separations or impending tread loss. The visible portions did not have any visible cuts, trauma or other damage. A portion of both tires were imbedded into the aircraft's belly structure and electronics equipment bay. Both tires had at least half of the original tread depth remaining.

The visible portions of the upper and lower drag braces and lock links were intact and were still connected. The lock links were in the unlocked position.

Hydraulic tubing at the hydraulic swivel and hoses to the retract actuator were severed. The lower end of the retract actuator was still attached to the upper drag brace.

The taxi light and air/ground sensor conduits on the torsion links were intact up to the junction box on the torsion link. The conduits at the left trunnion were damaged/severed. The taxi light was intact. The upper portions of the conduits were not examined due to limited access.

The lower portion of the aft bulkhead was crushed. Lower chords near the door hinges were crushed. The fuselage belly skins aft of the nose wheel well were dented, damaged and abraded from contact with the ground.

Both nose gear doors departed the aircraft. A fragment of the right door was found under the aft portion of the fuselage near the fence line and two fragments of the left door were found on the left side of the aircraft with one fragment just forward of the left main gear and the other just aft of the nose gear wheel well. Fragments of the door hinges were still attached to the door fragments. The door operator rods were still attached to the shock strut trunnions.

1.12.5.2. Right Main Landing Gear

The entire right main gear, including shock strut assembly, side strut assembly, actuator beam assembly, actuator assembly and the actuator beam structural attach fittings, electrical and hydraulic systems and doors, was completely intact and attached to the aircraft, with little, if any, observed damage to any of the components or the surrounding aircraft structure. No hydraulic leaks were observed at the strut, hydraulic tubing, hoses, actuators, brakes and damper. Approximately half of the tires and brakes and the bottom of the strut inner cylinder were buried in the sandy soil. The condition of the lower torsion link, tires, brakes and antiskid harness below the inner cylinder were not examined due to inaccessibility. The gear components were contaminated with sand, dirt and other debris.

The brakes appeared to be intact and undamaged. No leaks were observed at the brake pistons. Both brakes were P/N 2-1587-1. The serial numbers were not recorded due to lack of access. The inboard brake wear pin measured approximately 1⅜ inches and the outboard brake wear pin measured approximately 13/16 inch in the unpressurized state.

The wheels appeared to be intact and undamaged. Both wheels were P/N 3-1558. The serial numbers were not recorded due to limited access.

The tires were intact and pressurized with no evidence of impending tread loss. The inboard tire s/n was 809YS129 and the outboard tire s/n was Y10YS030. The visible portions of the tire sidewalls, shoulders and crown (tread area) were undamaged. The tread areas had very little tread wear or abrasion damage and no visible cuts were observed. There were also no signs of hydroplaning damage or flat spots due to skidding. The tread depth of the outboard tire was approximately ⅜ inch and the tread depth of the inboard tire ranged from approximately ⅛ to ¼ inch.

No airframe structural damage was noted in the vicinity of the right main landing gear, the wheel well, wing trailing edge and rear spar, wing root, wing-to-body fairing or wheel well surrounding structure.

1.12.5.3. Left Main Landing Gear

The entire left main gear, including shock strut assembly, side strut assembly, actuator beam assembly, actuator assembly and the actuator beam structural attach fittings, electrical and hydraulic systems and doors, was completely intact and attached to the aircraft, with little, if any, observed damage to any of the components or the surrounding aircraft structure. No hydraulic leaks were observed at the strut, hydraulic tubing, hoses, actuators, brakes and damper. Approximately half of the tires and brakes and the bottom of the strut inner cylinder were buried in the sandy soil. The condition of the lower torsion link, tires, brakes and antiskid harness below the inner cylinder were not examined due to inaccessibility. The gear components were contaminated with sand, dirt and other debris.

The brakes appeared to be intact and undamaged. No leaks were observed at the brake pistons. Both brakes were P/N 2-1587-1. The serial numbers were not recorded due to inaccessibility. The inboard brake wear pin measured approximately 1¾ inches and the outboard brake wear pin measured approximately 1 inch in the unpressurized state.

The wheels appeared to be intact and undamaged. Both wheels were P/N 3-1558. The serial numbers were not recorded due to limited access. The tires were intact and pressurized with no evidence of impending tread loss. The inboard tire s/n was Y10YS057 and the outboard tire s/n was 111YS054. The visible portions of the tire sidewalls, shoulders and crown (tread area) were undamaged. The tread areas had very little tread wear or abrasion damage and no visible cuts were observed. There were also no signs of hydroplaning damage or flat spots due to skidding. The tread depth of the outboard tire was approximately ¼ inch and the tread depth of the inboard tire ranged from approximately 1/32 to 3/16 inch.

No airframe structural damage was noted in the vicinity of the left main landing gear, the wheel well, wing trailing edge and rear spar, wing root, wing-to-body fairing or wheel well surrounding structure.

1.12.5.4. Main Landing Gear Wheel Wells

Both main gear wheel wells were completely intact, with no visible damage to system components, tubing, wiring and airframe structure. The wheel blade seals and ski jump fairings and surrounding structure were contaminated with sand, dirt and debris. There were no signs of hydraulic leakage.

The antiskid valves and the auto-brake module located within the main gear wheel wells were examined and appeared to be intact and undamaged. The part numbers and serial numbers were recorded. They are as follows:

- RH Inboard antiskid valve: P/N 39-353 s/n 32461
- RH Outboard antiskid valve: P/N 39-353 s/n 32553
- LH Inboard antiskid valve: P/N 39-353 s/n 32605
- LH Outboard antiskid valve: P/N 39-353 s/n 32452
- Auto-brake Module Servo valve: P/N20102070-106 s/n 3062

1.12.6. Wings

1.12.6.1. Left Wing

The left wing trailing and leading edge panels and the upper and lower wing skins were undamaged and had no visible scuff marks or abrasions. The winglet was intact and undamaged. The leading edge slats and trailing edge flaps were retracted to the full up positions and had no visible damage, scuff marks or abrasions. The lower surfaces of the trailing edge flaps and flap track fairings inboard of the engine were covered in a layer of dirt, except for a 1¼ inch band on the number 3 flap track fairing at the forward edge of the moveable part of the fairing that translates with the flaps during flap extension and retraction. The characteristics of this area were consistent with being covered while the flaps were down and being revealed after the flaps were retracted during the accident.

1.12.6.2. Right Wing

The right wing leading edge panels and the upper and lower wing skins were undamaged and had no visible scuff marks or abrasions. The winglet was intact and undamaged. The leading edge slats and trailing edge flaps were retracted to the full up positions. The leading edge had no visible damage, scuff marks or abrasions. The lower surfaces of the trailing edge flaps and flap track fairings inboard of the engine were covered in a layer of dirt, except for a 1¼ inch band on the number 6 flap track fairing at the forward edge of the moveable part of the fairing that translates with the flaps during flap extension and retraction. The characteristics of this area were consistent with being covered while the flaps were down and being revealed after the flaps were retracted during the accident.

The following damages were noted on the wing trailing edge flaps and flap track fairings:

- Number 8 Flap Track Fairing: The lower inboard edge of the number 8 flap track fairing had a deep gouge that measured approximately 8 inches long by ½ inch wide by ½ inch deep. The aft end of the gouge was located approximately 71 inches from the trailing edge of the fairing.
- Trailing Edge Flap Damage: There was an 8 inch long by 1 inch wide scrape on the aft flap starting at the trailing edge. It was located approximately 29 inches inboard of the number 8 flap track fairing. There was another 8 inch long by 1 inch wide scrape starting at the aft flap that was located 20 inches inboard of the number 7 flap track fairing. Forward of this scrape was a 4 inch diameter puncture hole

in the lower skin of the mid-flap. This puncture was located 12 inches inboard of the number 7 flap track fairing. There was a 3 inch diameter imprint on the surface of the punctured skin that was consistent with the inside diameter of a steel perimeter fence post that was knocked down by the aircraft.

1.12.7. Flap Control Unit

The flap control unit (FCU) was examined by removing the cover from the unit. The internal components of the unit were found to be in a position where the rig pin holes in the trailing edge flap control valve link appeared to align with the rigging slot. CAL personnel examined the FCU on an exemplar aircraft. The position of the internal components was photographed when the flaps were at 30° and again at 0°. Comparison of the FCU internal components on the accident aircraft with the photographs from the exemplar aircraft's FCU indicated that the FCU on the accident aircraft was in the 0° flap position.

The flap control lever and flap position indicator in the cockpit indicated 30º. Further investigation revealed the cable operated by the flap control lever was moved due to the aircraft fracture, resetting the FCU to the 0º position.

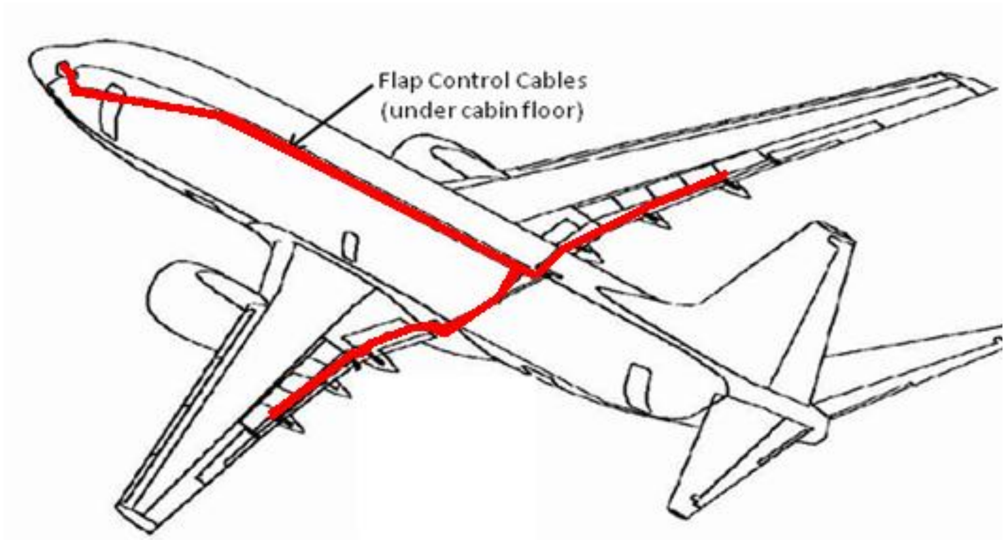

Figure16: Flap Control Cables in normal position

1.12.8. Fuselage

The aft section of the fuselage was resting on a section of concrete from one of the perimeter fence post anchors. The entire fuselage from BS 500D forward of the wing root area to the tail was undamaged except for some tears and crinkles in the composite material in the tail section above and below the horizontal stabilizer (approximately BS 1129 and BS1138).

The forward section of the fuselage tore open from the crown to the belly starting at approximately BS 500B. The crown area structure was completely separated and it appeared that most of the structure from the crown to below the floors boards was severed. There was no noticeable wrinkling in the crown fuselage skin aft of the break. The lower skins and some structural components were still attached and crumpled. The nose was pointed downward and approximately 15° to the left with the nose cone and nose section crushed into the ground approximately half way through the cone. The forward fuselage section was displaced downward approximately 2ft as measured from the “Air Jamaica” logo located below the window belt line at the BS 500B break. The belly of the forward fuselage section was crumpled and had longitudinal scrapes, abrasions and scratches from the nose all the way to the break line. There were tears and crumpled skin up to 12 inches below the cockpit windows on both sides at BS 259. There was a puncture in the crown directly above the cockpit door that was determined to be from the cockpit door frame.

1.12.9. Miscellaneous

The engine fire bottles were examined, and the pressure gauge indicated that there was 8.5psi of pressure in both the left and right fire bottles.

The brake accumulator pressure gauge indicated a reading of 1000psi.

According to the aircraft logbooks recovered from the wreckage, the total time on the aircraft prior to the accident flight was 14861:2 hrs. The next scheduled inspection was an A2 inspection due at 15238:6 hrs.

1.12.10. Cockpit

Inspection of the cockpit after the accident revealed the following:

- The cockpit escape windows could not be opened using normal forces on the handles.
- The floor of the cockpit forward of the crew seats was bent upward toward the rudder pedals, but did not affect the areas where the seats were mounted. Seats were firmly attached to the floor. However after the accident the vertical adjustment would not lock in any position.
- Main Instrument Panel – Switch positions on the main instrument panel indicated that most of the systems in the cockpit were functioning normally. It was noted that the Auto Brake switch was at position 3. The left and right flap indicator was at 30° and the gear handle was in the down position.
- Glare shield – there were no unusual settings on the glare shield.
- Overhead Panel – Overhead panel indicators were all normal.
- Fuel – Fuel indicators were normal.
- Navigation – The aircraft navigation systems were normal.
- Flight Controls – Flight control indicator switches were in standard positions.
- Electrical – Electrical switches were in anticipated positions. However for the emergency exit lights the guard was up and the switch was at the off position.
- Window Heat – Window heat switch positions were in standard positions.
- Hydraulic Pumps – hydraulic pumps switches were in standard positions.

- Pedestal – The speed brake lever was down, but was not extended into the armed position, while the parking brake was disengaged. The power lever 1 was full forward and the piggyback lever was down, while the power lever 2 was full aft while the piggyback lever was up. The stabilizer trim was at 6.5°, nose up and the flap lever was at 30º. Both engine cutoff levers 1&2 were in the cutoff position and both stabilizer trims were in the normal position.
- Fire Panel – The fire panel indicators were in the anticipated positions.
- Circuit Breakers in popped (out) position were:
  DME 2; Wx. Radar RT; BDS; MACH TRIM DC; AFCS B SNSR EXC AC; SECT 8; Window Heat Pwr. – Left side; AFCS A SNSR EXC AC; AFCS A SNSR Engage Interlock; PASS Left Oxygen.
- Circuit Breakers Collared in the Out Position were:
  OVRLD ENT – ENT Control; Entertain Pass IFE Signs; IFE Main AC.

1.12.11. Power Plants

1.12.11.1. Engine #1

Maintenance records from CAL Trinidad showed that the part number and serial number for engine #1 were:

P/N: CFM56-7B26/3

S/N: 894748

Inspection of the data plate on the engine showed the same part number and serial number.

The #1 engine had crush damage on the lower portion of the inlet such that the inside of the inlet was displaced to a point approximately 80% of the distance from where the inner wall of the inlet used to be to the center of the engine. There were sections of chain link fence imbedded into the inlet from approximately the 4 o'clock to the 7 o'clock position.

The fan blades had numerous small distortions on the leading edges, but there were nicks on only a few blades.

The thrust reversers were found in the deployed position with the measurement of the thrust reverser actuator of 43 7/8 inches when measured from the extend side rod end bolt to the stationary side rod end bolt.

All blocker doors were deployed. A small amount of dirt was noted on the forward side of the blocker doors. The dirt had accumulated up to approximately ½ -1 inch thick on the inner edge of the blocker door.

All turbine blades/stators visible from the rear of the engine were intact with no visible damage.

1.12.11.2. Engine #2

Maintenance records from CAL Trinidad showed that the part number and serial number for engine #2 were:

P/N: CFM56-7B26/3

S/N: 894767

Inspection of the data plate on the engine showed the same part number and serial number.

The inboard cowling was found in the released and up position after the accident.

The engine had crush damage on the lower portion of the inlet such that the inside of the inlet was displaced to a point approximately 50% of the distance from where the inner wall of the inlet used to be to the center of the engine. There were sections of chain link fence imbedded into the inlet from approximately the 4 o'clock to the 7 o'clock position.

The fan blades had numerous nicks and slight deformations on the leading edges. One blade tip was bent in the direction opposite rotation.

The thrust reversers were found in the deployed position with the measurement of the thrust reverser actuator of 44¼ inches when measured from the extend side rod end bolt to the stationary side rod end bolt.

All blocker doors were deployed. A small amount of dirt was noted on the forward side of the blocker doors. The dirt had accumulated up to approximately 1/16 inch thick on the inner edge of the blocker door.

All turbine blades/stators visible from the rear of the engine were intact with no visible damage.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

1.13.1. Medical Reports

Both pilots were examined and interviewed at the Georgetown Public Hospital Corporation by the Head of Accident and Emergency Unit.

Blood alcohol and other routine toxicology screening were carried out at the Eureka Medical Laboratory in Georgetown. This laboratory is certified and approved by the Guyana National Bureau of Standards.

1.13.2. The Captain

The captain was triaged at 03:40LST and treated at approximately 04:00 LST at the Hospital. He was fully conscious during the examination and complained of lower back pain. He was treated and discharged with a diagnosis of Soft Tissue Injury. Blood alcohol and other routine toxicology tests were all negative. He was prescribed analgesics and rest and advised to seek further psychological counseling.

1.13.3. The First Officer

The First Officer was triaged at 03:46LST and was treated at approximately 04:00LST at the hospital. He complained of pain in his lower back and both ankles. He reported no loss of consciousness after the accident and was fully conscious during the examination. He was treated and discharged with diagnoses of Soft Tissue Injury and Muscle Strain. Blood alcohol and other routine toxicology tests were all negative. He was prescribed analgesics and rest and is expected to make a full recovery.

1.14. FIRE

There was no fire.

1.15. SURVIVAL ASPECTS

1.15.1. Notification of Accident

The Air Traffic Control Officer reported that at all times during the landing she had the aircraft in sight. She reported that there was light rain but not enough to obscure her view of the aircraft. The touchdown of the main landing gear appeared to be normal but it appeared to her that the nose wheel did not touchdown until in the vicinity of taxiway ‘A’. She reported that the aircraft seem to make a left turn as if it intended to turn off the runway at taxiway ‘C’, but then disappeared from view. She notified the fire service via radio and they responded after the third call. She stated that she felt it was an unusual landing. Review of the daily log sheet for the day of the accident shows the Controller reported the accident to the Timehri Fire Service at 05:33UTC.

The Control Tower daily log sheet shows that the Airport Duty Officer was notified about the accident at 05:34UTC. At 05:36UTC reports were made to senior GCAA staff, CAL Timehri, and the Trinidad and Suriname Aeronautical Reporting Offices.

1.15.2. Actions by the Aerodrome Fire and Rescue Service

The Officer-in-Charge of the SYCJ Fire Station reported that his Control Room Attendant observed when the aircraft over shot the runway. He immediately sounded the alarm and dispatched three rescue vehicles, with their crews to the scene. Shortly after the vehicles departed the station house, a call was received from the Air Traffic Controller to notify him of the occurrence. The Controller was advised that the crash vehicles were already on their way to the accident site. He further reported that the Control Room Attendant was alerted by the unusual sound of the landing aircraft and he immediately knew that something was wrong.

Upon receiving notification, the Station Officer immediately proceeded to the site and took control of the site as On-scene-Commander, in accordance with the SYCJ Emergency Manual. Some of the passengers had already exited the aircraft, via the over-wing exits and two slides that had been deployed from the aircraft, and were seen running in all directions, some into the bushes. About twenty-five minutes later all persons on board were safely off the aircraft. The Captain who was stuck in the cockpit was the last person to be evacuated. The passengers and crew were assembled at a collection area, approximately 90m west of the crash site and were then taken to the airport terminal building.

The Station Officer stated that there was no fire but light grey smoke was seen coming from the #2 engine. One of the crash tenders was tasked to use foam to cool the engine. The firemen used water to cool the engine cowling and remained on watch on the runway, above the wreck. The fire tenders were able to provide a little lighting at the site.

The Station Officer also reported that the first security on site was the Guyana Defence Force and the Guyana Police Force, who arrived on the scene about forty minutes later and established the inner cordon. He reported that he did not recall seeing the Airport Police at the scene. He also noted that several residents were on the scene immediately after the crash and expressed the view that it was commendable that they were very helpful to the survivors and there were no reported incidents of indiscipline among them.

1.15.3. Report from Flight Crew

The flight crew reported that due to the unexpected nature of the occurrence, they were in no position to alert cabin crew or passengers about the impending disaster. Therefore there was no opportunity to carry out any emergency drills.

The First Officer reported that after the impact he removed his harness and got up. The cockpit was completely dark as there was no power. All displays were black. Using his flashlight he attempted to access the audio panel but it was blocked by something that had fallen on it. The cockpit door was ajar and he saw lights outside the door. He shouted “evacuate, evacuate, evacuate” through the door.

He attempted to assist the captain, who said his back was hurt and didn’t want to move. Using the fire extinguisher he attempted to punch through the door but the blowout panels remained on the door and the door remained jammed. The door, although ajar, was not open enough to allow him to escape. He attempted to unlock and open the FO’s cockpit window, but it was jammed. He then attempted to unlock and open the captain’s window, as the captain had moved up to the area above the flight library bag, but that window was jammed also.

As he returned to the door the purser called and asked for the crash axe, which he was able to pass through the door. An able bodied person assisted the flight attendant. He stated that he then removed the pins in the door blowout panels and removed the panels. Even with the removal of the blowout panels, egress from the cockpit was still hampered because the lavatory door was jammed open and blocking passage. The FO stated that he managed to move the door sufficiently to be able to crawl through.

Before leaving the cockpit he initiated the evacuation drill, giving the evacuation command orally. He stated that he turned the emergency exit lights switch on and the seat belt sign off, switched the two engine start levers to cutoff and overrode and pulled both engine and APU fire switches.

After he squeezed through the cockpit door, firemen arrived and assisted in removing the captain from the cockpit and carried him out. The FO checked the cabin and saw no one. The captain told him to go down the R1 slide, which he did. The captain followed. They met the cabin crew on the ground and commanded everyone around the nose of the aircraft and to the left.

1.15.4 Report from Cabin Crew

The purser reported that although she was not sure if the aircraft had stopped, she felt that something was wrong and she shouted commands "bend over and get your heads down" three times to the passengers. She stated that there were no communications or emergency signals from the cockpit, and that the evacuation was started by passengers. She stated that a scared looking male passenger approached her from the darkness (coming forward) looking for a way out. In response to her query he said that he did not see any fire. He opened the R1 exit and the slide inflated. Several passengers exited the aircraft using the R1 exit. The L1 exit was jammed shut by Galley Unit 7 which had shifted forward.

She could not recall if the emergency lights were on, but did note there was light in the galley area but the passenger cabin was dark. She recalled that for landing the cabin ceiling lights was set to Dim, Galley lights were 'Off' and the window lights 'Off'. She stated that there are no controls for emergency lights at the forward attendant control panel, but there was an emergency light switch at the aft cabin crew panel.

She noted that the flight deck door and windows were jammed, hampering the flight crew's exit. She attempted to open the flight deck door, but realized that the floor in the local area was raised. The Lavatory 'A' door was jammed in an open position and it appeared that the forward ceiling was low. All of this may have prevented the flight deck door from opening properly. She asked the FO to pass the crash axe through the partially open flight deck door and with assistance from a male passenger and the combined efforts of the FO tried to get it open. In the meantime, Emergency personnel arrived and climbed up the slide. They asked the passenger and cabin crew to get to safety while they continued efforts to free the flight crew. The purser also stated that, before leaving the aircraft, she retrieved two flashlights and attempted to retrieve the ELT, but that compartment door could not be opened as it appeared to be jammed.

She exited the aircraft via the R1 door and walked down the slide. Once outside she used the flashlight to guide passengers to a collection area forward of the aircraft. No headcount was done because the crowd was a mixture of passengers and emergency personnel and she could not tell the difference in the darkness. She noted light smoke from the #2 engine. She stated that some passengers were attempting to go back to the aircraft for luggage but they were prevented from doing so by the crew. By this time several vehicles had arrived on the scene. She had taken note of one seriously injured passenger who was placed in the back of a pick-up. No ambulances had arrived at the scene up to the time she left.

The other Cabin Attendants reported that efforts to open the L2 door had to be abandoned and the R2 door opened with difficulty, requiring two of them to open it. The slide at this door opened and deflated rapidly. About five to ten passengers were able to exit on this slide before it became unusable.

One Cabin Attendant jumped to the ground and got a passenger to assist in holding the slide out like a chute, so that others could use it. About ten more passengers were able to use it. This Attendant then assisted passengers who were on the wing and on the ground near to the aircraft. She then went back into the aircraft through the R2 door and went forward up to the break and called for the forward cabin crew, but they were already out of the aircraft.

It was noted that there was no attempt to turn on the emergency lights using the switch above the rear attendants' seat. There was an attempt to use the intercom system but it was not responsive. The L2 slide was unusable as the cabin attendants were unable to open the L2 door.

1.15.5. Extract from Passenger Questionnaires

A questionnaire, comprising one hundred and three questions was sent by mail to one hundred and one passengers. Fifteen responses have been received. The passengers who responded were quite lucid. They described the landing as violent, the aircraft bounced up and down and most said they were thrown around. The after landing was described as being in a race car with the driver playing with the brakes.

It was noted that the actions of the flight attendant in the business class were commendable as she remained calm and assisted both the passengers and flight crew.

All respondents commented about the darkness in the cabin which added to the resultant confusion and panic among passengers. Injuries were received both during the impact and during evacuation and included sprains, strains, fractures and abrasions. The most serious injury resulted when a passenger's leg was broken during evacuation. This subsequently resulted in amputation.

Discussions with passengers revealed that several passengers were hesitant in getting off the wings as they were unsure of the best way down. It was also noted that during evacuation one passenger suffered burns when she touched the engine cowling.

1.16. TESTS AND RESEARCH

1.16.1. Performance Studies

The performance study describes the aircraft motion during the accident sequence based on the available data sources. This includes aircraft position, speed, and attitude derived from the recovered FDR, weather information services, and data collected during the on-scene portion of the investigation. No radar data was available for the accident.

1.16.1.2. Performance Study Window

The study window encompasses the time from when Caribbean Airlines flight, BW523 departed Port of Spain and ended at the time the aircraft over ran RWY06 at SYCJ and subsequently came to a stop.

The aircraft was cleared for the RNAV-GPS RWY06 approach. The Initial Approach Fix is (WP) AKSIN, which is located 11.2nm from the threshold RWY06 along the extended runway center line. The Final Approach Fix (FAF) for this approach is (WP) OLVIK, which is 5.2nm from the threshold RWY06.

The aircraft touched down on RWY06, and did not stop before it exited the end of the runway, eventually stopping 130ft off the end and about 64ft to the left of the extended runway center line. The aircraft ran through a chain link fence and across a dirt road before the main gear became embedded in a small dirt berm on the far side of the road. Nothing about the flight appeared unusual until the aircraft was approaching the runway to land. The performance study focuses on the flight from just inside (WP) OLVIK until the end of the FDR, which was about the time when the aircraft collided with the chain link fence.

1.16.1.3. Calculated Performance

Readings from the FDR examination indicate the following;

1. The FDR data indicate that the flaps were extended from 15° to 30° just inside OLVIK at 05:29:39.

2. The aircraft touched down about 2.5 minutes later at 05:32:12. The weight-on-wheels discrete signal recorded on the FDR indicates touchdown at the same time.
3. The aircraft touched down at a computed airspeed of 146kt and a ground-speed of 151kt.
4. The throttles were set at 75% N1 about 15 seconds prior to crossing the runway threshold and were transitioning from 75% N1 to 65% N1 approximately 3 seconds prior to reaching the threshold at approximately 05:31:50.
5. The throttles stayed at a 65% N1 level until 05:32:01 when they were reduced to a level that reached 33% N1 at 05:32:06, six seconds before touchdown.
6. The throttles were advanced three seconds before touchdown. The average N1 of the two engines reached about 59% near touchdown at 05:32:12. Correlation with the CVR contains comments about going around at about this time.
7. The thrust reversers deployed approximately two seconds later at 05:32:14 as N1 was increasing from 51% to 58%.
8. The aircraft largely maintained a 3° glide slope throughout the approach except for a twenty second window starting around 05:31:20. This corresponds to the time just after the auto-throttles were disengaged and the power was reduced to 34% N1. The flight path angle was as steep as 5º during this period.
9. There was almost no control input until the autopilot was disconnected at 05:31:05. At this point there were small aileron and spoiler inputs of less than 5º all the way to the end of the FDR. The directional parameters

are similar except that there are rudder inputs upwards of 5º degrees beginning at touchdown.

10. The inertial velocity and position of the aircraft on the runway were obtained by using a combination of FDR inertial data (ground speed, drift angle, heading), FDR acceleration data, runway information and the final resting spot as there were no RADAR data available for the accident.
11. The wind speed decreased below 5kt and the wind direction shifted almost 180° on short final. This corresponds to a point in the approach where the crew reported seeing three red lights on the PAPI. The wind shift may be explained by the rapidly increasing elevation of the terrain that exists approaching the threshold of runway 06.
12. Main gear touchdown occurred at or slightly beyond taxiway A, just in front of the international ramp. This is approximately 4700ft down the runway, leaving 2900ft until the end of the pavement.
13. The ground spoilers were armed and, as a result, deployed around the time of touchdown at 05:32:12. The thrust reversers deployed approximately two seconds later at 05:32:14 when the aircraft was 2000ft from the end of the runway or 2200ft from the end of the pavement.
14. The brake pressure increased gradually starting at touchdown. The maximum brake pressure of 3000psi was not reached until the aircraft was 250ft from the end of the runway or 450ft from the end of the pavement.
15. The calculated aircraft braking coefficient for the combined wheel, brake, anti-skid, and grooved runway surface reached a maximum value

of 0.35. This number represents the total aircraft braking coefficient and does not distinguish between aircraft stopping performance/capability and the runway surface to tire friction coefficient. Factors such as tire tread depth, brake wear, anti-skid efficiency, and runway contaminants were not considered.

16. Both Boeing and NTSB calculations indicate that the accident aircraft demonstrated braking levels that were as good as or better than that for a CFR 25.109[6] "wet grooved" runway above 70kt.
17. The rumbles on the CVR support the touchdown estimates quoted earlier.

1.16.1.4. FDR Summary

Caribbean Airlines Flight, BW523 was properly configured for landing at Georgetown, Guyana, early in the morning of July 30, 2011. There was no evidence of an aircraft malfunction, and the aircraft reached the runway threshold close to the QRH reference speed of Vref =149kt.

The aircraft touched down approximately 4700ft down the runway, leaving 2900ft of pavement to stop on.

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[6]CFR125.109 is the Code of Federal Regulations for accelerate-stop distances for aircraft on wet or dry runways.

The touchdown was 3700ft beyond the runway "aiming point" (or fixed distance marker) and 1700ft beyond the runway touchdown zone for landing operations.

Assuming good braking on a wet runway with an average aircraft braking coefficient of 0.2, the aircraft could not have stopped before reaching the end of the runway using Auto-brakes 3.

The captain carried a power setting of 65% N1 for approximately the first 2000ft of runway. The high power setting explains the excessive float during the flare reported by the crew as well as the long touchdown.

Boeing was able to match the flight's performance with their B737-800 simulation using the recorded FDR inputs. When the TLA's were reduced to flight idle at 20ft AGL in the simulation, the aircraft touched down over 1700ft sooner than with the actual FDR TLA's.

Select simulation time histories are shown in Appendix 4, Figure 20. Boeing also used the simulation to show that it was possible to remain on the runway using Detent 2 reverse thrust. This is shown in Appendix 4, Figure 21.

The ground spoilers deployed at touchdown. The thrust reversers deployed as commanded by the crew to a position between idle and Detent 2 reverse thrust approximately three seconds after touchdown and 2000ft from the end of the runway. The Detent 2 reverse thrust position assumed in the QRH estimates was never commanded by the flight crew.

1.16.2. Landing Performance

The Boeing Company simulation of the landing, using a calculated aircraft braking co-efficient as a function of groundspeed, indicated that it was possible to stop the aircraft on the runway using either Detent 2 or maximum reverse thrust. The FDR-based braking co-efficient along with Detent 2 reverse thrust after touchdown resulted in the aircraft stopping approximately 50ft before the end of the improved runway surface in the 737-800 simulation. Boeing was also able to match BW 523 performance with their B737-800 simulation using the recorded FDR inputs. When the thrust lever angles were reduced to flight idle at 20ft AGL in the simulation, the aircraft touched down over 1700ft sooner than with the actual FDR TLA's (Figure20 in Appendix 4). The rumbles on the CVR support the touchdown estimates quoted earlier.

Below are the sea level landing V-speeds at different flap settings, provided by Boeing. The numbers were computed based on the simulated accident conditions.

Vref, flaps 0, is 196kt

Vref, flaps 15, is 156kt

Vref, flaps 30, is 148kt

Vref, flaps 40, is 141kt

1.16.3. Effects of Wind on Landing Speeds

To examine the winds that were present during the landing and to view pertinent FDR and calculated parameters relative to the aircraft's location on the runway, the FDR accelerometer data were integrated to obtain an inertial velocity and position. The accelerometer biases needed to perform the integration were calculated using positions derived from FDR groundspeed and drift angle. The biases that were calculated and applied are listed in Figure 8-Appendix 4. The true north and east positions relative to the airport origin that resulted from the integration are shown in Figure 9-Appendix 4.

The winds are the difference between the inertial velocity determined from the accelerometer integration and the true airspeed which can be calculated from parameters recorded on the FDR. The calculated wind speed and direction, as well as those recorded on the FDR, are shown in Figure 10A-Appendix 4 as a time history. The calculated winds are also plotted in Figure 10B-Appendix 4 as a function of the height above the ground. This indicates that the wind speed decreased below 5kt and the wind direction shifted almost 180° on short final. This corresponds to a point in the approach where the flight crew reported seeing three red lights on the PAPI.

1.16.4. Runway Friction Tests

Runway friction tests were carried out on Runway 06/24 in order to determine the friction characteristics of the runway surface. Tests were carried out by the Engineering Services Supervisor from the Grantley Adams International Airport, using the Findley Irvine Mark 2 Grip Tester SN# GT 289. The runway testing regime was conducted under controlled conditions, using self-wetting equipment to establish the friction characteristics of the runway, as well as to identify any area on the runway which may require remedial attention. The controlled conditions were in accordance with the conditions in ICAO Annex 14 - Aerodromes (Aerodrome Design and Operations) Vol.1, 4th ed. and ICAO Document # 9137 – Airport Services Manual Pt.2, Pavement Surface Conditions.

It was noted that no historical data was available for runway friction testing. Therefore no comparison could be made. The analysis was based solely on the results of the tests. Seven test runs were done, four runs were in keeping with ICAO standards and three were done under conditions that mimicked heavy showers. Tests for most of the runway surface showed friction values exceeding those set by ICAO, for both wet and dry conditions. There was some concern about the possibility of damage to the asphalt in the area between 200m-300m (656ft - 984ft.) from the threshold RWY06, where the values registered as 0.41 were a little below ICAO minimums. In response to this, Airport Management has taken action to clean and re-groove the area to improve its friction measure.

The Runway Friction Test is at Appendix 5.

1.16.5. Other Tests

The R2 emergency slide which was partially deployed, and had a large fabric tear on the underside of the slide, was shipped to the manufacturer, Goodrich Service Centre in Phoenix Arizona for testing. It was concluded that the slide was damaged on deployment, after inflation had commenced. The damage prevented further inflation.

Figure 17: Showing tear in R2 slide

The PSUs, which were located in the vicinity of the forward windscreen, rows 6 and 7, were broken at the outboard clips and hanging from hoses, were sent to the Boeing Company in Seattle Washington for examination.

CAL engineers were requested to carry out tests on the cockpit seats to check for any breakage or other damage and to inspect the vertical attachments locking mechanism to determine if they were intact.

They were also requested to test the emergency lights using a battery hook up to determine if the lights were functional.

1.17. ORGANIZATION AND MANAGEMENT

1.17.1. General

Caribbean Airlines Ltd is a Trinidad and Tobago operator, owned by the Governments of the Republic of Trinidad and Tobago and Jamaica. The airline is an amalgamation of the operations of Caribbean Airlines and Air Jamaica. It is a merger of two legacy carriers in the Caribbean, operating regional and western hemisphere international flights. BWIA, the predecessor of CAL, was founded in 1939 and has been operating into Guyana for over fifty years. CAL continued the service started by BWIA. The B737-800 has been the company's aircraft of choice for flights to Guyana. The company operates regularly into Guyana with as many as twenty-one flights per week into SYCJ during peak periods.

1.17.2. CAL Operations Manual

The operations manual is subdivided into four parts. Part A – Administration, Requirements and Operations; Part 'B' – Aeroplane Type Operational Procedures and Requirements, includes the Aeroplane Flight Manual and Type Specific Flight Crew Operating Manuals; Part C – Flight Guide, is the route guide/airways manual or Jeppesen; Part D – Training Manual, is used by personnel assigned to operations duties in connection with the conduct of flight. The entire Operations Manual is approved by the TTCAA.

1.17.2.1. Part A – Administration, Requirements and Operations

Part A of the CAL Operations Manual has guidelines for their aircraft operations. It includes details such as flight crew scheduling and composition; the duties and responsibilities of each crew member; requirements for sleep and rest and the need for crews to make proper use of the time allocated by the company for this, along with flight and duty time limitations.

Operating procedures highlight the need for company aeroplanes to operate in compliance with their respective Certificates of Airworthiness and within the approved limitations contained in their Aeroplane Flight Manuals. Part A of the Operations Manual also reinforces the Company's Procedures and Policies that may not be covered in the manufacturer's FCOM.

1.17.3. Landing Techniques

CAL has outlined in its Operations Manual the "Boeing recommended operating practices and techniques for landing, rejected landings and landing roll. Techniques are provided to help the pilot effectively utilize approach lighting, control the aircraft during crosswind landings and maintain directional control after landing. Additionally, information on factors affecting landing distance and landing geometry is provided." Flaps 30° and 40º are normal landing flap positions. Runway length and condition must be taken into account when selecting a landing flap position. Boeing training indicates that flaps 30° should be used for normal landings. Flaps 40º is recommended to minimize landing speed and landing distance and is the preferred setting for short runways.

The Operations Manual advises that a minimum landing distance could be achieved on short runways if the aircraft touches down at the 1000ft point even if the airspeed is a few knots high. It further states that auto brakes should be used and reverse thrust applied to achieve desired retardation.

1.17.3.1. Landing Distances

Table 3 below shows the Wet Performance figures taken from the CAL B737 Runway Analysis Manual for runway 06 at SYCJ. The table takes account of the wind, temperature and landing weight. It is not stated if reported braking action, braking configuration, touchdown speed and reversers were taken into account.

Table: 3 – Wet Performance Figures for CAL B737-800 landing at SYCJ with Flaps 30° and Flaps 40°

FLAP 30°

Wind	Temp°	Max Weight (000kg)	Landing Distance(ft.)	Actual (ft.)
-10	+25	63.9	7448	3885
0	+25	66.4	6693	3492
+10	+25	66.4	6370	3323

FLAP 40°

Wind	Temp°	Max Weight (000kg)	Landing Distance(ft.)	Actual (ft.)
-10	+25	66.4	7255	3785
0	+25	66.4	6267	3269
+10	+25	66.4	5953	3105

Normal Configuration Landing Distances tables for flaps 30° and flaps 40° are also provided in the QRH to help determine the actual landing distance performance of the aircraft for different surface conditions and brake configurations. Braking may be achieved by manual braking configuration or by selection of auto-brake settings of "MAX, 3, 2, or 1". Selection of any auto-brake setting results in a constant rate of deceleration. "MAX" is used when minimum stopping distance is required or when the runway is contaminated and/or braking action is reported as "poor".

"Auto-brake 3"should be used for wet or slippery runways, when landing distance beyond glide slope is less than 8000ft or braking action is reported as less than "good" or with a tailwind of 5 or more knots. However maximum effort at manual braking should achieve shorter landing distance than the max auto-brake setting.

Flight crew/airline experience with aircraft characteristics relative to the various runway conditions routinely encountered, provide initial guidance as to the desirable level of deceleration selected.

1.17.3.2. Factors Affecting Landing Distance

Advisory information for normal[7] and non-normal configuration landing distances is contained in the PI section of the QRH. Actual stopping distances for a maximum effort stop are 52% of the dry runway field length

[7]Normal operation means that all engines and aircraft systems are functioning; the equipment for the aid to be used is serviceable, both in the aircraft and on the ground, and the weather conditions at the time of landing will permit the DA and RVR specified for landing.

requirement. Factors that affect stopping distance include; height and speed over the threshold, glide-slope angle, landing flare, lowering the nose to the runway, use of reverse thrust, speed-brakes, wheel brakes and surface conditions of the runway.

It is noted that reverse thrust and speed-brake drag are most effective during the high speed portion of the landing. It is advisable to deploy the speed-brake lever and activate reverse thrust with as little time delay as possible. Speed-brakes fully deployed, in conjunction with maximum reverse thrust and maximum manual anti-skid braking provides the minimum stopping distance.

Floating above the runway before touchdown must be avoided because it uses a large portion of the available runway. The aircraft should be landed as near the normal touchdown point as possible. Deceleration rate on the runway is approximately three times greater than in the air.

Height of the aircraft over the runway threshold also has a significant effect on total landing distance. For example, on a 3° glide path, passing over the runway threshold at 100 feet altitude rather than 50feet could increase the total landing distance by approximately 950feet. This is due to the length of runway used up before the aircraft actually touches down.

Glide path angle also affects total landing distance. As the approach path becomes flatter, even while maintaining proper height over the end of the runway, total landing distance is increased.

1.17.3.3. Landing Roll

The Boeing Operations Manual gives the following advice for landing:

1. Avoid touching down with thrust above idle, since this may establish an aircraft nose up pitch tendency and increases landing roll.
2. After main gear touchdown, initiate the landing roll procedure. If the speed-brakes do not extend automatically move the speed-brake lever to the UP position without delay.
3. Fly the nose wheel onto the runway smoothly by relaxing aft control column pressure. Control column movement forward of neutral should not be required.
4. Do not attempt to hold the nose wheel off the runway. Holding the nose up after touchdown for aerodynamic braking is not an effective braking technique.
5. Use an appropriate auto brake setting or manually apply wheel brakes smoothly with steadily increasing pedal pressure as required for runway condition and runway length available.
6. Maintain deceleration rate with constant or increasing brake pressure as required until stopped or desired taxi speed is reached.

1.17.3.4. Speed-brakes

The speed-brake system is controlled with the SPEEDBRAKE lever, which is moved UP and DOWN. The system consists of individual spoiler panels which the pilot can extend and retract by moving the SPEEDBRAKE lever. The speed-brakes can be fully raised after touchdown while the nose wheel is lowered to the runway, with no adverse pitch effects. The speed-brakes spoil the lift from the wings, which increases the aircraft weight on the main landing gear, providing improved brake effectiveness. Unless speed-brakes are raised after touchdown, braking effectiveness may be reduced initially as much as 60%, since very little weight is on the wheels and brake application may cause rapid anti-skid modulation.

Normally, speed-brakes are armed to extend automatically. Both pilots should monitor speed-brake extension after touchdown. In the event auto extension fails, the speed-brake should be manually extended immediately. Pilot awareness of the position of the speed-brake lever during the landing phase is important in the prevention of over-run. The position of the speed-brakes should be announced during the landing phase by the PM. This improves the crew's situational awareness of the position of the spoilers during landing and builds good habit patterns which can prevent failure to observe a malfunctioned or disarmed spoiler system.

1.17.3.5. Directional Control and Braking during Landing Roll

If the nose wheels are not promptly lowered to the runway, braking and steering capability are significantly degraded and no drag benefit is gained. The landing roll procedure must be performed immediately after touchdown. Any delay markedly increases the stopping distance. Stopping distance varies with wind conditions and any deviation from recommended approach speeds.

1.17.4. Aerodrome Operating Minima (AOM)

CAL has established AOM for each aerodrome to which it plans to operate, to provide guidance as to the weather conditions in which aircraft may take off or land. All flights are subject to AOM. This is usually expressed as a minimum decision altitude or height and minimum visibility or Runway Visual Range (RVR). For approach and landing, these are the minimum altitudes or heights by which the specified visual reference must be available and at which the decision to continue for a landing, or to execute a missed approach must be made. There is also an indication of the minimum visibility in which the pilot may be considered to have the visual information necessary for continued control of the flight path of the aeroplane during the visual phase of the approach and landing.

Some states also publish a minimum cloud ceiling which is a requirement as well as minimum visibility. The published specific AOM is not an order, as the captain is authorized to exercise discretion and apply minima higher than those prescribed, if in his opinion it is necessary to do so in order to secure the safety of the aircraft. The Captain’s decision in such matters is final.

1.17.5. Visual Illusions Awareness

The CAL Operations Manual provides detailed information on visual illusions, listing causes and effects of these and the defenses that can be developed to lessen the effects.

Causes include;

i) the airport environment, including the 'black hole effect' along the final approach flight path;

ii) the runway environment, such as terrain drop off at the approach end of the runway and;

iii) The weather conditions, such as ceiling and visibility.

The manual states that visual illusions may modify the pilot's perception of his position relative to the runway threshold and also affects flight crews' situational awareness particularly during final approach. Visual illusions also affect the decision process and perception.

The manual gives guidelines that flight crews should follow in order to lessen the possible effects of visual illusions. It recommends that Company accident prevention strategies and personal lines of defense should be developed and implemented based on hazard assessment, type of approach, terrain awareness, flight path monitoring and most importantly crew resource management, which should ensure continuous monitoring of both visual and instrument references throughout the transition to the visual segment of an instrument approach.

1.17.6. Crew Resource Management

The CAL Operations Manual emphasizes the role of the PNF to monitor instrument references and flight progress as an effective cross check and back up for the PF.

The Boeing FCOM Vol. 3 states as follows:

“Crew resource management is the application of team management concepts and the effective use of all available resources to operate a flight safely. In addition to the aircrew, it includes all other groups routinely working with the aircrew who are involved in decisions required to operate a flight. These groups include, but are not limited to, aircraft dispatchers, flight attendants, maintenance personnel, and air traffic controllers.

Throughout this manual, techniques that help to build good CRM habit patterns on the flight deck are discussed. For example, situational awareness and communications are stressed. Situational awareness or the ability to accurately perceive what is going on in the flight deck and outside the aircraft, requires on-going questioning, crosschecking, communication, and refinement of perception.

It is important that all flight deck crewmembers identify and communicate any situation that appears unsafe or out of the ordinary. Experience has proven that the most effective way to maintain safety of flight and resolve these situations is to combine the skills and experience of all crewmembers in the decision making process to determine the safest course of action.” The FCOM further states that one of the basic fundamentals of CRM is that each crew member must be able to supplement the other crew member. Review of the training records for both the Captain and First Officer shows that they were both subjected to company CRM training. The Captain’s latest training was done on May 20, 2011. The latest training for the First Officer was done on January 7, 2011.

During the interview with a Check Airman/Instructor, he stated that CRM training was well established at CAL and traditionally there have been no problems with CRM issues in the company. In concurring, the Fleet Manager stated that as far as he was aware the Captain always exhibited good CRM, and having flown with the First Officer recently, he felt that he would have been assertive enough to speak up as he had demonstrated good leadership qualities.

The CAL Operations Manual states that the following CRM principles should be observed:

1. **Captain's Authority**

First Officers must know the duties and responsibilities of the captain in the event the captain becomes incapacitated.

2. **Training and Development of Crew Members**

Example: A senior pilot offers suggestions and encouragement to less experienced pilots. A very experienced first officer helps a new-to-type captain entering a complicated arrival in the FMC.

3. **Positive Interpersonal and Group Climate**

The Captain should promote open communication. The tone in the cockpit is relaxed and supportive, crew members do not interrupt each other, and they exhibit patience and answer questions directly.

4. **Communications**

Inquiry, Advocacy, Conflict Resolution and Critique. Communications is the most basic CRM element and is critical to safe aircraft operations.

5. **Problem Solving Process**

The crew recognizes a problem, gathers information, defines the problem, formulates solutions, applies the best solution; evaluate the results, if the solutions fails restart the process.

6. **Decision Making**

This is the determination to act or not to act in response to an input or event. Decision making occurs after all relevant information has been gathered and any differences or disagreements resolved, resulting in a clear plan of attack and briefing from all crew members.

7. **Workload Management**

The ability to effectively prioritize and sequence tasks required for safe flight while avoiding work overload.

8. **Situational Awareness**

Crew must always know where the airplane is and where it will be (thinking ahead of the airplane).They must be alert to factors effecting the flight and to factors that might have an effect later and must be fully informed of all available cockpit resources.

- **Resource Management**

The flight crew's use of resources available outside the cockpit.

1.17.7. Threat and Error Management

Since its development, TEM[8] has become an organizational safety management tool used in training, incident reporting, and accident and

[8] Extract from **Defensive Flying for Pilots: An Introduction to Threat and Error Management -** Ashleigh Merritt, Ph.D. & James Klinect, Ph.D. The University of Texas Human Factors Research Project. The LOSA Collaborative – December 12, 2006

incident analysis. The TEM framework focuses simultaneously on the operating environment and the humans working in that environment. The framework captures performance in its "natural" or normal operating context, thus the resulting description is realistic, dynamic, and holistic. Because the TEM taxonomy can also quantify the specifics of the environment and the effectiveness of performance in that environment, the results are also highly diagnostic.

TEM is considered to be defensive flying for pilots. It promotes a proactive philosophy and provides techniques for maximizing safety margins despite the complexity of one's flying environment. TEM proposes that threats are everyday events that flight crews must manage to maintain safety. Maintaining adequate safety margins is the overarching objective of TEM, that is, to provide the best possible support for flight crews in managing threats, errors, and undesired aircraft states[9].

The origin of TEM is inextricably tied to the origin of Line Operations Safety Audits (LOSA). LOSA is a voluntary safety program in which data on the various threats encountered and errors committed by flight crew is collected and evaluated. Evaluation is also done of how flight crews manage these situations to maintain safety. Specially trained LOSA observers also collect data on CRM performance and conduct structured interviews that ask pilots for their suggestions to improve safety. These combined LOSA

[9]Undesired Aircraft State (UAS): A flight-crew-induced aircraft state that clearly reduces safety margins; a safety compromising situation that results from ineffective error management

data sources provide airlines with a diagnostic snapshot of the safety strengths and weaknesses in normal flight operations. LOSA is recognized as a FAA Voluntary Safety Program and is considered by several other aviation organizations, including ICAO and IATA, as an industry best practice for normal flight operations monitoring.

In TEM, threats are defined as the events or errors that are not caused by the crew but which increase the complexity of a flight as they add to the crew's workload and require crew attention and management if safety margins are to be maintained. On the other hand an error is defined as a crew action or inaction that leads to a deviation from crew or organizational intentions or expectations. Put simply, threats come "at" the crew, while errors come "from" the crew. These errors lead to a deviation from crew or organizational intentions or expectations; reduce safety margins; and increase the probability of adverse operational events on the ground or during flight. Flight crew errors can be the result of a momentary slip or lapse, or induced by an expected or unexpected threat.

Flight crew errors can be divided into three types: *aircraft handling, procedural* and *communication* errors. Aircraft handling errors are those deviations associated with the direction, speed and configuration of the aircraft. They can involve automation errors, such as dialing an incorrect altitude, or hand-flying errors, such as getting too fast and high during an approach. Procedural errors are flight crew deviations from regulations, flight manual requirements or airline standard operating procedures. Lastly, communication errors involve miscommunication between the pilots, or between the crew and external agents such as ATC controllers, flight attendants, and ground personnel.

Error management is now recognized as an inevitable part of learning, adaptation, and skill maintenance; hence, a primary driving force behind TEM is to understand what types of errors are made under what circumstances (i.e., the presence or absence of which threats) and how crews respond in those situations. The heart of error management is detecting and correcting errors. For example, do crews detect and recover the error quickly, do they acknowledge the error but do nothing, perhaps because they believe it is inconsequential or will be trapped later, or do they only “see” the error when it escalates to a more serious undesired aircraft state? An important point to note is the importance of effective error management. An error that is not detected cannot be managed. An error that is detected and effectively managed has no adverse impact on the flight. Unfortunately not all errors are properly managed and a mismanaged error reduces safety margins by linking to or inducing additional error or an undesired aircraft state.

TEM training is now an ICAO standard and is therefore mandatory for airline flight crews engaged in international operations. It must now be delivered during initial as well as during recurrent training. ICAO has also introduced standards making TEM training mandatory for licensing and training requirements of private and commercial pilots and air traffic controllers. In order to support these standards, ICAO is continually developing guidance material on TEM which reflects and is aligned with the concepts discussed in the referenced paper (*Human Factors Training Manual*, *Procedures for Air Navigation Services, Training, PANS/TRG*, and *An introduction to TEM in ATC).*

The CAL Operations Manual contains guidance on TEM and is mentioned as part of CRM training in the CAL Training Pilot Manual.

1.17.8. Fatigue

"Crewmember fatigue can be defined as: A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties."

The traditional regulatory approach to managing crewmember fatigue has been to prescribe limits on maximum daily, monthly, and yearly flight and duty hours, and require minimum breaks within and between duty periods. This approach reflects early understanding that long unbroken periods of work could produce fatigue (now known as 'time-on-task' fatigue), and that sufficient time is needed to recover from work demands and to attend to non-work aspects of life. It is agreed that Flight and Duty time Limitations represent a simplistic view of safety as it does not take account of operational differences or differences among flight crew.

Scientific evidence now implicates other causes of fatigue, other than time on task, particularly in 24/7 operations. It is now recognized that adequate sleep and not just rest is vital if an individual is going to be able to function effectively while awake. The importance of adequate sleep is considered to be particularly relevant in the aviation industry with its unique combination of 24/7 operations and trans-meridian flight. Research has shown that lack of sleep can affect performance, the ability to assess and process information and the reaction time to information. It has also been shown that even increased effort will not bring about better performance.

It has also been found that subjectively, an individual may not be aware that he is fatigued and will typically report that he is not, when in fact he suffers from physiological fatigue due to lack of sleep, time awake and disruption to his circadian rhythm. The masking of his physiological fatigue may be due to external stimuli such as caffeine or physical activity or interesting conversation.

Fatigue is now recognized as a major human factors hazard due to its adverse effects on most aspects of a crewmember's on the job performance. In tandem with fatigue research, understanding of human error and its role in accident causation has also increased.

As a result ICAO has introduced Fatigue Risk Management Systems (FRMS) as a Standard in Annex 6. "The FRMS approach applies new knowledge from fatigue and safety science with the intention of providing an equivalent or enhanced level of safety and allows greater operational flexibility by using multi-layered defensive strategies to manage fatigue related risks. FRMS is both complex and costly and operators may choose not to implement, or only partly implement FRMS. However where an FRMS is not implemented, it remains the operator's responsibility to manage fatigue-related risks through their existing safety management processes.[10]

The CAL Operations Manual details the flight and duty time limitations developed by the company. The requirements of the system are programmed into a computerized system which will not allow the limits to be breached. It can generate rest and duty records for the past 7, 30, 100 and 365 days for all crew members. In keeping with this system CAL had provided adequate rest time for the flight crew, and the Operations Manual states that the onus of ensuring adequate rest while off duty is the responsibility of the crew. This two pronged approach to ensuring adequate rest is also enshrined in FRMS, but FRMS has the additional advantage of incorporating the building blocks of SMS which requires shared responsibility between the individual pilot and the operator.

Prior to the accident flight, the Captain was off duty for twenty-four hours. He stated that on the day prior to the flight, he slept from 21:30hrs LST to 05:00hrs LST. On the day of the flight, he reported that he had attended an all-day union meeting and rested for 2½ hours prior to preparing for the flight. He considered his rest to be adequate as he usually retired late.

[10] Entire section taken from Fatigue Risk Management Systems Implementation Guide for Operators 1st Ed. July 2011. IATA, ICAO, IFALPA

The First Officer stated that he was off duty for eleven hours, having been relieved from reserve duty at 12:00hrs during the day, prior to the flight. The First Officer indicated that he considered himself to be well rested.

Records indicate that the flight and duty times for both flight crew members were within acceptable limits.

It was also noted that there was yawning, sighs and susurration recorded on the CVR.

It has been noted that fatigue risk management has not been mentioned as part of the CAL training programme.

1.17.9. CAL Operations Manual (Boeing 737) - Part D - Training

The Chief Pilot is responsible for maintaining training records and determining syllabi contents and timescales for all training courses. He ensures that ground and flight training are available and ensures the adequacy of the training and checking staff.

The Fleet Manager, who reports to the Chief Pilot, is responsible for ensuring that company training requirements are met. He advises on training needs and prepares the training plan. During an interview, he stated that CAL training for the B737 is "very standard Boeing curricula and SOPs and they hardly vary from it at all". Training includes touch and go landings, go-around and missed approach, landing geometry, flare and touchdown and landing roll.

During an interview with a contract check airman/instructor for CAL he stated that CAL does train go-around procedures from inside minima (baulked landings) and pilots are taught to conduct stabilized approaches. Touch and go training is done during base training (landing of aircraft) and go around after touchdown. He indicated that no specialized training is done for SYCJ as it is similar to and typical of many island approaches over water, but pilots are made familiar with the requirements during line training. The Fleet Manager concurred with statements made by the check airman/instructor.

The procedures outlined by the Fleet Manager and the Check Airman are reflected in the Training Manual.

1.18. OTHER INFORMATION

1.18.1. The Authority

The certifying Authority for Caribbean Airlines is the Trinidad and Tobago Civil Aviation Authority. The Authority is staffed and equipped to carry out the certification and oversight responsibilities that are required for Caribbean Airlines Limited Operations.

The State of Trinidad and Tobago achieved FAA Cat 1 status during December 2005.

1.18.2. Air Traffic Control Officer

The Air Traffic Control Officer is a female aged twenty-five years, with five years' experience. She was trained locally and is qualified to work Aerodrome, Approach and Flight Information Services. She is current in all facilities. Her last medical examination for renewal of her ATCO License # 60 was done on July 1, 2010 and remains valid until June 30, 2012. The Controller has no limitations on her license.

1.18.3 Weights Removed from Aircraft

Total fuel removed from aircraft-	840US gallons.
Weight of fuel	- 5,628lbs
Weight of baggage - Economy cabin	- 1,405lbs (637.3kg)
Weight of baggage - Fwd. cargo hold	- 5,519.62lbs (2503.7kg)
Weight of baggage - Aft. cargo hold	- 8,471.78lbs (3842.0kg)
TOTAL Baggage weight	- 15,362.6lbs (6983.0kg)

It should be noted that an unknown amount of carry-on bags were removed by passengers and therefore were not accounted for in the weighing.

Baggage was weighed using a Salter Brecknell electronic platform scale; S/N – 7C190071003015; Model #200E. The scale was calibrated on May 12, 2011 by the Guyana National Bureau of Standards. The calibration was done in accordance with the requirements of International Recommendation R76 and was found to be accurate within the limits of maximum permissible error.

All baggage and cargo removed from the aircraft were weighed under IIC supervision and handed over to CAL to be returned to owners.

2.0 ANALYSIS

2.1. THE AIRCRAFT

2.1.1. General

Review of the aircraft records reveal that the aircraft and the related systems designed to decelerate the aircraft on landing, were all serviceable and airworthy.

The HF radio and the Electronic Flight Bag (EFB), which were recorded in the aircraft technical logbook as unserviceable, but were not necessary for this flight, were deferred in accordance with the MEL. The investigation revealed that the aircraft had no mechanical defects that could have contributed to the accident.

2.2 FLIGHT CREW

2.2.1. General

The captain and first officer were certified in accordance with the Trinidad and Tobago Civil Aviation Authority Regulations. There was no evidence of any pre-existing medical or behavioral conditions which might have adversely affected the flight crew's performance during the accident flight.

Crew scheduling and control falls under the purview of the Fleet Manager. This was the first flight on which the flight crew was rostered together. They were both qualified for the flight having met the company requirements.

Both pilots were familiar with operations into SYCJ as they had done several flights previously into the SYCJ with other crews.

2.2. 2. Flight Crew Fatigue

During a post-accident interview, The Pilot in Command stated that he had rested for 2.5hrs between 05:00hrs and 22:00hrs prior to the accident flight. He said that he considered himself to be well rested.

The First Officer, in his initial interview stated that he was on reserve call from 5:00hrs until 12:00hrs on the day of the flight. He was notified of the flight at 8:00hrs on the same day. He considered himself to be fully rested for the flight.

Although the captain considered himself to be well rested, research shows that it is possible for fatigued individuals to be unaware of their true state and their fatigue may be masked by external stimuli. The TTCAA regulations contains prohibitions preventing flight crew from flying and airline operators from using crew who may be suffering from fatigue. CAL also has policies for fatigue and sickness and these are included in the pilot association contract agreement with CAL.

2.2.3. Crew Experience and Training

2.2.3.1. The Captain

Flight test records for the Captain for May 2010 indicated that he had achieved an acceptable standard of operation[11] during a scheduled flight test. Remarks indicated that there were many 'non-conformities' with SOPs regarding procedures while operating as PF. Areas of weaknesses identified were "Conformity to SOPs and CRM".

Records of a subsequent Flight Test done in July 2010 indicated that the Captain had exceeded all standards of normal operation, with very good R/C, excellent CRM, management and handling. The latest flight test done in May 2011 indicated that the Captain had achieved a "Good" rating with good manual flying and CRM.

The CAL Chief Pilot when interviewed explained that an acceptable rating is satisfactory and meant that the examinee has met the standard. However, another acceptable rating would mean that the examinee could not function as commander and remedial training would be required. The accident captain did not obtain such a second 'acceptable' rating.

The accident captain said that CAL did not have a SOP to check charts for wet runways and expressed uncertainty as to whether there was any

[11] CAL Flight Test Report Form has ratings of "Exceeds", "Good" and "Acceptable". The explanatory notes states "There are possible operational implications with an assessment other that Good and the Chief Pilot must be notified ASAP".

guidance for landing on wet runways and therefore was not sure what was the recommended flap setting for wet runway landings. When asked, the Captain stated that he was never trained to go-around after touch-down.

However, the Boeing FCOM Vol. 1, adopted by CAL, provides information for landing on wet runways with flaps 40º which will minimize landing distance required. Landing distances and adjustments are provided for dry runways and runways with good, medium and poor reported braking action. The performance level associated with "good" is representative of a wet runway

The CAL Operations Manual states that automatic go-around is available throughout the approach and can be engaged by pushing either go-around switch. Go-around mode will remain engaged even if the aircraft touches the runway during the go-around manoeuvre. The FCOM Vol. 3 has detailed procedures for touch and go landings, but it states that "the primary objective of touch and go landings is for approach and landing practice. It is not intended for landing roll and takeoff procedure training." There is also a warning that states "after reverse thrust is initiated, a full stop landing must be made."[12] This is also reinforced in the Caribbean Airlines Operations Manual[13]

[12] FCOM VOL 3 – 1:5;1-1 Pg.68

[13] Caribbean Airlines Operations Manual Part A General Pg. – 8.13-13

Two other captains, employed with CAL, when interviewed by the investigation team, said that there is existing guidance for wet runway landings and indicated that it was company policy to use flaps 40° for landings at airports with useable length less than 8000ft. It was also said that during training every six months they do a number of missed approaches and training go-arounds from landing and flare. A contract check airman/instructor for CAL when interviewed also confirmed that CAL conducts training in go-around procedures from inside minima (baulked landings) and pilots are taught to conduct stabilized approaches. Touch and go training is done during base training (landing of aircraft) and go around after touchdown training is also carried out. He also stated that go-arounds that occur on line are not investigated by the company.

The fact that the accident Captain could not recollect the existence of the wet runway procedures or receiving any training in a go round after touchdown invites some concern as to whether there may have been deficiencies in his recurrent training in these particular areas.

In relation to SYCJ itself, the captain stated that he was very familiar with the approaches to SYCJ and on the accident flight he had set up the RNAV-GPS Approach early and there were no concerns about this approach. He said however, that he was thinking about the weather and conditions of wet and dry and did not want to float due to the length of the runway. He also stated that he knew that the runway is well grooved thus was not worried about standing water.

2.2. 3.2 The First Officer

The First Officer received his initial conversion ground school training on the B737 during January 2011. These sessions were satisfactorily completed. During January and February 2011 he received initial conversion flight simulator training. This included pre-flight preparation and dispatch procedures, route and area operations, operational policies, flight conduct procedures and 120 minutes diversion – maintenance procedures. From records provided, every session was satisfactorily completed. In several simulator sessions, among the objectives listed were, "Integrate selected normal and non-normal procedures" and "Apply Crew Resource Management attributes while practicing selected normal and non-normal procedures".

In the CAL Pilot Training Manual it was noted that the Synthetic Training Device conversion syllabus provides a progressive sequence of training that is appropriate for the average pilot. It provides approximately ten details (sessions) for up to forty hours of training for two pilots in accordance with the syllabus determined by the Chief Pilot. The aims of this training are intended to achieve a high standard of overall pilot performance by:

a) Providing environmental training in instrument flying and normal, abnormal and emergency in-flight procedures so that the pilot will react without error or loss of control to any given situation;
b) Instilling pilot confidence in his own ability and in the integrity of the aeroplane and its systems;
c) Providing realistic and complete practice of abnormal drills.

It is noted that the same types of training and practice are provided for both First Officers and Commanders.

Initial conversion emergency equipment drills and drill performance evaluation were done during March 2011. Emergency drills included door operation and window exit, which were satisfactorily completed. From records provided it could not be determined if specific training was provided for emergency exit from the cockpit using the blowout panels.

His first line flight was on 1st March, 2011. And he was recommended for his line check on 16th March 2011.

2.2.3.3. The Cabin Crew

The four cabin crew were all signed off as having completed the required training in accordance with the Crew Training Policy and Procedures Manual. Statements were received showing that all four cabin crew completed training in the 'slide drill', 'door exit operation – normal', 'door exit operation – emergency', 'window exit' and 'wing evacuation drill'. Two of these cabin crew did their initial training for the window exit and wing evacuation in 1999 and 2000 respectively. They subsequently did refresher training for the window exit and wing drill training, however the date of the refresher training has not been provided.

2.3 CREW RESOURCE MANAGEMENT

Flight crew training records indicate that both the Captain and First Officer received initial and recurrent CRM training in keeping with company policy. Assessment of CRM is a standard part of routine flight checks done with flight crew. The CVR data indicates that during the flight there was initially good coordination between the flight crew. The Captain carried out his functions professionally. The required briefings were done; including briefing for the weather, the approach procedure for a RNAV-GPS approach and procedures for the possibility of a missed approach. These briefings were conducted in the early stages of the flight, in keeping with company requirements. The landing phase checks were also completed in a timely manner in accordance with recommended practices. The conversation was quite cordial.

It was noted from the CVR that after passing 11,000ft at 05:19:15.1 there was a considerable amount of light chatter in the cockpit, most of it unrelated to flying the aircraft[14]. The F-COM VOL. 3 states that casual conversation reduces crew efficiency and alertness and should be avoided below 10.000ft[15]. Further, during the landing phase, the recordings suggest that there was a temporary loss of situational awareness as it seems that neither of the flight crew was aware of the aircraft's location in relation to the remaining runway. There is also some doubt as to whether the flight crew was certain that the aircraft had actually floated down the runway,

[14] Appendix – 2 CVR Report

[15] Boeing 737-800 F-COM VOL. 3 CHAP. 1:1:1-1 Pg. 14

which might have been as a result of the high power setting of 59%N1 carried by the captain.

During his interview, the First Officer indicated that he was aware that the aircraft was floating, and he recalled that the Captain had voiced concerns about this. But there is no indication from the CVR that the First officer initiated any action that would have helped to alleviate the accident results. As explained in the F-COM, phase of flight duties are divided between the Pilot Flying (PF) and the Pilot Monitoring (PM).[16] The FO was the PM and was required to make callouts based on instrument indications or observations of appropriate conditions. He is also expected to make callouts of significant deviations from command airspeed. Additionally the Caribbean Airlines Operations Manual Part A – General requires the Co-Pilot to volunteer advice, information and assistance to the Captain that will contribute to the safe conduct of the flight; and to maintain adequate look out during arrival.[17] Thus there was no concerted attempt or decision to take effective action to compensate for the occurrence by either flight crew.

The CVR indicated that three seconds before touchdown the Captain called that he was going around and at the same time he advanced the throttles. The First Officer acknowledged the go around call, but that decision was not carried through. The Caribbean Airlines Operations Manual Part A-General states that once a decision to "Go-Around" has been made, it must

[16]Boeing 737-800 F-COM Vol. 3 Chap.1:1;1-1 Pg. 1

[17] Caribbean Airlines Operations Manual Part A – General Section 1 Pg. Part A- 1-16 & 1-17

never be revoked. The aircraft touched down approximately 4700ft down the runway, which is 3700ft from the beginning of the touchdown zone. Thus the need for a go around was recognized but the same was not executed. The fact that the aircraft touched down three seconds after the pilot made the call suggests that there was a serious lack of situational awareness on the part of the flight crew. The lack of coordination and the absence of joint control and effective decision making further served to exacerbate the situation.

The deployment of the thrust reversers three seconds after touch down in any event would have negated the aircraft's ability to execute a go around after touch down. The performance study of the FDR indicated that the aircraft thrust reversers were deployed approximately three seconds after touchdown and at approximately 2000ft from the end of the runway. Boeing guidance states that a go-around should never be attempted after reverse thrust has been deployed.[18]

CRM is a management system that makes the best use of available resources, equipment, procedures and personnel to promote safer and more efficient aircraft operations. While it recognizes technical knowledge and skill it is more concerned with the cognitive and interpersonal skills and attitudes including communications, situational awareness, problem solving, decision making and team work that are all needed to manage a

[18] F-COM VOL 3 – 1:5;1-1 Pg.68

[18] Caribbean Airlines Operations Manual Part A General Pg. – 8.13-13

flight safely and efficiently. The F-COM states that CRM "is the application of team management concepts and the effective use of all available resources to operate a flight safely." It further states "that situational awareness, the ability to accurately perceive what is happening on the flight deck and outside the airplane, requires ongoing questioning, cross checking, communication and refinement of perception."[19]

2.4 AIRPORT/RUNWAY 06

RWY06 at Cheddi Jagan International Airport meets the ICAO specified criteria for safe aircraft operations. The runway does not have any potholes or other physical deficiencies. Although the runway surface was wet at the time of the accident, the lateral grooves along its entire length allows for enhanced drainage so there was no standing water on the runway. The grooves also served their primary purpose of providing increased frictional forces between the aircraft's tires and the runway surface. Analysis of the friction test data shows that there was no noticeable friction loss along the runway or in the turn area of the high speed exit off the runway.

The runway is 7448ft. long and there is no Runway End Safety Area, but beyond both ends of the runway there is an additional 200ft of usable paved surface. The RESA is a Standard required by ICAO Annex 14. The availability of RESA at the end of RWY06 may have reduced the severity of the accident.

[19] F-COM VOL. 3 Chap. 1 :1:.1-1 Pg. 2

The runway is not equipped with approach lights, or center line lighting, or Runway End Identifier Lights but nothing from the crew interviews indicated that there was a difficulty with runway lighting or locating the runway. However the lack of the approach lights and center line lighting for RWY06 together with the general environment (location) of the airport which requires transition from dark jungle terrain to the airport lights does lend to the possibility of the black hole illusion, which may have caused some confusion for the flight crew. This along with the slope of the runway and the fact that the runway was wet and would have been reflecting light, thereby affecting depth perception by appearing to be farther away, could have contributed to the flight crew suffering from possible visual illusion.

RWY06 at SYCJ is a Category 1 – precision approach runway. ICAO Annex 14 requires Approach lighting for a Category 1 runway, where physically practicable. The Annex recommends that runway center line lighting should be provided on a Category 1 – precision approach runway particularly when it is used by aircraft with high landing speeds or where the distance between the runway edge lights is greater than 50m. Thus while center line lighting is not mandatory, it has been determined that the presence of center line lighting, configured in accordance with the characteristics developed by ICAO, would be advantageous to aircraft operating there, as it would present a straight-ahead view of runway lighting to flight crew.

It has been noted that Aerodrome Chart – ICAO Cheddi Jagan Int'l/TIMEHRI (SYCJ) in the Guyana AIP, page SYCJ AD 2-8 indicates that there are white Runway End Identifier Lights, however, these were not functioning at the time of the accident. REIL is not an ICAO requirement, however its presence may have assisted with the flight crew's awareness of the aircraft position in relation to threshold of the runway.

The runway is equipped with PAPIs. The beam projection of the PAPIs was 2.39º and was not coincident with the approach slope of the RNAV–GPS RWY06 approach, which is 3°. This slope has since been adjusted to coincide with the RNAV-GPS approach (February 2012).

The shallow approach slope could have exacerbated the previously mentioned visual illusion presented by the lack of approach lighting and the wet runway. This may have accounted for the excessive power inputs by the Captain, which contributed to the aircraft floating down the runway.

The runway is equipped with red runway end lights, green threshold lights and white edge lights. The lighting and marking of the runway meets ICAO standards. At the time of the accident there were no distance-to-go markings on the runway. While these are not required by ICAO, management of the airport has since erected distance-to-go signboards at one thousand feet intervals, beginning from 4000ft, along runway 06/24.

It is noted that CAL has established special categories of airports. SYCJ is not in a special category as it is considered similar to and typical of many island approaches over water.

2.5 METEOROLOGICAL INFORMATION

Meteorological information was collected from both local and international weather stations. The weather at the time was not unusual for the time of day or season. Thunderstorm activity ended approximately one hour before the accident. From 04:57UTC, thirty-five minutes before the accident, until 05:43UTC, rainfall was recorded with total precipitation of 1.8mm. The aircraft FDR showed only one significant deviation, during approach, attributed to weather. There were no significant winds at the station; however readings from the FDR indicated that there was an abrupt 180° directional change while the aircraft was on short final. However, at the time of the shift in wind direction, the wind magnitude was less than 5kts and had minimal effect on the aircraft.

2.6 AIDS TO NAVIGATION

The only ground-based aid to navigation at the SYCJ was a VOR which was functioning normally. The VOR approach procedure was last flight tested on February 2, 2011. The Flight Check organization, ASECNA, certified that the VOR was operating within ICAO established limitations. Neither DME nor ILS was available.

The Cheddi Jagan Int'l Runway 06 is served by an RNAV-GPS Approach designed by SATNAV and commissioned for use by the Guyana Civil Aviation Authority on 31 July, 2008. The chart is published in the Guyana AIP 4th Edition, 2006 and is in the Jeppesen Data Base. In the notes on the chart it is stated that the RNAV-GPS final approach slope (3.00º) is not coincident with the ILS Glide slope and PAPIs (2.39º). Both slopes were published and the pilots were aware of these differences.

The aircraft was cleared for the RNAV-GPS approach. The pilot stated that he knew that the VOR Approach was an option but he had become accustomed to using the RNAV-GPS Approach at SYCJ.

2.7. AIR TRAFFIC SERVICES

The Aerodrome Controller was properly trained and qualified to work in the Control Tower. She was scheduled to work sixteen hours instead of the normal eight hours shift. The accident occurred one and a half hours into her second eight hour period. Assessment of both the CVR and ATC transcripts indicate that she was alert while in control of the aircraft as she responded promptly to requests. Air Traffic Control was not considered to be a factor in this accident.

2.8. COMMUNICATIONS

From the CVR, communications in the aircraft during the flight and between the aircraft and Air Traffic Services were effective. It was noted that there was some difficulty in contacting the company ground station while en route. This may have been due to the ground staff not manning the radio at the time of the first contact.

2.9. FDR ANALYSIS

The analysis of the FDR shows that while on short final the aircraft was sinking below the desired glide-path and the crew increased power. The airplane regained the glide-path, but the pilot did not reduce power as the airplane entered the flare. The excess power resulted in the aeroplane floating beyond the intended touchdown point. Power was not reduced until the airplane was approximately 4000ft down the runway, about 6 seconds before touchdown. 3 seconds later the pilot called a go-around and advanced power, which contributed slightly to the float. However 3 seconds later the wheels touched down.

BW523 had approximately 2900ft of pavement to stop on when it touched down, 4700ft down the runway. Boeing's landing distance estimates using a calculated aircraft braking coefficient as a function of groundspeed indicate that it was possible to stop the aircraft on the runway using either Detent 2 or maximum reverse thrust. However the ground spoilers were armed and as a result deployed at about the time of touchdown at 05:32:12 and the thrust reversers deployed (less than Détente 2 was commanded by the crew) 2 seconds later at 5:32:14 when the aeroplane was 2000ft from the end of the runway. Further the crew applied gradual brake pressure starting at touch down, maximum brake pressure of 3000psi was not achieved until the aircraft was 250ft from the end of the runway.

Because the aircraft touched down so far down the runway and the crew did not use all of the available deceleration devices, it was not stopped on the paved surface and exited the prepared surface of the runway and impacted a berm resulting in substantial damage to the airframe.

2.10. SURVIVAL ASPECTS

2.10.1. Survival General

The aircraft touched down at 05:32UTC and review of the daily log sheet shows that the Controller reported the accident, via radio, to the SYCJ Rescue Fire Service at 05:33UTC. The ARFFS responded after the third call. However the ARFFS reported that they were monitoring the flight and they realized that something was wrong even before notification from the Control Tower. The Fireman on watch stated that the landing sounded different and he immediately advised his colleagues that the aircraft had run off the runway. He sounded the alarm and dispatched three fire tenders to the accident site. This is what caused his delay in responding to the first call from the Control Tower. The Station Officer, who lives opposite the fire station, was notified and he immediately went to the scene and took control as the On-Scene-Commander. This is in keeping with the SYCJ Emergency Plan. He deployed the men and fire tenders to assist passengers and monitor the aircraft in case of fire.

After the aircraft came to a stop, the First Officer reported that the cockpit was completely dark; there was no power. All displays were black. Using his flashlight he attempted to access the audio panel but it was blocked by something that had fallen on it so he was not sure that the PA system was working. He stated that he then called out “Evacuate, evacuate, evacuate” to notify the cabin crew to evacuate the aircraft. It is commendable that the FO was able to immediately initiate the emergency evacuation procedure.

The sudden and unexpected nature of the accident did not allow the flight crew to use the intercom system to give any warning prior to the accident. Thus the cabin crew were also caught by surprise; in the circumstances their response was generally commendable. However the difficulty in opening the two rear doors, as reported by some cabin crew, is cause for concern. Although the fuselage was tilted they should have been able to successfully operate the L2 door/slide as the door operated normally and locked into position when checked at the accident site. It is believed that the Flight Attendants did not exert the extra effort which is required to open the door when the aircraft is in an emergency or unusual configuration and allowed it to close on to the inflating slide. This resulted in an unusable exit.

As reported by the cabin crew, it was a passenger who made the first move and opened the R1 exit which started the evacuation process. Several passengers had exited the aircraft through the over-wing exits. From reports and the disposition of the aircraft it was determined that the majority of passengers had exited the aircraft through the right side over-wing exits.

There were no fatalities. Several persons suffered minor injuries. During the evacuation, one passenger suffered a broken leg, which resulted in an amputation.

Both Captain and First Officer suffered minor injuries. They were trapped in the cockpit as all cockpit emergency exits were jammed due to damage caused by the impact. This prolonged the personnel rescue until approximately twenty-five minutes after the crash as reported by the Station Officer.

One flight attendant noted that the hand held megaphone in the cabin could not be used because the storage compartment door, to access same, could not be opened due to deformation of the closet frame.

2.10.2. Emergency Lighting

The First Officer stated that before leaving the cockpit he turned on the emergency exit lights. However examination of the wreckage after the accident revealed that the emergency exit lights were at guard up and the switch was at the off position. During interviews none of the flight attendants recall seeing any emergency lights, but two of them said that there was light in the galley area and that the cabin was dark. The ARFFS Station Officer also said that the cabin was dark and he did not see any lights inside, but he did notice lights on the outside in the over wing exit areas. Only one flight attendant noted that the exterior lighting was on.

Despite reports that the cabin was dark, it has been concluded that the emergency lights were on, but the witnesses could have perceived the cabin environment to be dark because of the time of the occurrence which was further compounded because it was a dark night with no moon visible. It must also be noted that the evacuation sign lights and body lights are all on the same circuit as the cabin emergency lights. Further in an interview with the duty engineer, who was the first staff to enter the aircraft after the crash, he reported that as part of safety measures he switched off the lights to safe guard the wreckage from explosion.

It should also be noted that there was no attempt to activate the emergency lights switch located at the aft cabin crew panel. This switch overrides the one in the cockpit when the cockpit control switch is in the armed position.

2.10.3. Emergency Exits

A passenger opened the R1 exit. He reported that it was easy to open and as soon as he opened it the slide deployed and inflated. The L1 exit could not be opened because it was jammed shut by the No.7 galley unit which had shifted out of place. The R2 exit was opened with some difficulty requiring the efforts of two flight attendants. The R2 slide deployed but then deflated rapidly. Tests carried out on the R2 slide indicates possible damage after deployment as it came into contact with barbed wire or other sharp object on the ground.

The cabin attendants reported that they experienced difficulty in opening both the R2 and L2 exits. During investigation at the scene the L2 exit operated normally and locked into the open position. This indicates that the cabin attendants may not have opened the door fully and allowed it to fall back towards the close position as the escape slide was in the initial stages of deployment. It is considered that the flight attendants did not exert enough energy to ensure that the L2 exit opened properly. This may reflect a training deficiency as flight attendants should be trained to open exits with the aeroplane in an unusual attitude, which would require extra effort on their part. This therefore meant that the passengers were denied use of an emergency exit.

The over wing emergency exits functioned properly.

The cockpit window exits were jammed in the closed position preventing the cockpit crew from exiting immediately after the crash. The cockpit door was ajar but did not facilitate egress because it was blocked by the lavatory door. The blowout panels in the door were eventually removed by the FO but the lavatory door had to be shifted before he was able to crawl out. Evidence suggests that the cockpit door and windows were jammed due to damages sustained to the front of the aircraft caused by the impact. The FO’s delayed use of the blow out panels calls into question flight crew training in the use of this emergency exit. Further review of the emergency training programme reveals that there is nothing specific with regard to this.

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3.0 CONCLUSION

The probable cause of the accident was that the aircraft touched down approximately 4700 feet beyond the runway threshold, some 2700 feet from the end of the runway, as a result of the Captain maintaining excess power during the flare, and upon touching down, failure to utilize the aircraft's full deceleration capability, resulted in the aircraft overrunning the remaining runway and fracturing the fuselage.

3.1. Contributory Factors

The Flight Crew's indecision as to the execution of a go-around, failure to execute a go-around after the aircraft floated some distance down the runway and their diminished situational awareness contributed to the accident.

3.2. Findings

3.2.1. General Findings

1. The aircraft possessed a valid Certificate of Airworthiness.
2. The flight originated in New York as BW 523, and made a transit stop in Port-of-Spain, Trinidad.
3. The flight was properly dispatched from Trinidad to Guyana, in keeping with company requirements.
4. The flight departed Piarco at 04:36UTC. The en-route and approach portions of the flight were conducted normally.
5. The cabin crew were trained and qualified for their duties on the flight.

3.2.2. Airplane Performance

1. The aircraft executed a non-precision approach to RWY06.
2. The pilots reported that the wind screen wipers functioned effectively.
3. There was no reported malfunction of any systems within the cockpit prior to the accident.
4. The pilot increased power on short final to maintain glide path and did not significantly reduce power when crossing the runway threshold.
5. Although the wind was calm the FDR recorded a 180° wind shift when the aircraft was on short final. However, at the time of the shift in wind direction, the wind magnitude was less than 5kts and had minimal effect on the aircraft.
6. The pilot reduced power briefly, then increased power slightly three seconds before touch down.
7. The excess power resulted in the aircraft touching down approximately 4700ft from the threshold of RWY 06.
8. The readings from the FDR indicate that the lifting devices functioned effectively.
9. The ground spoilers were extended on touchdown.
10. Tests carried out by Boeing indicate that the spoilers worked properly during landing.
11. The pilot applied reverse thrust between IDLE and DET 2.
12. Calculations by Boeing and NTSB indicated that the aircraft's braking systems functioned satisfactorily.

13. The crew did not command maximum brake pressure of 3000psi until the aircraft was 250ft from the end of the runway or 450ft from the end of the paved area.
14. The vehicle performance study shows that under the event conditions, the aircraft could have safely stopped on the remaining pavement had the crew applied DET 2 reverse thrust or maximum manual braking immediately after touchdown.
15. The wet surface of the runway did not inhibit good braking ability.
16. The aircraft did not stop and came to rest approximately 130 feet off the end of the runway and 64 feet left of the extended center line.
17. Had the crew touched down within the touchdown zone and applied stopping devices as they did, the aircraft could have stopped on the runway remaining.

3.2.3. Cabin Safety

1. L1 door was jammed due to impact damage
2. L2 door was not completely opened, allowing it to close onto the partially deployed slide, thereby making it unusable.
3. Evacuation at R1 was started by a passenger.
4. The R2 door was opened and the slide deployed, however it was punctured during deployment.
5. The flight crew were initially trapped in the cockpit.
6. Efforts to rescue the flight crew resulted in the evacuation not being completed until twenty-five minutes after the crash.
7. The Cabin Crew's response to the emergency could have been more effective had they used correct procedures to open the L2 exit.

3.2.4. Ops/Human Factors

1. The flight crew possessed the necessary licenses and qualifications to perform the flight.
2. The flight crew flight and duty time commenced approximately two hours before the accident occurred.
3. The off duty/rest time provided by the Company was in keeping with the requirements of its Operations Manual.
4. Although sighs and yawns were recorded on the CVR; there is insufficient evidence to determine if the effects of fatigue contributed to this accident.
5. The captain and copilot were very different in age and experience, and had not been paired together previously. However they were both familiar with operating conditions at CJIA as they had previously done several flights here with other crew.
6. The crew executed a non-precision approach to RWY06.
7. Conditions on approach and over the runway were conducive to visual illusions. These conditions include the lack of approach lights, the featureless terrain, rain on the windscreen, the shallow approach path that was engendered by the glide slope angle of the beam projection of the PAPIs, and wet and sloping runway. Notwithstanding both flight crew members' familiarity with conditions at the CJIA, they may have been affected by these visual illusions.
8. Upon reaching minimums the captain expressed doubt about the airplane's approach profile and remarked that the airplane was

slightly low on the glide-path. He then increased power to correct the glide-path.

9. The captain did not reduce power during the flare.
10. The copilot did not notice or call out the excess power during the flare.
11. From the CVR it was noted that 16 seconds after crossing the threshold, the captain made a go-around call and briefly increased power, the copilot acknowledged the call.
12. The captain then decreased power as the airplane touched down and he did not follow through with the go-around.
13. After touch down, the captain did not apply maximum available reverse thrust or braking.
14. The cabin crew did not attempt to activate the rear emergency light switch.
15. There was poor coordination (CRM) during the landing phase, a critical phase of flight, the CVR did not record any positive actions from the flight crew, towards the end of the flight.

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4. RECOMMENDATIONS

4.1. Actions by CAL

1. The need to confirm with and operate within Standard Operating Procedures must be emphasized during training.
2. Pilots must be trained to the landing techniques as detailed in the Boeing Operations Manual
3. CAL must train pilots on the appropriate use of maximum reverse thrust, spoilers and maximum manual braking.
4. The importance of decision making must be emphasized in initial and recurrent training.
5. CRM training must be reviewed to address the roles of the pilot flying and the pilot monitoring especially in relation to the call for "GO AROUND" when it is observed that an aircraft does not touchdown in the touchdown area. The CAL Operations Manual Part A, clearly outlines when a "go around" call must be made and although not applicable to this accident CAL should consider emphasizing that either flight crew member can make the "go around" call and the response to this must be immediate.
6. CAL should conduct an analysis with their pilots to determine their understanding of go around from flare to touchdown and when a go around is mandatory.
7. CAL must reinforce training with regard to recommended flap setting for wet runways.
8. CAL must develop procedures for flight crew to check charts for landing on wet runways.

9. CAL must provide proactive training in TEM and Visual Illusions Awareness.
10. CAL should review the guidance provided by ICAO in Annex 6 to the ICAO Convention on Fatigue Risk Management Systems.
11. Training for flight crew in the use of the blow out panels to facilitate quick escape must be developed
12. Based on the fact that the combined efforts of two cabin crew did not allow them to properly open the L2 door, there is the need to review cabin crew training to ensure that they are aware of the correct procedures that are pertinent to operating the exits when aircraft are in an unusual attitude.
13. CAL to consider placement of additional information on the Safety Briefing Card to include directions for the safest and easiest way to get off the aircraft wings and what to do after getting out of the aircraft. Note should include warning not to touch the engines cowlings in order to avoid burns.

4.2. Actions by TTCAA

1. Carry out a full review of the CAL flight crew training program to ensure that it is in keeping with the Boeing program. Emphasis must be put on decision making, situational awareness and CRM. The company will also benefit by placing greater emphasis on TEM.
2. In reviewing CAL flight crew training programmes, TTCAA must ensure that the required flight and ground training is carried out and properly documented.

3. Cabin crew training needs to be reviewed to ensure it is in keeping with requirements of the Training Manual.
4. Generally, TTCAA should review CAL's record keeping to ensure that documents are properly completed including sign off and dating.

4.3 Actions by SYCJ

1. In the planned extension of the Runway at SYCJ the development of RESA in keeping with ICAO Annex 14 must be included. Also the use of EMAS (Engineered Materials Arrestor Systems) should be considered.
2. Approach lighting and Touchdown zone lighting and center line lighting should be included as part of the extension plans for the airport.
3. SYCJ should provide an easily identifiable area that is set aside to provide comfort to passengers, who may be in distress, and their relatives.
4. The airport should arrange for an engineering assessment of the runway slope and provide notification for publication of same in the Guyana AIP.
5. It was noted that there was no reaction from the Airport Security Service. SYCJ must carry out an investigation to determine why there was no reaction and implement training exercises to familiarize its security service with its responsibility in keeping with the Airport Emergency Manual.

4.4. Action by GCAA

Consider need for a meteorological officer to be stationed at a strategic location on the field to provide local weather information.

5. SAFETY ACTIONS TAKEN

5.1 Actions by CJIA

1. Management of CJIA has checked the REIL and it is now functioning effectively.
2. The approach slope for the PAPIs has been adjusted to make it co-incidental with the approach slope of the RNAV-GPS approach of RWY06.
3. Distance-to-go signboards have been erected at 1000ft intervals, beginning from 4000ft along RWY06/24.
4. A full emergency exercise was carried out and all areas of response were tested. The response of the CJIA Security was considered to be satisfactory.

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APPENDICES

APPENDIX 1 – SYCJ APPROACH CHARTS

APPENDIX 2 – PARTIAL TRANSCRIPT OF CVR

APPENDIX 3 – FDR PLOTS – FDR DATA RECORDED DURING THE ACCIDENT FLIGHT AND THE PREVIOUS FLIGHT

APPENDIX 4 – AIRCRAFT PERFORMANCE STUDY

APPENDIX 5 – REPORT ON FRICTION CHARACTERISTICS AT CHEDDI JAGAN INTERNATIONAL AIRPORT

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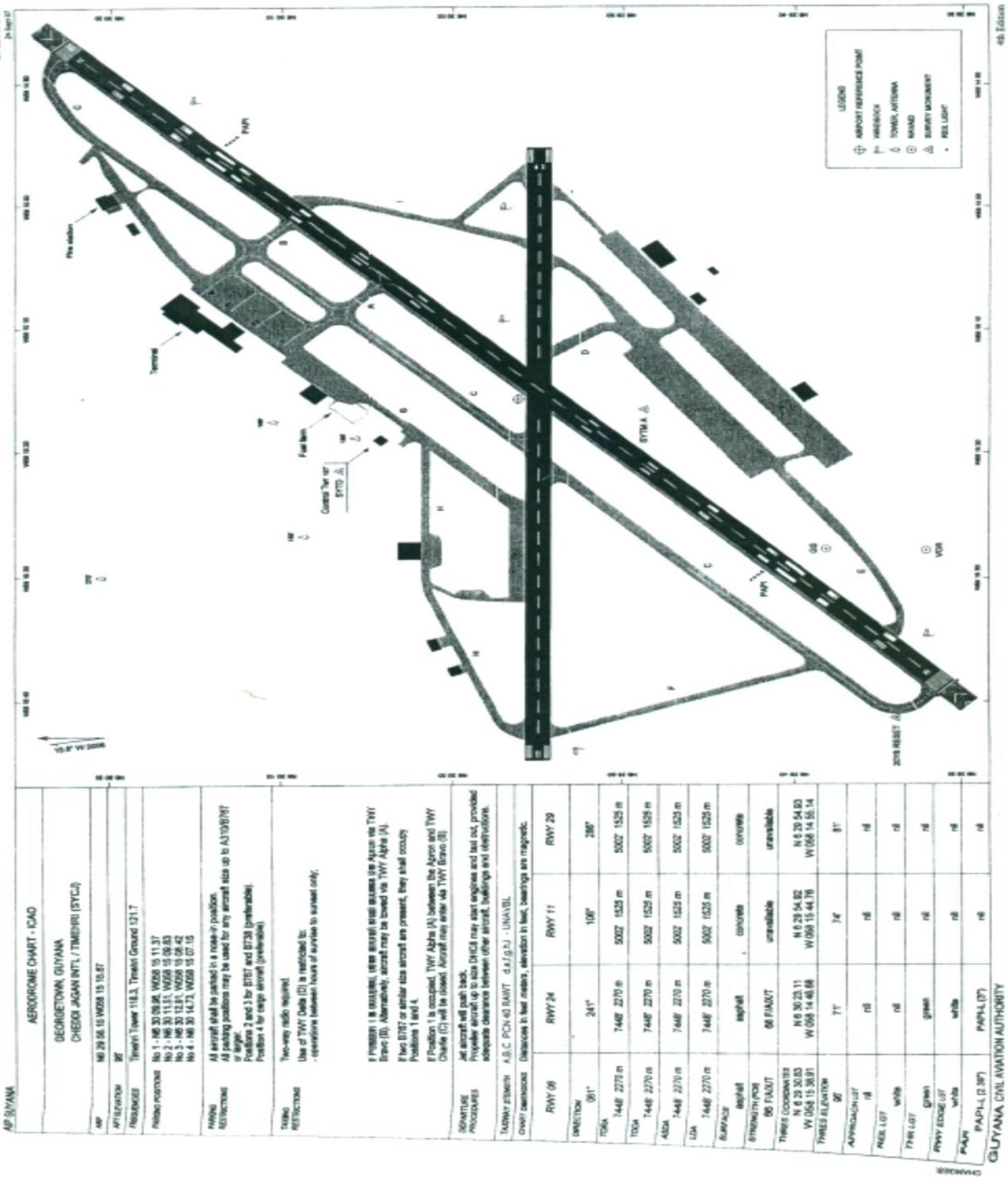
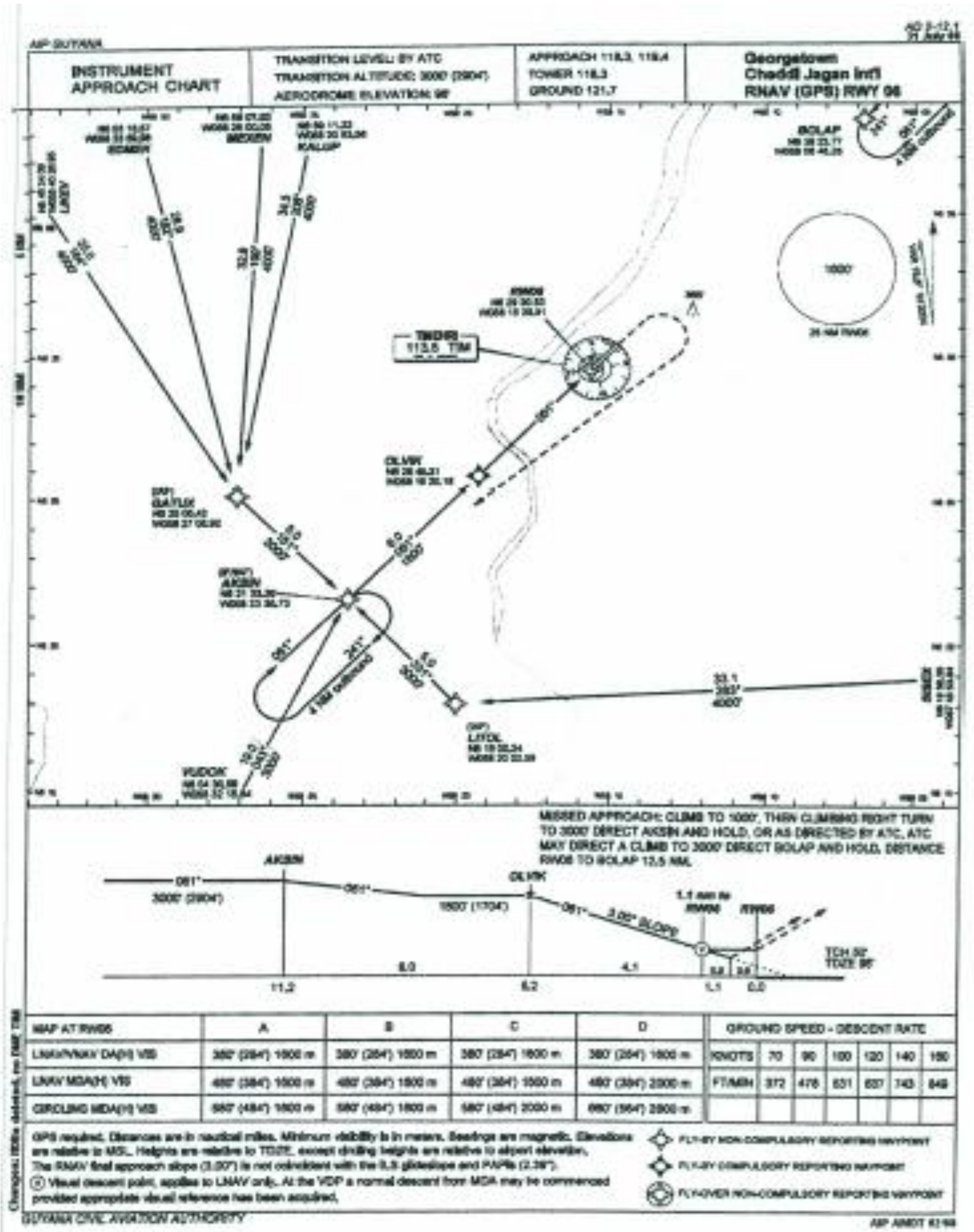
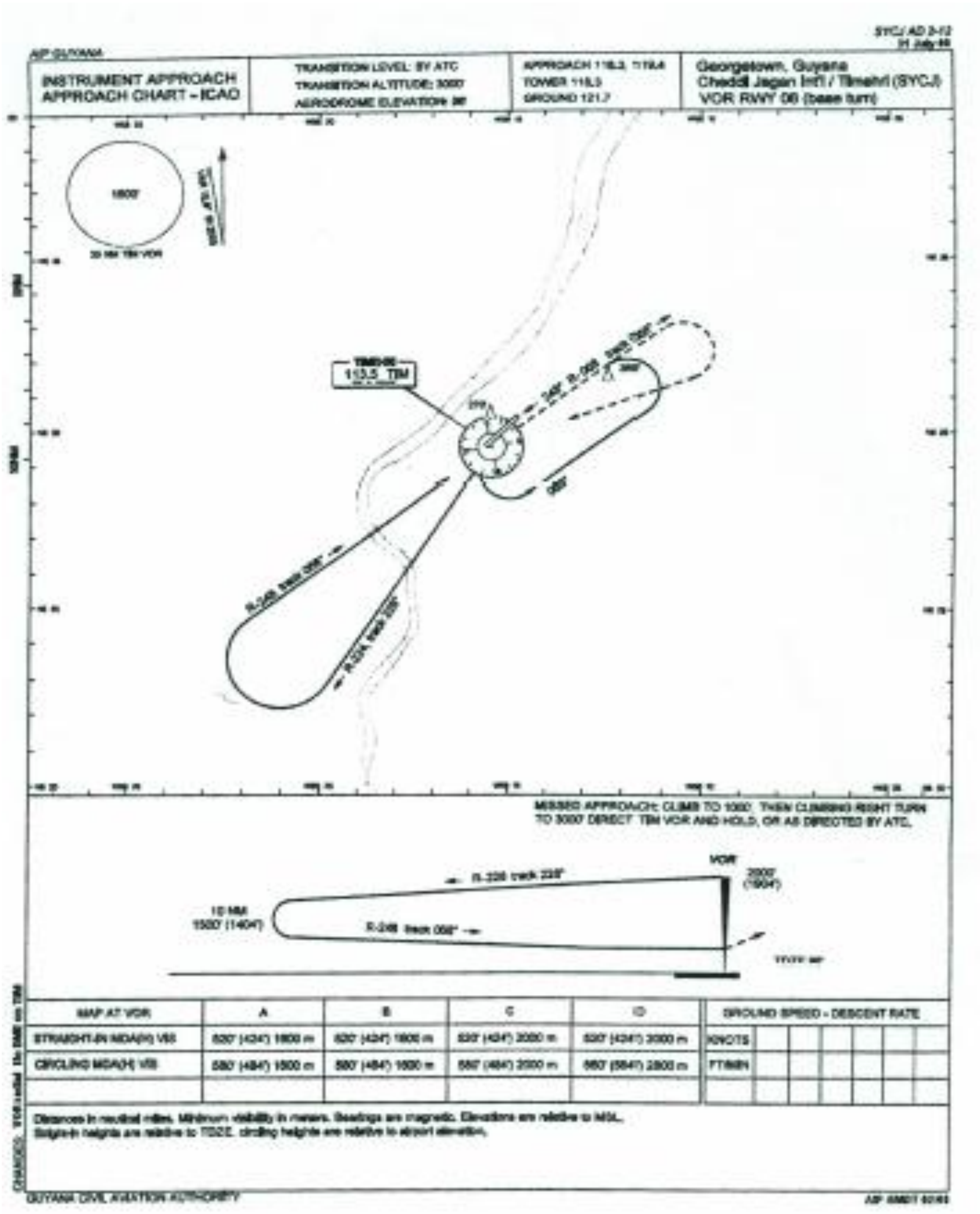
APPENDIX - 1

SYCJ CHARTS




AIP GUYANA
INSTRUMENT APPROACH CHART
TRANSITION LEVEL: BY ATC
AERODROME ELEVATION: 95'
APPROACH 118.3, 119.4
TOWER 118.3
GROUND 121.7
Georgetown
Cheddi Jagan Int'l
RNAV (GPS) RWY 06
113.5 TIM
1000'
OLVIK
AKSIN
LITOL
VUDOK
BOLAP
MISSED APPROACH: CLIMB TO 1000', THEN CLIMBING RIGHT TURN TO 3000' DIRECT AKSIN AND HOLD, OR AS DIRECTED BY ATC. ATC MAY DIRECT A CLIMB TO 3000' DIRECT BOLAP AND HOLD. DISTANCE RW06 TO BOLAP 12.5 NM.
3.00° SLOPE
11.2
6.2
1.1
0.0
GROUND SPEED - DESCENT RATE
GUYANA CIVIL AVIATION AUTHORITY


AIP GUYANA
INSTRUMENT APPROACH
APPROACH CHART - ICAO
TRANSITION LEVEL: BY ATC
TOWER 118.3
GROUND 121.7
Georgetown, Guyana
Cheddi Jagan Int'l / Timehri (SYCJ)
VOR RWY 06 (base turn)
113.5 TIM
MISSED APPROACH: CLIMB TO 1000'. THEN CLIMBING RIGHT TURN TO 3000' DIRECT TIM VOR AND HOLD, OR AS DIRECTED BY ATC.
VOR
10 NM
GROUND SPEED - DESCENT RATE
KNOTS
GUYANA CIVIL AVIATION AUTHORITY

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APPENDIX – 2

CVR REPORT

WARNING

The reader of this report is cautioned that the transcription of a cockpit voice recorder audio recording is not a precise science but is the best product possible from a Safety Board group investigative effort. The transcript or parts thereof, if taken out of context, could be misleading. The transcript should be viewed as an accident investigation tool to be used in conjunction with other evidence gathered during the investigation. Conclusions or interpretations should not be made using the transcript as the sole source of information.

A. EVENT

Location: Georgetown, Guyana
Date: July 30, 2011, 0525 Greenwich Mean Time (GMT)*
Aircraft: Boeing 737-800, 9Y-PBM
Operator: Caribbean Airlines, Flight 523
NTSB Number: DCA11RA092

B. GROUP

A group was convened on August 4, 2011.

* All times are expressed in Greenwich Mean Time (GMT), unless otherwise noted.

C. SUMMARY

On July 30, 2011, at about 0525 Greenwich Mean Time (GMT), a Boeing 737-800, Trinidad & Tobago registration 9Y-PBM, operated by Caribbean Airlines as flight 523, overran the runway upon landing at Cheddi Jagan International Airport, Georgetown, Guyana. Of the 156 passengers and six crew on board, there was reportedly one serious and multiple minor injuries. Weather was reported as raining at the time of the accident. A solid-state cockpit voice recorder (CVR) was sent to the National Transportation Safety Board Vehicle Recorder Division's Audio Laboratory for readout. The CVR group meeting convened on August 4, 2011 and a partial transcript was prepared for the last 35-minutes, 33-seconds of the 2-hour, 4-minute digital recording (see attached).

D. DETAILS OF INVESTIGATION

On August 1, 2011, the NTSB Vehicle Recorder Division's Audio Laboratory received the following CVR:

Recorder Manufacturer/Model: **L-3 Communications FA2100-1020**
Recorder Serial Number: **147351**

Recorder Description

CVRs record a minimum of the last 30 minutes of aircraft operation; this is accomplished by recording over the oldest audio data. When the CVR is deactivated or removed from the airplane, it retains only the most recent 30 minutes or 2 hours of CVR operation, depending on the CVR model. This model CVR, the L-3 Communications FA2100-1020, is a solid-state CVR that records 2 hours of digital cockpit audio. Specifically, it contains a 2-channel recording of the last 2 hours of operation and separately contains a 4-channel recording of the last 30 minutes of operation. The 2-hour portion of the recording is comprised of one channel of audio information from the cockpit area microphone (CAM) and one channel that combines two audio sources: the Captain's audio panel information and the First Officer's audio panel information. The 30-minute portion of the recording contains 4 channels of audio data; one channel for each flight crew and one channel for the CAM audio information.

Recorder Damage

Upon arrival at the audio laboratory, it was evident that the CVR had not sustained any heat or structural damage and the audio information was extracted from the recorder normally, without difficulty.

Audio Recording Description

For the 2-hour portion of the CVR recording, each channel contained good quality† audio information. As shown in the table below, the 30-minute portion of the recording consisted of four channels of audio information. Each channel's audio quality is indicated in Table 1. Notably, channel number one contained a Morse code station identifier.

Table 1: Audio Quality

Channel Number	Content/Source	Quality
1	Observer	N/A
2	First Officer	Good
3	Captain	Good
4	CAM	Good

Timing and Correlation

Timing on the transcript was established by correlating the CVR events to common events on the flight data recorder (FDR). Specifically, the last 11 radio transmissions that the aircraft made were correlated to the radio transmit microphone key parameter from the FDR. Each of the 11 radio transmissions acted as an anchor point for a linear interpolation between the remaining CVR events. This correlation resulted in the CVR elapsed time on the 30-minute CVR of 0027:50.789 corresponding to FDR subframe reference number (SRN) of 97786.8164. Once a correlation between the two recorders was established, GMT time recorded on the FDR was used to convert SRN to GMT. FDR SRN of 97975.70313 = 0532:28 GMT. The CVR and FDR times were offset to reflect the local GMT of the accident by adding 0501:28.324 to the 30-minute recording and 0328:15.048 to the 120-minute recording.

Description of Audio Events

The recording began with the prior approach and landing into the Piarco International Airport in Trinidad by another crew. After power was removed from the CVR for an undetermined amount of time, at 0431:30, the crew of flight 523 was recorded preparing for the flight to Georgetown. At 0432:22, the aircraft was cleared for take-off from Trinidad, and after taxiing into position, took off at 0435:30. The aircraft climbed to flight level 330 and was given a clearance direct AKSIN to expect the RNAV runway 6 approach. At 0456:35, air traffic control cleared the aircraft to descend at pilot's discretion to 3,000 feet.

The transcript began at 0457:06 and continued until the end of the recording. The partial transcript is attached.

CVR Quality Rating Scale

The levels of recording quality are characterized by the following traits of the cockpit voice recorder information:

Excellent Quality Virtually all of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate only one or two words that were not intelligible. Any loss in the transcript is usually attributed to simultaneous cockpit/radio transmissions that obscure each other.

Good Quality Most of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate several words or phrases that were not intelligible. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.

Fair Quality The majority of the crew conversations were intelligible. The transcript that was developed may indicate passages where conversations were unintelligible or fragmented. This type of recording is usually caused by cockpit noise that obscures portions of the voice signals or by a minor electrical or mechanical failure of the CVR system that distorts or obscures the audio information.

Poor Quality Extraordinary means had to be used to make some of the crew conversations intelligible. The transcript that was developed may indicate fragmented phrases and conversations and may indicate extensive passages where conversations were missing or unintelligible. This type of recording is usually caused by a combination of a high cockpit noise level with a low voice signal (poor signal-to-noise ratio) or by a mechanical or electrical failure of the CVR system that severely distorts or obscures the audio information.

Unusable Crew conversations may be discerned, but neither ordinary nor extraordinary means made it possible to develop a meaningful transcript of the conversations. This type of recording is usually caused by an almost total mechanical or electrical failure of the CVR system.

Transcript of an L-3 Communications FA2100-1020 solid-state cockpit voice recorder, serial number 147351, installed on a Caribbean Airlines Boeing 737-800 (9Y-PBM), which crashed during landing at the Cheddi Jagan International Airport in Georgetown, Guyana.

LEGEND

CAM	Cockpit area microphone voice or sound source
HOT	Flight crew audio panel voice or sound source
RDO	Radio transmissions from 9Y-PBM
ATC	Radio transmission from center controller
TWR	Radio transmission from the Georgetown airport tower controller
OPS	Radio transmission from the Timehri (Georgetown) airline operations
RA	Radio Altimeter
-1	Voice identified as the captain
-2	Voice identified as the first officer
-3	Voice identified as a flight attendant
-4	Voice identified as a flight attendant
-?	Voice unidentified
*****	Unintelligible word
#	Expletive
@	Non-pertinent word
( )	Questionable insertion
[ ]	Editorial insertion

Note 1: Times are expressed in Greenwich Mean Time (GMT).

Note 2: Generally, only radio transmissions to and from the accident aircraft were transcribed.

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
03:28:15.0 **START OF RECORDING** 04:57:06.3			
04:57:06.3 **CAM-1**	you have controls for a while.		
04:57:11.5 **CAM-1**	[captain discusses weather at destination]		
04:57:23.6 **CAM-1**	altimeter was one zero zero nine *.		
04:57:31.0 **CAM-1**	zero six one inbound course.		
04:57:34.7 **HOT-2**	check.		
04:57:40.1 **CAM-1**	eighteen hundred at OLVIK uhm we do have to have. makin' it hard.		
04:57:45.3 **HOT-2**	check.		
04:57:46.6 **HOT-1**	three thousand for AKSIN.		
04:57:48.7 **HOT-2**	yeh.		
04:57:51.5 **CAM-1**	confirmed one zero *.		
04:57:54.0 **CAM-1**	three degree glidepath going down the road.		
04:57:57.0 **CAM-2**	check.		
04:57:58.9 **HOT-1**	decision altitude at three eighty.		
04:58:03.8 **HOT-1**	touchdown is both ninety six.		
04:58:05.5 **HOT-2**	hundred.		
04:58:08.4 **CAM-1**	and we know its direct AKSIN * zero six one *.		
04:58:11.3 **CAM-2**	yeh *.		
04:58:12.7 **CAM-1**	L-NAV V-NAV going down we need sixteen hundred meters the last one we had was ten plus.		
04:58:17.3 **HOT-2**	that's right.		
04:58:18.6 **HOT-1**	if we have any reason to carry out the missed approach climb to a thousand and climbing right turn to three thousand.		
04:58:25.2 **HOT-1**	back to AKSIN and hold which is the better one depending on the weather.		
04:58:28.6 **HOT-2**	yeh.		
04:58:29.0 **HOT-1**	rather than going out south and a little bit further out....they have one at BOLAP.		
04:58:33.9 **HOT-2**	yep sound good.		

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
04:58:34.9 **HOT-1**	so if we have to its just going to be...TOGA set thrust flap fifteen positive climb gear up and clean up on schedule.		
04:58:42.0 **HOT-2**	**.		
04:58:42.5 **HOT-1**	see how much we need. I think what we need to go back to Barbados is…		
04:58:46.6 **HOT-2**	C-M-R four point seven.		
04:58:48.6 **HOT-1**	…we could use four point two and we could go back to Piarco.		
04:58:52.2 **HOT-2**	sounds good.		
04:58:52.9 **HOT-1**	right yeh.		
04:58:55.8 **HOT-1**	so that's the brief.		
04:58:58.4 **HOT-2**	no questions.		
04:58:58.8 **HOT-1**	so you have there so anytime you want...do the descent check.		
04:59:01.4 **HOT-2**	right you have controls.		
04:59:02.8 **HOT-1**	I have control again.		
04:59:03.4 **HOT-2**	recall watch your eyes.		
04:59:07.2 **HOT-2**	right. just now eh		
04:59:09.1 **HOT--2**	right.		
04:59:09.6 **HOT-1**	check.		
04:59:11.4 **HOT-2**	descent. pressurization landing altitude of one hundred feet for Georgetown. recall checked. autobrake. three. landing data. v-ref. one four nine. baro three eight zero set twice. approach briefing complete. descent checks completed.		
04:59:22.8 **HOT-1**	thank' ya' much.		
04:59:24.6 **HOT-1**	no big *** I'll use the reverse as required and manual braking let it go down and we just taxi back in via charlie and.		
04:59:28.0 **HOT-2**	yeh.		
04:59:41.8 **HOT-2**	[muttering]		
04:59:48.5 **HOT-2**	thirty three. thirty two seven.		
04:59:53.3 **HOT-2**	oh just uh. ah. put as nine.		

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
04:59:58.1 **HOT-1**	that's eight or nine.		
04:59:59.1 **HOT-2**	that's eight that's why it's so low.		
05:00:02.5 **HOT-1**	yeh should have put on my glasses.		
05:00:04.7 **HOT-2**	check. thanks. so seven *. seven eighty.		
05:00:06.4 **HOT-1**	yeh.		
05:00:18.4 **HOT-2**	zero five. set. [muttering]		
05:00:37.0 **HOT-1**	[laughter]. ah next thing. she's the little sucker is just waiting there.		
05:00:44.2 **HOT-2**	this radar kind'a funny too.		
05:00:46.2 **HOT-1**	I know this is there is probably nothing here because this is two down.		
05:00:49.9 **HOT-2**	right.		
05:00:50.8 **HOT-1**	right but you don't want to really take the chance.		
05:00:53.1 **HOT-2**	true.		
05:00:54.7 **HOT-1**	not at night anyway.		
05:00:56.0 **HOT-2**	yeh.		
05:01:02.3 **HOT-1**	well they have stuff out there I saw the lightning flashing just now.		
05:01:05.8 **HOT-2**	yeh there we go.		
05:01:44.2 **HOT-2**	* strobes.		
05:01:45.9 **HOT-1**	yeh *** we're comin' out just goin' past it in a lil' while.		
05:01:49.5 **HOT-2**	alright.		
05:01:54.3 **HOT-1**	bring your scale back down to to ah...		
05:01:56.6 **HOT-2**	what you want?		
05:01:56.6 **HOT-1**	one down for me.		
05:01:57.8 **HOT-2**	sure...forty. yeh. no problem.		
05:01:58.3 **HOT-1**	yeh please.		
05:02:02.5 **CAM**	[sound of single chime, similar to cabin call]		
05:02:03.7 **HOT-2**	*. you want anything?		
05:02:06.0 **HOT-1**	naw I'm fine.		
05:02:06.8 **HOT-2**	flight deck. @.		
05:02:07.9 **FA-3**	hi @ speaking. do y'all need anything?		
05:02:10.0 **HOT-2**	hey @. uhm no. we good. we cool.		
05:02:12.0 **FA-3**	okay.		
05:02:12.6 **HOT-2**	thanks.		

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:02:13.0 **FA-3**	alright thanks.		
05:02:14.4 **HOT**	[sound of intercom hanging up]		
05:02:32.6 **HOT-2**	yep. three thousand.		
05:02:38.2 **HOT-2**	verified.		
05:02:41.5 **HOT-1**	** come up *.		
05:02:44.1 **HOT-2**	I don't know it just show up.		
05:02:48.3 **HOT-1**	eh eh.		
05:02:51.2 **HOT-2**	[chuckle]		
05:02:54.6 **HOT-1**	because of the turn.		
05:02:55.4 **HOT-2**	yeh that's why yeh.		
05:03:04.7 **HOT-1**	I'll have to go right of dee track.		
HOT-2	yeh come back out...alright.		
05:03:08.1 **HOT-1**	* parallel the track *.		
05:03:21.5 **HOT-?**	***.		
05:03:27.8 **HOT-1**	we gotta go just about five miles right of track. **. then direct AKSIN please.		
05:03:33.4 **HOT-2**	sure.		
		05:03:35.8 **RDO-2**	Georgetown. Caribbean Airlines five two three.
		05:03:37.9 **ATC**	Caribbean Airlines five two three go ahead.
		05:03:40.1 **RDO-2**	five two three we turning back onto the original track however we have to deviate to the right of track now about five miles and parallel to return direct AKSIN.
		05:03:48.7 **ATC**	oh sure left and right deviation approved for direct AKSIN. report established.
		05:03:53.2 **RDO-2**	five two three.
05:03:55.2 **HOT-2**	yep ya have it.		
05:03:55.7 **HOT-1**	**.		
05:04:20.5 **HOT-2**	GATUX		
05:04:32.0 **HOT**	[sneeze]		
05:04:48.2 **HOT-1**	yes *** so take these out *** LNAV and then breakoff from here.		
05:04:54.7 **HOT-2**	yeh of course.		
05:04:55.2 **HOT-1**	so what I'll do * and it will give me a more gradual angle as well too.		
05:04:55.8 **HOT-2**	let's keep dee heading.		
05:04:58.3 **HOT-2**	right.		
05:04:59.6 **HOT-2**	right.		

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:05:29.4 **HOT**	[sneeze]		
05:05:33.6 **HOT-1**	and if we have any specials?		
05:05:35.5 **HOT-2**	uhm...* call * [sniffle].		
05:05:42.6 **FA-3**	[sound of interphone] @ speaking.		
05:05:44.8 **HOT-2**	hi @ J uhm @ here. you know if you have any specials?		
05:05:49.0 **FA-3**	uhm I'll find out.		
05:05:50.6 **HOT-2**	thanks call me back nuh.		
05:05:51.6 **FA-3**	okay.		
05:05:56.7 **HOT**	[sound of click, similar to interphone hanging up]		
05:06:12.8 **HOT-2**	[sneeze]		
05:06:20.6 **HOT-2**	[yawn]		
05:06:22.4 **HOT**	*		
05:06:24.8 **HOT-1**	yep looks for a little ([boyd or boy]) right there.		
05:06:26.9 **HOT-2**	you saw it okay.		
05:06:27.7 **HOT-1**	a big. a little big boy.		
05:06:29.3 **HOT-2**	what huh.		
		05:07:32.1 **RDO**	Europa aircraft talking to ATC]
05:07:34.8 **HOT-1**	* Europa.		
05:07:35.9 **HOT-2**	they come back here?		
05:07:37.8 **HOT-1**	headin' this way yeh.		
05:07:38.8 **HOT-2**	oh. okay.		
05:07:40.8 **HOT-2**	retard.		
		05:07:47.6 **RDO-2**	Georgetown Caribbean Airlines five two three leaving level three three zero for three thousand. ah one zero three miles Timehri.
05:07:55.3 **CAM**	sound of single chime]		
		05:07:55.3 **ATC**	roger report passing one zero zero.
		05:07:58.0 **RDO-2**	report passing one zero zero five two three.
05:07:58.7 **HOT-1**	yep.		
05:07:59.3 **FA-3**	hi I'm seeing one wheel chair passenger.		
05:08:02.3 **HOT-1**	** only one we need.		
05:08:04.5 **FA-3**	yeh.		
05:08:06.2 **HOT-1**	one wheelchair.		
05:08:06.9 **HOT-2**	copy off one passenger.		
05:08:10.8 **HOT-1**	arm.		
		05:08:12.4 **RDO-2**	Timehri ops good morning Caribbean five two three.

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:08:16.1 **HOT-2**	requesting how much on the?		
05:08:18.9 **HOT-2**	no the fuel.		
05:08:19.1 **HOT-1**	* seven point five.		
05:08:20.3 **HOT-2**	seven five.		
		05:08:30.0 **RDO-2**	Timehri ops Caribbean five two three.
05:08:39.9 **HOT-2**	*** the fuel * six five five [muttering].		
05:08:46.9 **HOT-2**	*.		
05:08:54.6 **HOT-2**	zero five on five six.		
05:09:04.7 **HOT-2**	yep.		
05:09:07.7 **HOT-2**	like they fall asleep?		
05:09:09.0 **HOT-2**	hmph.		
05:09:09.4 **HOT-1**	ahh?		
05:09:10.1 **HOT-2**	are they sleepin'?		
		05:09:12.2 **RDO-2**	Timehri goodnight Caribbean Airlines five two three.
05:09:26.2 **HOT-2**	ahh * o.		
05:09:29.2 **HOT-2**	[yawn]		
05:09:45.1 **CAM**	[sound of click]		
05:09:49.7 **HOT-2**	[singing]		
05:10:14.6 **HOT-1**	[clearing throat]		
		05:10:15.8 **RDO-2**	Timehri ops Caribbean five two three goodnight.
05:10:22.2 **HOT-1**	ah when we get a little closer man.		
05:10:24.1 HOT-2	alright.		
05:10:26.5 HOT-2	yeh.		
05:10:28.1 HOT-1	it's not like I guess it's not like they have twenty five plane comin' in all at the same time. [laugh] at least I hope not [laugh].		
05:10:31.2 HOT-2	well * true * [laughter].		
05:10:55.2 HOT-2	I guess that's why they forecast rain.		
05:10:56.0 HOT-1	yeh just there or I'll no its ah hope it ain't blowin' that way because look where dee wind is.		
05:11:00.1 HOT-2	yeh...but daz' it.		
05:11:02.7 HOT-1	I don't know where dee rain comin' from because I when I looked at the satellite picture tonight before I left home.		

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:11:07.6 HOT-2	ah hah.		
05:11:08.6 HOT-1	they had a lil' bit of stuff further down to the south east but.		
05:11:12.0 HOT-2	right.		
05:11:12.2 HOT-1	that was so far away.		
05:11:13.8 HOT-2	well dat is it.		
05:11:13.9 HOT-1	we'll be down there for three hours.		
05:11:15.5 HOT-2	well exactly yah.		
05:11:21.3 HOT-2	I want to see if I can get ah weather one time.		
05:11:24.1 HOT-1	yah we should.		
05:11:30.7 HOT-1	well. if we usin' Piarco I guess for dee paperwork well we know Piarco good anyway so don't worry with it yet. yeh I cool with that.		
05:11:33.9 HOT-2	oh but.		
05:11:35.8 **HOT-2**	yeh alright true.		
05:11:37.1 **HOT-2**	I should ah send for that [muttering].		
05:11:42.3 **HOT-1**	if it have rain.		
05:11:44.4 **CAM**	[sound of hi-lo chime, similar to cabin call]		
05:11:44.9 **HOT-1**	well for Piarco it means some big ole # spittin' from dee hills or something in Morvant peeing or something.		
05:11:48.6 **HOT-2**	[laughter]		
05:11:50.3 **CAM**	[sound of hi-lo chime]		
05:11:51.2 **HOT-2**	had to be.		
05:11:54.5 **HOT-1**	yeh some of these F-M-Cs real...ah hah.		
05:11:56.8 **HOT-2**	yeh. Jagan.		
05:11:58.8 **HOT-1**	see.		
05:11:59.4 **HOT-2**	well look at dat.		
05:12:01.2 **HOT-2**	calm nine K-M. light showers.		
05:12:02.0 **HOT-1**	nine kilometers.		
05:12:04.0 **HOT-1**	so dey definitely gettin' something. one zero zero nine.		
05:12:06.4 **HOT-2**	good. calm.		
05:12:07.4 **HOT-1**	C-Bs to the north east east north east.		
05:12:10.8 **HOT-2**	east northeast for the winds.		

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:12:14.5 **HOT-2**	sssss but that blowin' in alright.		
05:12:22.2 **HOT-2**	well we know Adams is good I mean uh *.		
05:12:24.3 **HOT-1**	okay.		
05:12:24.9 **HOT-2**	Adams is wide open.		
05:12:34.8 **HOT-1**	puttin' it on early for them.		
05:12:36.1 **CAM**	[sound of switch] [sound of single chime]		
05:12:36.8 **HOT-2**	yep.		
		05:13:06.4 **RDO-2**	Timehri ops good morning Caribbean five two three.
05:14:26.6 **HOT-2**	[clearing throat]		
05:14:37.2 **HOT-2**	yeh bring it down already.		
05:14:37.9 **HOT-1**	yeh okay.		
05:14:43.3 **HOT-2**	hmm.		
05:14:44.0 **HOT-1**	see look we away from it and we still feelin' it.		
05:14:46.1 **HOT-2**	and still because of the breeze [followed by unintelligible mutter]		
05:14:48.7 **HOT-1**	yep and its only fifteen knots eh.		
		05:14:53.2 **ATC**	Caribbean Airlines five two three go ahead passing level.
		05:14:55.9 **RDO-2**	Caribbean Airlines five two three passing level one eight six.
		05:14:58.9 **ATC**	roger contact Timehri one one eight three goodnight.
		05:15:01.5 **RDO-2**	one one eight three good night Caribbean Airlines five two three.
		05:15:06.3 **RDO-2**	Timehri goodnight ah Caribbean Airlines five two three.
		05:15:11.2 **TWR**	Timehri five two three tower goodnight go ahead.
		05:15:13.6 **RDO-2**	Caribbean Airlines five two three...five niner miles north Timehri passing level one eight zero descending to three thousand altimeter one zero zero niner. routing...a little right slight right deviation routing direct AKSIN shortly estimate zero five two seven.

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
		05:15:33.3 **TWR**	Caribbean five two three roger cleared for the R-NAV approach runway zero six report AKSIN inbound. wind calm. there is light rain at the field. Q-N-H one zero zero nine.
		05:15:42.9 **RDO-2**	cleared R-NAV zero six. report AKSIN inbound. altimeter one zero zero niner Caribbean Airlines five two three.
05:15:47.3 **HOT-1**	what's the vis?		
05:15:48.9 **HOT-2**	say again?		
05:15:48.9 **HOT-1**	just ask her to confirm the visibility.		
05:15:51.0 **HOT-2**	um.		
		05:15:52.0 **RDO-2**	okay (can you) just say again visibility for the five two three.
05:15:54.0 **HOT-1**	confirm direct.		
05:15:55.3 **HOT-2**	yep @ [followed by muttered unintelligble].		
05:15:58.9 **HOT-1**	L-NAV.		
		05:15:59.5 **TWR**	visibility * is eight kilometers.
		05:16:01.7 **RDO-2**	thank you
05:16:02.3 **HOT-1**	okay.		
05:16:02.8 **HOT-2**	eight K-M.		
05:16:05.9 **HOT-2**	L-NAV [sigh].		
05:16:08.7 **HOT-2**	cleared for the approach.		
05:16:10.1 **HOT-1**	okee-dokie.		
05:16:16.3 **HOT-2**	oh.		
05:16:20.6 **HOT-1**	should. technically it should be point five. I know we use...yeh because it is not a G-P-S approach.		
05:16:26.7 **HOT-2**	oh.		
05:16:27.5 **HOT-1**	yeh.		
05:16:28.5 **HOT-2**	it's not.		
05:16:29.1 **HOT-1**	what does that say. does it. no it doesn't say on that chart.		
05:16:31.7 **HOT-2**	R-NAV G-P-S.		
05:16:32.9 **HOT-1**	okay.		
05:16:33.4 **HOT-2**	well that's weird but but they must have changed that * here.		
05:16:36.2 **HOT-1**	naw leave it den'.		
05:16:37.3 **HOT-2**	alright put point three.		
05:16:38.8 **HOT-1**	yeh.		
05:16:39.5 **HOT-2**	cool.		

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:16:50.0 **HOT-1**	you can change that. you can't change the numbers. so I just got rid of the at or above.		
05:16:55.0 **HOT-2**	okay. yeh yeh yeh. right.		
05:16:55.6 **HOT-1**	on your three you can change the letters though.		
05:16:58.7 **HOT-1**	see they sent out a email stating that for some airports recently. and then they recalled it. I don't know what for though.		
05:17:03.2 **HOT-2**	yeh.		
05:17:06.9 **HOT-2**	that was just for Antigua?		
05:17:09.2 **HOT-1**	it wah--yeh.		
05:17:10.2 **HOT-2**	right but no they.		
05:17:11.6 **HOT-1**	but they recall it I don't know.		
05:17:13.0 **HOT-2**	they recall it because they made a mistake. they put one hundred feet instead of a thousand feet. but they sent it back so.		
05:17:16.6 **HOT-1**	see there.		
05:17:18.6 **HOT-1**	they did?		
05:17:19.3 **HOT-2**	yeh I got back dee dee update...not too long after.		
05:17:22.9 **HOT-1**	is a good thing I delete.		
05:17:24.4 **HOT-2**	[laugh] yeh.		
05:17:34.0 **HOT-1**	well I'll just let the L-NAV V-NAV do its stuff until I'm visual and.		
05:17:36.6 **HOT-2**	sure.		
05:17:38.3 **HOT-2**	looks good.		
05:17:39.3 **HOT-1**	[yawn] leave the autothrottle in till...depending on the wind.		
05:17:41.9 **HOT-2**	yeh.		
05:17:44.4 **HOT-2**	try these guys one more time and then.		
05:17:46.5 **HOT-1**	yep.		
		05:17:47.4 **RDO-2**	Timehri ops goodnight Caribbean five two three.
		05:17:56.8 **OPS**	good evening five two three. this is company Timehri go ahead please.
		05:18:00.4 **RDO-2**	good evening company five two three we are estimating you at zero five three zero that's half past and requesting seven decimal five on the fuel for this same aircraft and one wheelchair on arrival.

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:18:13.0 **HOT-1**	fuel is required. right?		
05:18:14.0 **HOT-2**	yeh I told him already.		
		05:18:14.3 **OPS**	roger that fuel to go.
		05:18:16.2 **RDO-2**	and confirm fuel is required seven decimal five.
05:18:28.9 **HOT-2**	yep. back on one now.		
05:18:30.6 **HOT-1**	thank you no change.		
05:18:34.9 **HOT-2**	uhgh.		
05:18:38.7 **HOT-2**	[muttering] * GATUX *** should I take it by GATUX anyhow but you know *** [yawn] ***.		
05:18:53.2 **CAM**	[sound of single chime]		
05:18:54.8 **HOT-2**	I have it. flight deck @.		
05:18:57.1 **FA-4**	yeh. cabin is secured.		
05:18:58.1 **HOT-2**	thanks @.		
05:18:59.0 **FA-4**	okay.		
05:19:00.2 **HOT-2**	cabin is secured.		
05:19:01.5 **HOT-1**	okay. you wanna do it. yeh might as well we know where we are.		
05:19:01.9 **HOT-2**	and we goin' down to three thousand. so.		
05:19:05.3 **HOT-1**	one zero zero nine.		
05:19:06.4 **HOT-2**	one zero zero nine. passing eleven thousand two hundred.		
05:19:09.4 **CAM**	[sound of click]		
05:19:13.9 **HOT-1**	uhhmm. yep.		
05:19:15.1 **HOT-1**	now eleven one now. yeh.		
05:19:15.1 **HOT-2**	eleven one now. leaving eleven now. cabin secure approach checks complete.		
05:19:18.2 **CAM**	[sound of click]		
05:19:18.5 **HOT-1**	thank ya' much.		
05:19:18.5 **CAM**	[sound of click]		
05:19:20.1 **HOT-2**	got my lights *. [mutter]. uuhherrrhhh.		
05:19:23.2 **HOT-1**	out of eleven.		
05:19:24.6 **HOT-2**	short of eleven.		
05:19:29.3 **HOT-2**	[humming]		
05:19:36.5 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:19:41.1 **HOT-2**	*		
05:19:46.8 **HOT-2**	*		

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:19:51.5 **HOT-2**	[double yawn]		
05:20:16.9 **HOT-1**	must be light rain because I not even seein' a cloud at.		
05:20:20.3 **HOT-2**	well that...dat's it yeh.		
05:20:20.3 **HOT-1**	drop in the water.		
05:20:24.3 **HOT-1**	seein' clouds out here though...		
05:20:26.4 **HOT-2**	[chuckle]		
05:20:27.5 **HOT-1**	...that have water.		
05:20:30.4 **HOT-1**	this lil' one have serious water.		
05:20:31.2 **HOT-2**	well they have things past the airport too ah. well and all dat...daz what.		
05:20:32.9 **HOT-1**	yeh.		
05:20:36.0 **HOT-1**	yeh.		
05:20:45.5 **HOT-2**	[exhale]		
05:21:16.4 **CAM**	[sound of click]		
05:21:42.7 **HOT-1**	[yawn] oh yes.		
05:21:51.9 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:21:58.8 **HOT-1**	twenty one eh?		
05:22:00.7 **HOT-2**	hmmm?		
05:22:01.2 **HOT-2**	[laugh]		
05:22:01.4 **HOT-1**	how old are you now?		
05:22:02.2 **HOT-2**	twenty-three [laughing].		
05:22:05.5 **HOT-1**	#.		
05:22:06.5 **HOT-2**	[scoff]		
05:22:09.0 **HOT-1**	I am more than twice your friggin' age. Lawdddd.		
05:22:10.6 **HOT-2**	[laughter]		
05:22:16.9 **HOT-1**	now ah feelin' old.		
05:22:18.7 **HOT-2**	hmmm.		
05:22:34.3 **HOT-1**	strange to see it this far below where it should be.		
05:22:37.6 **HOT-2**	and this one comin' up. there we go. F-M-C speed. that's why [laughter] yeh.		
05:22:38.1 **HOT-1**	and it's. yeh. ah hah. * [laughter] alright yeh .		
05:22:41.7 **HOT-2**	I was watchin' it too [laughter].		
05:22:44.3 **HOT-1**	and it held--holdin' it for the longest while and I'm sayin' okay let me see you do something so I can go and do something to.		

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:22:45.8 **HOT-2**	yeh [laughter] something...exactly [laughter].		
05:22:50.9 **HOT-1**	counteract what stupidness you doin'.		
05:22:52.7 **HOT-2**	[laughter]		
05:22:60.0 **HOT-1**	and he set us up and he only...and he only make ah ah little noise and come back to rest yes.		
05:23:01.2 **HOT-2**	eh ah little thing. [laughter]		
05:23:08.5 **HOT-1**	anyway this is the maestro yes once this once this sucker saying you good.		
05:23:10.3 **HOT-2**	yeh once you on the path [laughter] yeh.		
05:23:13.6 **HOT-1**	you have to trust him and then the banana backin' him up.		
05:23:16.2 **HOT-2**	exactly.		
05:23:35.4 **HOT-1**	then in a case like this though if I left the A in mi' boy would have been tryin' to figure out what the ass to do...yeh.		
05:23:38.5 **HOT-2**	uh huh...		
05:23:41.2 **HOT-2**	well daz it yeh.		
05:24:02.7 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:24:05.7 **HOT-2**	a fairly big town out there. that I never...noticed.		
05:24:07.7 **HOT-1**	yeh and it's gettin' bigger too.		
05:24:08.3 **HOT-2**	that's Lethem is it or?		
05:24:11.0 **HOT-1**	I doh even know...what..what it is.		
05:24:11.1 **HOT-2**	ah...forget dee name of it.		
05:24:14.0 **HOT-1**	but it grows fast.		
05:24:15.4 **HOT-2**	yeh.		
05:24:18.8 **HOT-1**	couple years ago dey' just had a few things there.		
05:24:21.7 **HOT-2**	right.		
05:24:23.6 **HOT-2**	huh.		
05:24:26.3 **HOT-2**	arm.		

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:24:27.1 **HOT-1**	arm.		
05:24:28.4 **HOT**	[sound of varied high pitch tone, similar to SELCAL]		
05:24:31.2 **HOT-2**	arrrmm.		
05:25:10.0 **HOT-1**	look at this. all of this not even showin' up.		
05:25:11.7 **HOT-2**	all that. wow.		
05:25:13.4 **HOT-1**	yeh.		
05:25:15.2 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:25:17.2 **HOT-2**	check (your) speed again.		
05:25:20.0 **HOT-2**	should come back in now.		
05:25:21.6 **HOT-1**	may I have flap one.		
05:25:22.7 **HOT-2**	speed check flap one.		
05:25:27.4 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:25:28.4 **HOT-2**	F-M...F...F-M-C speed.		
05:25:33.4 **HOT-1**	F-M-C speed.		
05:25:35.7 **HOT-2**	V-NAV path.		
05:25:36.8 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:25:42.8 **HOT-2**	flap one set. puttin' on the start switches from now.		
05:25:44.4 **HOT-1**	yeh man. yeh.		
05:25:48.2 **HOT-1**	even though it's so light you can't even see it on de damn radar eh.		
05:25:48.8 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:25:50.8 **HOT-2**	well daz it well.		
05:25:59.7 **HOT-2**	how low to the ground [muttering].		
05:26:00.2 **HOT-1**	eh hah.		
05:26:01.4 **HOT-2**	hah.		
05:26:01.9 **HOT-1**	out of four for three.		
05:26:03.2 **HOT-2**	four thousand for three thousand.		
05:26:12.1 **HOT-1**	flap five.		
05:26:12.8 **HOT-2**	speed check. flap five.		
05:26:12.8 **CAM**	[series of clicks, similar to flap handle movement and trim wheel movement]		

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:26:16.7 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:26:22.0 **HOT-2**	five set.		
05:26:27.0 **HOT-1**	what you say?		
05:26:27.2 **HOT**	[sound of c-chord, similar to altitude alert]		
05:26:28.6 **HOT-2**	flap five set.		
05:26:29.0 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:26:29.5 **HOT-1**	okay.		
05:26:30.3 **HOT-2**	four for three.		
05:26:37.6 **HOT-2**	[exhalation]		
05:26:44.3 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:26:54.0 **HOT-1**	eighteen hundred coming one time.		
05:26:55.2 **HOT-2**	checked. verified.		
05:26:57.2 **HOT-1**	roger.		
05:26:57.7 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:27:01.7 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:27:11.8 **CAM**	[sound of click]		
05:27:13.1 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:27:19.9 **HOT-1**	zero six one.		
		05:27:23.2 **RDO-2**	Timehri Caribbean Airlines five two three AKSIN inbound zero five two seven passing three thousand two hundred.
		05:27:33.5 **TWR**	Caribbean five two three roger the wind is calm runway zero six cleared to land caution runway surface wet.
		05:27:40.1 **RDO-2**	cleared to land runway one...ah...correction zero six Caribbean Airlines five two three.
		05:27:44.0 **TWR**	correct.
05:27:45.0 **HOT-2**	cleared to land.		
05:27:52.0 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		

TIME and SOURCE	INTRA - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:27:54.9 **HOT-2**	something...uhm.		
05:27:57.1 **HOT-1**	anything before dere' [there]. let's see on the runway.		
05:28:00.4 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:28:02.0 **HOT-2**	something.		
05:28:02.7 **HOT-1**	some stuff on the end.		
05:28:04.2 **HOT-2**	at the runway.		
05:28:12.9 **HOT**	[sound of c-chord tone, similar to altitude alert]		
05:28:14.8 **HOT-2**	there's twenty eight for eighteen.		
05:28:15.9 **HOT-1**	twenty eight for eighteen.		
05:28:20.9 **HOT-2**	* *.		
05:28:21.8 **HOT-1**	might as well take it early yes and let's setup. gear down.		
05:28:24.6 **HOT-2**	yes sir gear down.		
05:28:26.1 **CAM**	[sound of click, similar to gear handle movement]		
05:28:26.2 **CAM**	[sound of increased noise, similar to landing gear extension]		
05:28:26.2 **HOT-1**	flaps fifteen.		
05:28:26.9 **HOT-2**	speed checks. flaps fifteen.		
05:28:27.9 **CAM**	[sound of clicks, similar to flap handle movement]		
05:28:31.9 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:28:35.2 **HOT-1**	four hundred comin'.		
05:28:36.5 **HOT-2**	veri...yep...verified.		
05:28:40.0 **HOT-1**	rrrroger.		
05:28:43.5 **RA**	twenty five hundred.		
05:28:45.5 **HOT-1**	okay.		
05:28:47.1 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:28:47.2 **HOT-2**	checked.		
05:28:47.4 **HOT-1**	second autopilot comin' in.		
05:28:48.5 **HOT-2**	yep.		
05:28:50.8 **HOT**	[sound of low pitch unintelligible susurration]		
05:28:52.0 **HOT-1**	[laughter]		

TIME and SOURCE	INTR A - A IRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:28:52.0 **HOT-2**	what [laughter]		
05:28:53.2 **HOT-2**	alright.		
05:28:53.8 **HOT-1**	well yes.		
05:28:55.1 **HOT-2**	[laugh] rad alt alive.		
05:28:56.1 **HOT-1**	what a wierd ass kind of thing.		
05:28:58.1 **CAM**	[sound of click]		
05:28:58.9 **HOT-2**	hmmm.		
05:29:08.9 **HOT-1**	ask her wha is di vis now. okay down' worry.		
05:29:10.0 **HOT-2**	(oh) well. alright.		
05:29:11.5 **HOT-1**	runway in sight.		
05:29:12.3 **HOT-2**	runway in sight.		
05:29:12.7 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:29:15.5 **HOT-2**	*		
05:29:15.6 **HOT-1**	ask her if she could turn up the PAPIs for us a lil' bit please. not much.		
		05:29:19.1 **RDO-2**	tower Caribbean five two three is it possible we could turn up the PAPIs ah a knot or two.
05:29:24.8 **HOT-2**	*		
		05:29:29.7 **RDO-2**	thank you.
		05:29:32.1 **TWR**	[sound similar to radio modulation]
05:29:33.9 **HOT-2**	hah.		
05:29:36.6 **HOT-1**	flap thirty.		
05:29:37.7 **HOT-2**	speed checks. flaps thirrrrty.		
05:29:38.0 **CAM**	[sound of click]		
05:29:40.0 **CAM**	[sound of clicks]		
05:29:41.0 **HOT-1**	landing checks please.		
05:29:42.6 **HOT-2**	landing checks.		
05:29:45.2 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:29:47.7 **HOT-2**	landing check. engine start switches.		
05:29:49.2 **HOT-1**	continuous.		
05:29:50.1 **HOT-2**	speed brake.		
05:29:50.7 **HOT-1**	armed.		
05:29:51.1 **HOT-2**	landing gear.		
05:29:51.7 **HOT-1**	down.		
05:29:52.3 **HOT-2**	flap.		
05:29:52.9 **HOT-1**	thirty green.		

TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:29:54.0 **HOT-2**	landing checks complete.		
05:29:54.9 **CAM**	[sound of snap]		
05:29:55.3 **HOT-1**	and missed approach altitude comin'.		
05:29:56.4 **HOT-2**	OLVIK inbound yeh.		
05:29:58.1 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:30:00.2 **HOT-2**	three thousand.		
05:30:00.9 **HOT-1**	three thousand.		
05:30:01.7 **HOT-2**	verified.		
05:30:02.6 **CAM**	[sound of click]		
05:30:03.0 **HOT-1**	one more cloud to come in between.		
05:30:05.0 **HOT-2**	ah hah ha.		
05:30:57.6 **HOT-1**	rain?		
05:30:22.8 **HOT-2**	oh what the jail is this.		
05:30:24.5 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:30:41.1 **HOT-2**	one thousand.		
05:30:41.5 **RA**	one thousand.		
05:30:41.7 **HOT-1**	one thousand feet.		
05:30:59.4 **CAM**	[sound similar to wipers]		
05:30:59.5 **HOT-2**	yep. checked.		
05:31:01.9 **HOT-1**	let's turn on mine here.		
05:31:03.7 **HOT-2**	ya mon'.		
05:31:04.5 **CAM**	[sound of wailer, similar to autopilot disconnect]		
05:31:04.5 **HOT-1**	autopilot comin' off.		
05:31:06.1 **HOT-2**	flight director.		
05:31:13.4 **HOT-1**	autothrottle comin' off.		
05:31:14.3 **HOT-2**	checked...lights.		
05:31:19.7 **RA**	five hundred.		
05:31:20.1 **HOT-2**	five hundred.		
05:31:21.0 **HOT-1**	roger.		
05:31:21.3 **HOT-2**	on bug. all lights.		
05:31:22.5 **CAM**	[sound of clicks and thunks]		
05:31:22.6 **HOT-1**	okay we know where the runway is. just.		
05:31:24.4 **HOT-2**	yep.		

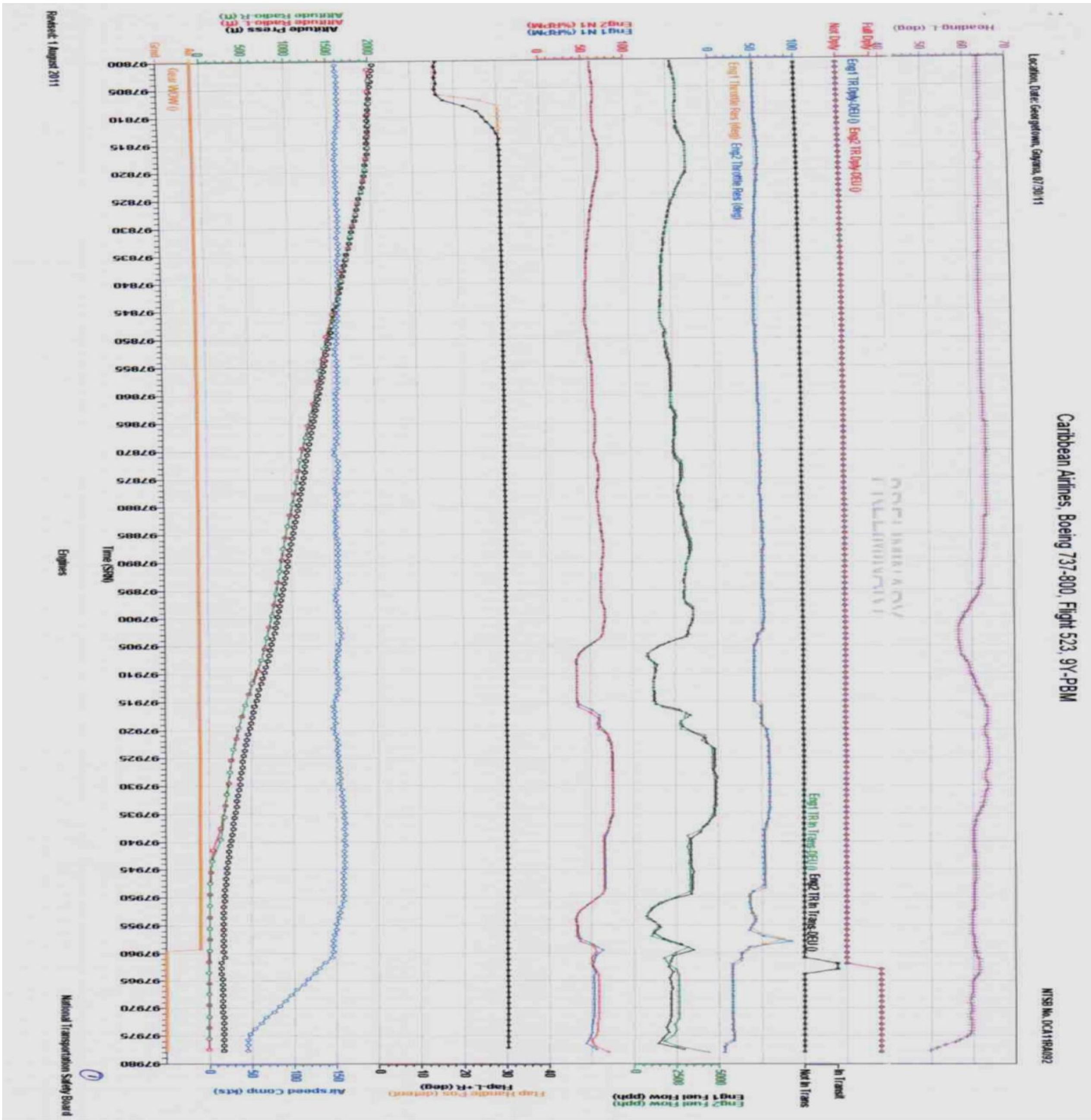
TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:31:25.5 **RA**	plus hundred.		
05:31:26.7 **HOT-2**	checked.		
05:31:28.8 **HOT-2**	speed.		
05:31:31.2 **RA**	minimums.		
05:31:31.7 **HOT-2**	thrust required.		
05:31:32.7 **HOT-1**	yep.		
05:31:36.8 **HOT-1**	ah not landing here.		
05:31:38.2 **HOT-2**	okay two (and) two yeh on profile.		
05:31:38.9 **HOT-1**	okay just (now).		
05:31:42.7 **HOT-1**	put the wipers on high for me.		
05:31:43.5 **HOT-2**	three reds. yep.		
05:31:46.3 **CAM**	[sound of cyclical rattle, similar to trim wheel movement]		
05:31:47.3 **HOT-2**	on profile. speed is good. checked.		
05:31:53.1 **RA**	one hundred.		
05:31:54.6 **RA**	forty.		
05:31:55.9 **RA**	thirty.		
05:31:57.5 **RA**	twenty.		
05:32:00.1 **RA**	ten.		
05:32:00.8 **CAM**	[sound of click]		
05:32:07.1 **CAM**	[sound of muted click]		
05:32:08.9 **HOT-2**	jeez.		
05:32:09.4 **HOT-1**	ah going around. uh 'kay. [breathless]		
05:32:10.1 **HOT-2**	going around. check.		
05:32:10.3 **CAM**	[sound of loud snap]		
05:32:10.8 **HOT-1**	okay.		
05:32:12.6 **CAM**	[sound of rumble, similar to touchdown]		
05:32:13.1 **CAM**	[sound of rumble, similar to touchdown]		
05:32:16.0 **HOT-2**	max?		
05:32:17.2 **HOT-1**	nah. I have it.		
05:32:17.5 **HOT-2**	nah autobrake disarmed. manual braking. checked.		
05:32:20.6 **HOT-1**	okay max.		
05:32:21.9 **HOT-2**	#.		
05:32:23.0 **HOT-2**	nah.		

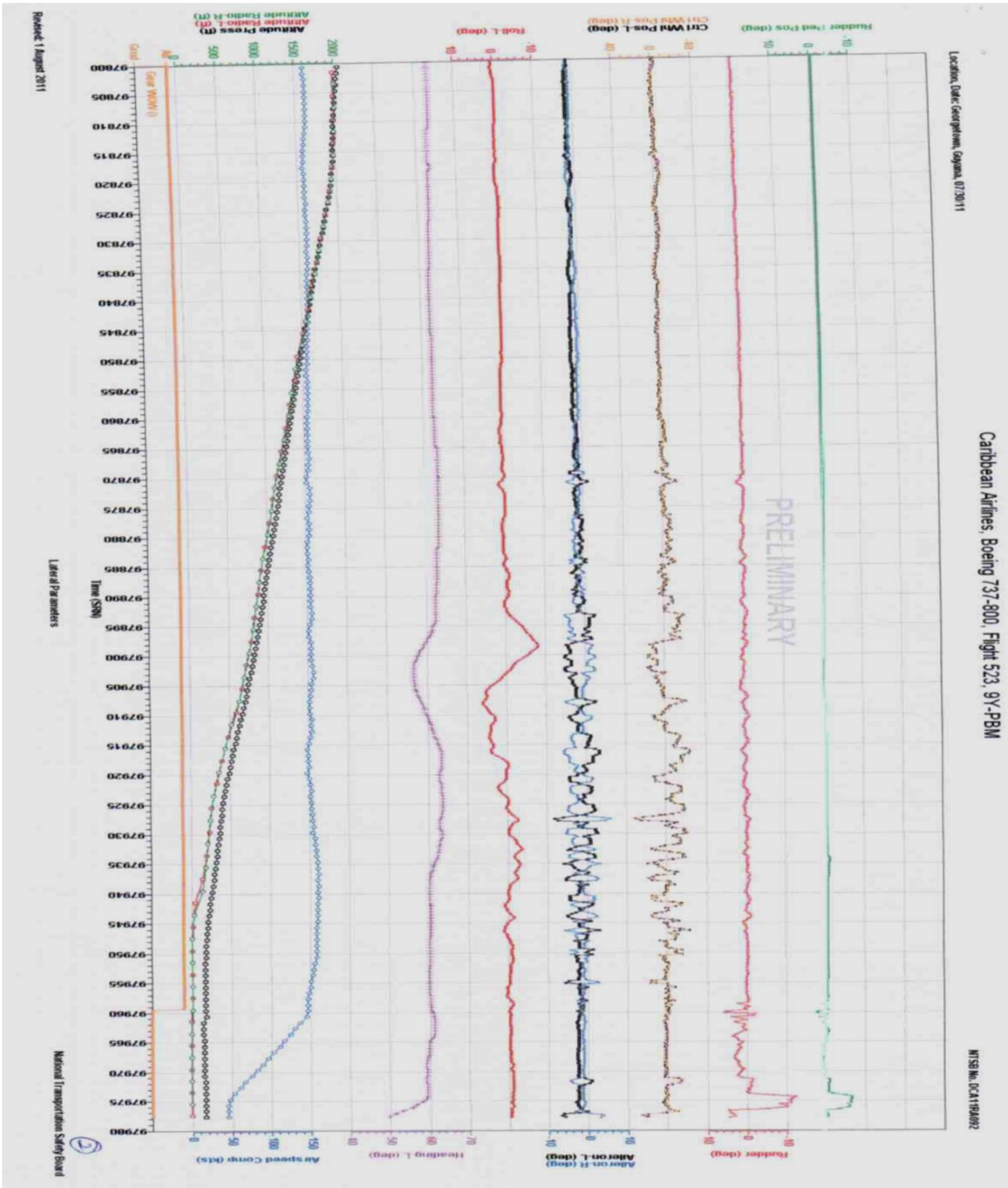
TIME and SOURCE	INTRA - AIRCRAFT CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
05:32:26.4 **HOT-2**	aye yaye yaye.		
05:32:28.6 **HOT-2**	[sound of scream]		
05:32:29.1 **CAM**	[sound of thunk, similar to first impact]		
05:32:29.9 **HOT-1**	[sound of scream]		
05:32:30.6 **CAM**	[sounds of impact]		
05:32:31.8			
END OF TRANSCRIPT			
END OF TRANSCRIPT			

APPENDIX – 3

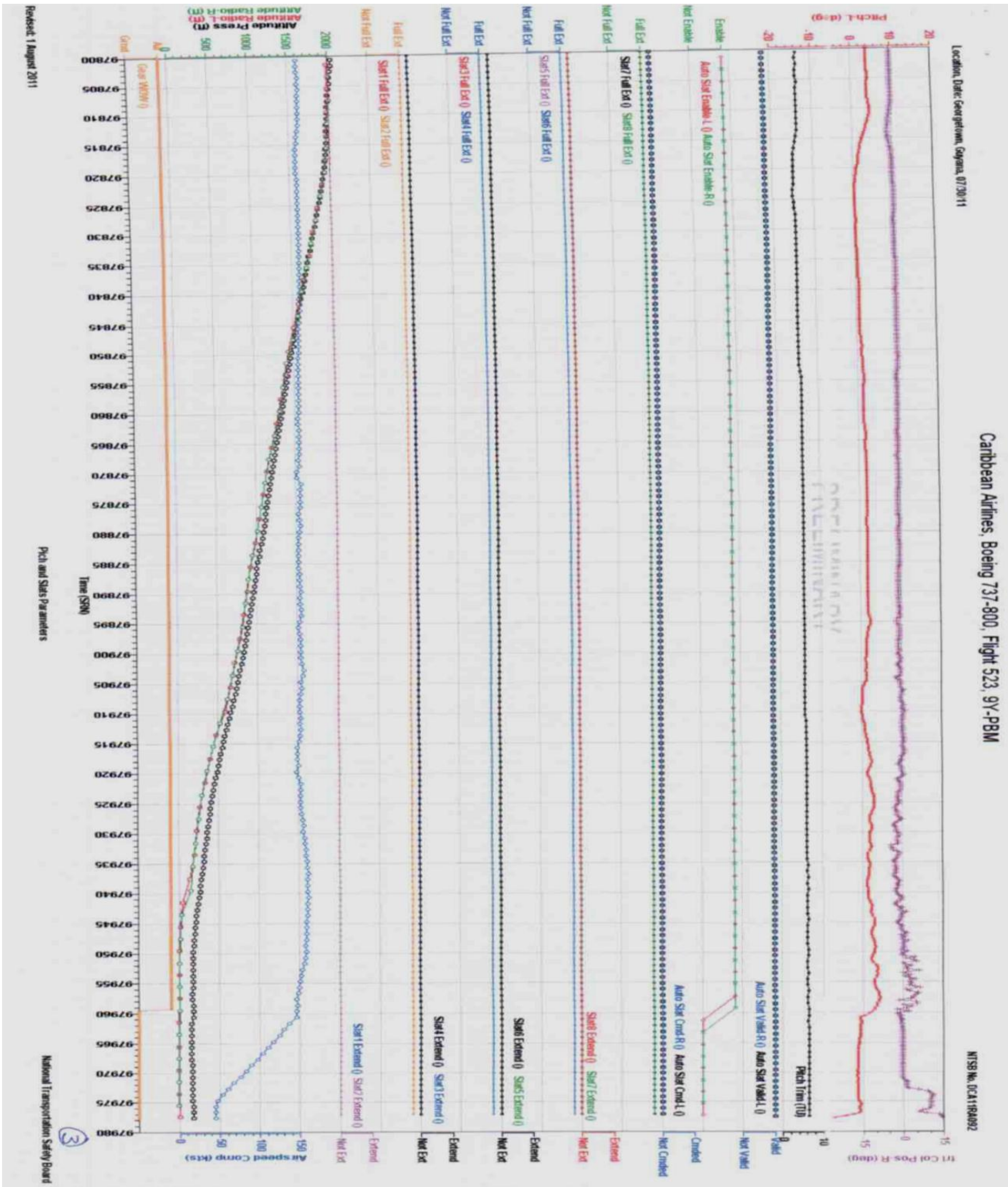
FDR Report

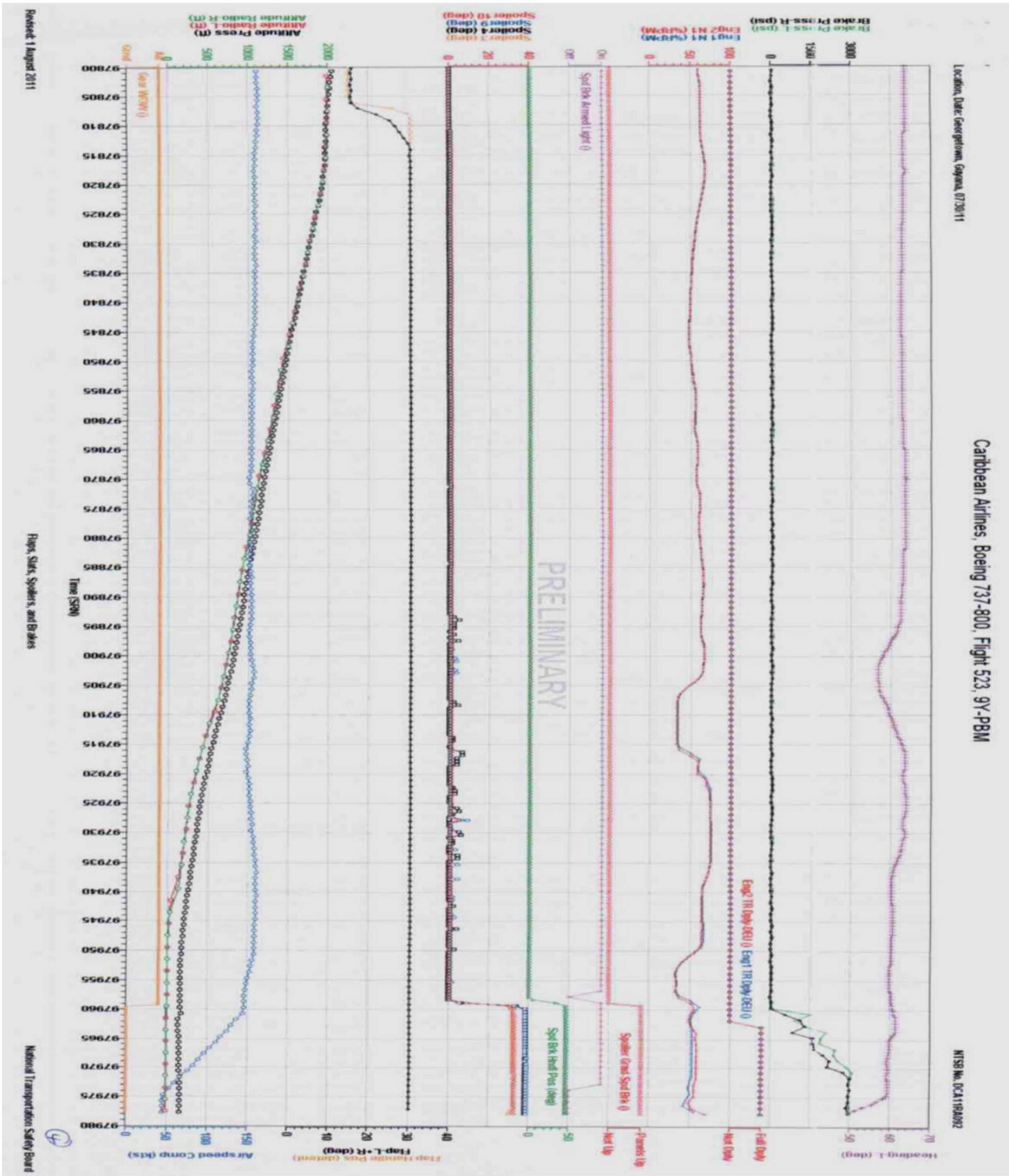
Note: - The figures herein are configured such that right turns are indicated by the trace moving towards the bottom of the page, left turns towards the top of the page and nose up attitudes towards the top of the page.


Caribbean Airlines, Boeing 737-800, Flight 523, 9Y-PBM
Location, Date: Georgetown, Guyana, 07/30/11
NTSB No. DCA11RA092
Engines
Time (SRN)
National Transportation Safety Board
Revised: 1 August 2011



Caribbean Airlines, Boeing 737-800, Flight 523, 9Y-PBM
PRELIMINARY
Lateral Parameters
Time (SRN)
National Transportation Safety Board


Caribbean Airlines, Boeing 737-800, Flight 523, 9Y-PBM
Location, Date: Georgetown, Guyana, 07/30/11
NTSB No. DCA11RA092
Time (SFN)
Pitch and Slats Parameters
Revised: 1 August 2011
National Transportation Safety Board
Altitude Press (ft)
Air speed Comp (kts)
Pitch Trim (TU)
Auto Slat Valid-R () Auto Slat Valid-L ()
Auto Slat Cmd-R () Auto Slat Cmd-L ()
Auto Slat Enable-L () Auto Slat Enable-R ()
Slat7 Fail Ext () Slat8 Fail Ext ()
Slat5 Fail Ext () Slat6 Fail Ext ()
Slat3 Fail Ext () Slat4 Fail Ext ()
Slat1 Fail Ext () Slat2 Fail Ext ()
Slat8 Extend () Slat7 Extend ()
Slat6 Extend () Slat5 Extend ()
Slat4 Extend () Slat3 Extend ()
Slat1 Extend () Slat2 Extend ()
Gear WOW ()


Caribbean Airlines, Boeing 737-800, Flight 523, 9Y-PBM
Location, Date: Georgetown, Guyana, 07/30/11
NTSB No. DCA11RA092
PRELIMINARY
Time (SRN)
Flaps, Slats, Spoilers, and Brakes
Revised: 1 August 2011
National Transportation Safety Board

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APPENDIX – 4

AIRCRAFT PERFORMANCE

National Transportation Safety Board
Office of Research and Engineering
Washington, D.C. 20594

Airplane Performance Study

Technical Advisor's Report
Timothy Burtch

A. ACCIDENT

Location:	Georgetown, Guyana
Date:	July 30, 2011
Time:	0532 GMT (1:32 am Guyana local time)
Airplane:	B-737-800, 9Y-PBM
NTSB Number:	DCA11RA092

B. GROUP

Technical Advisor:	Timothy Burtch National Transportation Safety Board Washington, DC
Member:	Mike Charles Ministry of Transport, Guyana Pilot
Member:	Robby Heerenveen Civil Aviation Safety Authority, Suriname Flight Safety Manager
Member:	Walter Willis Ministry of Public Works and Communication, Guyana

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

C. SUMMARY

On July 30, 2011, at approximately 1:32 am Guyana local time (LST), a Boeing 737-800, Trinidad & Tobago registration 9Y-PBM, operated by Caribbean Airlines as flight 523, overran the runway at Cheddi Jagan International Airport, Georgetown, Guyana. Of the 156 passengers and six crew on board, there was reportedly one serious and multiple minor injuries. The airplane fractured in two pieces as a result of the overrun. Weather was reported as raining at the time of the accident.

The flight was a scheduled passenger flight from Piarco International Airport, Port of Spain, Trinidad & Tobago (POS), and originated at John F. Kennedy International Airport in New York.

D. PERFORMANCE STUDY

The performance study describes the airplane motion during the accident sequence based on the available data sources. This includes airplane position, speed, and attitude derived from the recovered Flight Data Recorder (FDR), weather information services, and data collected during the on-scene portion of the investigation.

Times in the study are reported in Greenwich Mean Time (GMT): LST = GMT – 4 hr.

No radar data was available for the accident.

Weather Observation

Cheddi Jagan International Airport (GEO or ICAO id SYCJ) has an approximate field elevation of 95 feet above mean sea level and a magnetic variation of 16° west. The two weather observations taken one mile south of the field around the time of the accident (0132 LST) are as follows. (Note: cloud heights are reported above ground level.)

METAR SYCJ 300500Z 00000KT 9000 -SHRA FEW014CB BKN015 25/24 Q1009 CB-NE-ENE NOSIG=
SYCJ weather at **0100 LST**, wind calm, visibility 9 kilometers in light rain showers, a few clouds at 1,400 feet in cumulonimbus clouds, ceiling broken at 1,500 feet, temperature 25° Celsius (C), dew point 24° C, QNH 1009-hPa, cumulonimbus clouds northeast through east-northeast, no significant change expected.

METAR SYCJ 300600Z 00000KT 9000 BKN015 24/24 Q1008 NOSIG=
SYCJ weather at **0200 LST**, wind calm, visibility 9 kilometers, ceiling broken at 1,500 feet, temperature and dew point 24° C, QNH 1008-hPa, no significant change expected.

A more detailed description of the weather can be found in the Meteorological Field Notes.[1]

[1] "Meteorological Field Notes", DCA11RA02, August 2, 2011

2

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

Performance Study Window

Caribbean Airlines flight 523 proceeded from Port of Spain to Georgetown at flight level 330 and was cleared for the RNAV approach to runway 06. See Figure 1 for details on the instrument approach.

Figure 2 shows the last 20 nm of Caribbean Airline flight 523's approximate ground track into GEO based on integrated FDR accelerometer data[2]. The Initial Approach Fix for the "RNAV Rwy 6" approach is AKSIN, and it is approximately 11.2 nm from the airport along the extended runway centerline. The Final Approach Fix (FAF) for the "RNAV Rwy 6" approach is OLVIK, which is approximately 5.2 nm from the airport.

The airplane touched down on runway 06, but it did not stop before it exited the departure end of the runway, eventually stopping 130 ft off the end and about 64 ft to the left of the extended runway centerline. The airplane ran through a chain link fence and across a dirt road before the main gear became embedded in a small dirt berm on the far side of the road. Figure 3 shows the airplane in its final resting position. The FDR ended about the time the airplane collided with the chain link fence.

Nothing about the flight appeared unusual until the airplane was approaching the runway. The performance study focuses on the flight from just inside OLVIK until the end of the FDR.

FDR Summary

Figures 4 through 7 show select FDR parameters from approximately the FAF as a function of time. All recorded data are shown with symbols. A small runway is shown on the bottom right corner of the time histories to indicate the approximate location of the runway.

The FDR data indicate that the flaps were extended from 15 to 30 degrees just inside OLVIK at 05:29:39. The accelerations in Figure 4 all show that the airplane touched down about 2.5 minutes later at 05:32:12. The weight-on-wheels discrete signal recorded on the FDR indicates touchdown at the same time.

Figure 5a shows the airplane touching down at a computed airspeed of 146 kt (and a groundspeed of 151 kt as shown in Figure 5c.). The throttles were set to 75% N1 about 15 seconds prior to crossing the runway threshold and were transitioning from 75% N1 to 65% N1 as the airplane crossed the threshold at approximately 05:31:50. The throttles stayed at a 65% N1 level until 05:32:01 when they were reduced to a level that reached 33% N1 at 05:32:06, six seconds before touchdown. The throttles were advanced three seconds before touchdown and the average N1 reached about 59% near touchdown at 05:32:12[3]. The thrust

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[2] The integration in Figure 2 is about eight minutes long. The NTSB had no radar data to use as boundary conditions for the integration. As a result, the ground track is included only to provide an approximate ground track for the approach. Ground scars and the airplane's final resting spot were used to bound the integration closer to the airport.

[3] The CVR contains comments about going around just before touchdown. See Figure 18.

reversers deployed approximately two seconds later at 05:32:14 as N1 was increasing from 51% to 58%.

Figure 5b shows that the airplane largely maintained a 3 degree glideslope throughout the approach except for a twenty second window starting around 05:31:20. This corresponds to time just after the auto-throttles were disengaged and the power was reduced to 34% N1. The flight path angle was as steep as 5 degrees during this period.

Figure 5c shows the parameters from Figures 5a and 5b but with a larger scale.

The lateral FDR parameters in Figure 6 show almost no control input until the autopilot was disconnected at 05:31:05. At this point there are small aileron and spoiler inputs (less than 5 degrees) all the way to the end of the FDR. The directional parameters in Figure 7 are similar except there are rudder inputs upwards of 5 degrees beginning at touchdown.

Integration of Final Three Minutes

To examine the winds that were present during the landing and to view pertinent FDR and calculated parameters relative to the airplane's location on the runway, the FDR accelerometer data were integrated to obtain an inertial velocity and position. As previously mentioned, the NTSB did not have radar data for the accident. Instead, the accelerometer biases needed to perform the integration were calculated using position derived from FDR groundspeed and drift angle. The biases that were calculated and applied are listed in Figure 8. The true north and east positions relative to the airport origin[4] that resulted from the integration are shown in Figure 9.

The Winds

The winds are the difference between the inertial velocity determined from the accelerometer integration and the true airspeed which can be calculated from parameters recorded on the FDR. The calculated wind speed and direction, as well as those recorded on the FDR, are shown in Figure 10a as a time history. The calculated winds are also plotted in Figure 10b as a function of the height above the ground. Figure 10 indicates that the wind speed decreased below 5 kt and the wind direction shifted almost 180 degrees on short final. This corresponds to a point in the approach where the Caribbean crew reported seeing three red lights on the Precision Approach Path Indicator (PAPI)[5]. The shift may be explained by the rapidly increasing elevation of the terrain that exists approaching the threshold of runway 06. Other orographic changes (e.g., the transition from jungle to the airport environment) may have also contributed to the wind change. See Figure 11.

[4] Sworn Licensed Surveyor SLS R.I. Choo-Shee-Nam of Geomatics & Valuations referenced a point referred to as the "airport origin". It was located on the centerline and at the threshold of runway 24. All longitudinal and lateral displacements, as well as east and north distances, are with respect to this point.
[5] PAPI is a visual aid that provides a pilot with vertical guidance to the runway.

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

Over the Runway

Figures 12 through 15 show select FDR parameters over the runway until the end of the FDR recording. Figure 12 shows the integrated ground path over the runway as well as the approximate touchdown point. Main gear touchdown occurred at or slightly beyond taxiway A (see Figure 18), just in front of the airport ramp[6]. This was approximately 4900 ft down the runway (4700 ft from the threshold), leaving 2900 ft until the end of the pavement (2700 ft until the end of the runway).

The ground spoilers were armed and, as a result, deployed around the time of touchdown at 05:32:12 as shown in Figure 13a. The thrust reversers[7] deployed approximately two seconds later at 05:32:14 when the airplane was 2000 ft from the end of the runway or 2200 from the end of the pavement.

Figure 13b shows that the brake pressure increased gradually starting at touchdown. The maximum brake pressure of 3000 psi was not reached until the airplane was 250 ft from the end of the runway or 450 from the end of the pavement.

Figure 14 indicates that the calculated airplane braking coefficient for the combined wheel, brake, anti-skid, and grooved runway surface reached a maximum value of 0.35[8]. Figure 15 shows the Boeing and NTSB calculated airplane braking coefficient and FDR brake pressures versus groundspeed. Both Boeing and NTSB calculations indicate that the accident airplane demonstrated braking levels that were as good as or better than that for a CFR 25.109 "wet grooved" runway above 70 kt.

Boeing Computed Landing Distances from the QRH

Boeing advisory landing data[9] are located in the Quick Reference Handbook (QRH). The QRH is a convenient sized notebook which is in the possession of the flight crew and contains tabular charts of airplane performance. These charts, which are based on unfactored dry landing distances, include a number of landing distance adjustments based on braking configuration, weight, wind, runway slope, temperature, touchdown speed, reversers, and reported braking action.

Figures 16a and 16b contain estimated landing distances from Boeing's QRH for both the FAA and the JAA regulations, respectively, for the accident conditions.

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[6] There were 14 Caribbean Airline personnel on or near the airport ramp at the time of the accident landing that were interviewed. The ramp position is directly abeam the runway that spans taxiways A and B. Of these 14, 9 placed the airplane's main gear touchdown point between taxiway A and taxiway B. Four did not actually see the airplane touchdown. One placed the touchdown point just beyond taxiway B.

[7] Thrust reversers are most effective at higher speeds and on contaminated runway surfaces.

[8] This number represents the total airplane braking coefficient and does not distinguish between airplane stopping performance/capability and the runway surface to tire friction coefficient. Factors such as tire tread depth, brake wear, anti-skid efficiency, and runway contaminants were not considered.

[9] Advisory data as opposed to certification data, also referred to as "dispatch" or "factored" data that fulfill the requirements of CFR 14 Part 25. QRH landing distances assume Detent 2 reverse thrust and, for "good braking", an average airplane braking coefficient of 0.2 that does not vary with groundspeed.

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

Caribbean flight 523 had approximately 2900 ft of pavement to stop on when it touched down 4900 ft down the runway in Georgetown. Assuming "good" braking action and the associated average braking coefficient of 0.2, the QRH estimates indicate that the airplane could not be stopped before overrunning the runway. The QRH indicates that 4867 ft is required with Autobrakes 3 selected or, in the best case, 3550 ft is needed to stop with maximum manual braking. These numbers account for the 1000 ft air distance noted in footnote 10. The landing distances increase with "medium" braking action: 5620 ft with Autobrakes 3 and 5266 ft with maximum manual braking.

On the other hand, Boeing's landing distance estimates using a calculated airplane braking coefficient as a function of groundspeed indicate that it was possible to stop the airplane on the runway using either Detent 2 or maximum reverse thrust. The FDR-based braking coefficient along with Detent 2 reverse thrust after touchdown resulted in the airplane stopping approximately 50 ft before the end of the improved runway surface in the 737-800 simulation.

CVR Overlays

Finally, Figures 17-19 show the approach into Guyana from the FAF with increasing scale, including the integrated ground track and comments recorded on the cockpit voice recorder (CVR). The rumbles on the CVR support the touchdown estimates quoted earlier.

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

Summary

Flight 523 was properly configured for landing at Georgetown, Guyana, early the morning of July 30, 2011. There was no evidence of an airplane malfunction, and the airplane reached the runway threshold close to the QRH reference speed of Vref=149 kt.

The airplane touched down 4900 ft down the runway, leaving 2900 ft of pavement to stop on. The touchdown was 3700 ft beyond the runway "aiming point" (or fixed distance marker) and 1700 ft beyond the runway touchdown zone for landing operations. Assuming good braking on a wet runway with an average airplane braking coefficient of 0.2, the airplane could not have stopped before reaching the end of the runway using Autobrakes 3.

The captain carried a power setting of 65% N1 for approximately the first 2000 ft of runway. The high power setting explains the excessive float during the flare reported by the crew as well as the long touchdown; Boeing was able to match Caribbean flight 523's performance with their B-737-800 simulation using the recorded FDR inputs. When the TLA's were reduced to flight idle at 20 ft agl in the simulation, the airplane touched down over 1700 ft sooner than with the actual FDR TLA's. Select simulation time histories are shown in Figure 20. Boeing also used the simulation to show that it was possible to remain on the runway using Detent 2 reverse thrust. This is shown in Figure 21.

The ground spoilers deployed at touchdown. The thrust reversers deployed to a position between idle and Detent 2 reverse thrust approximately three seconds after touchdown and 2000 ft from the end of the runway. The Detent 2 reverse thrust position assumed in the QRH estimates was never obtained by the Caribbean crew.

Timothy Burtch
Technical Advisor – Airplane Performance
National Transportation Safety Board

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

E. Figures

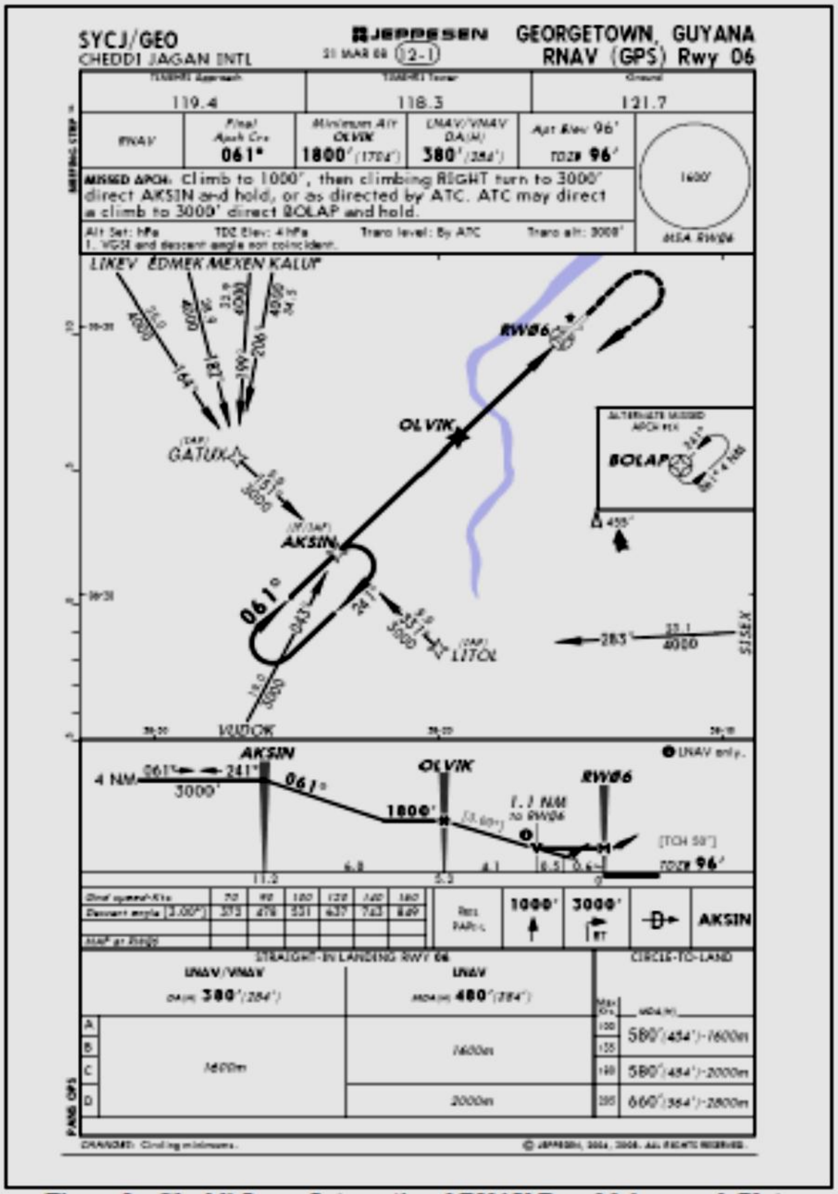


Figure 1: Cheddi Jagan International RNAV Rwy 06 Approach Plate

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

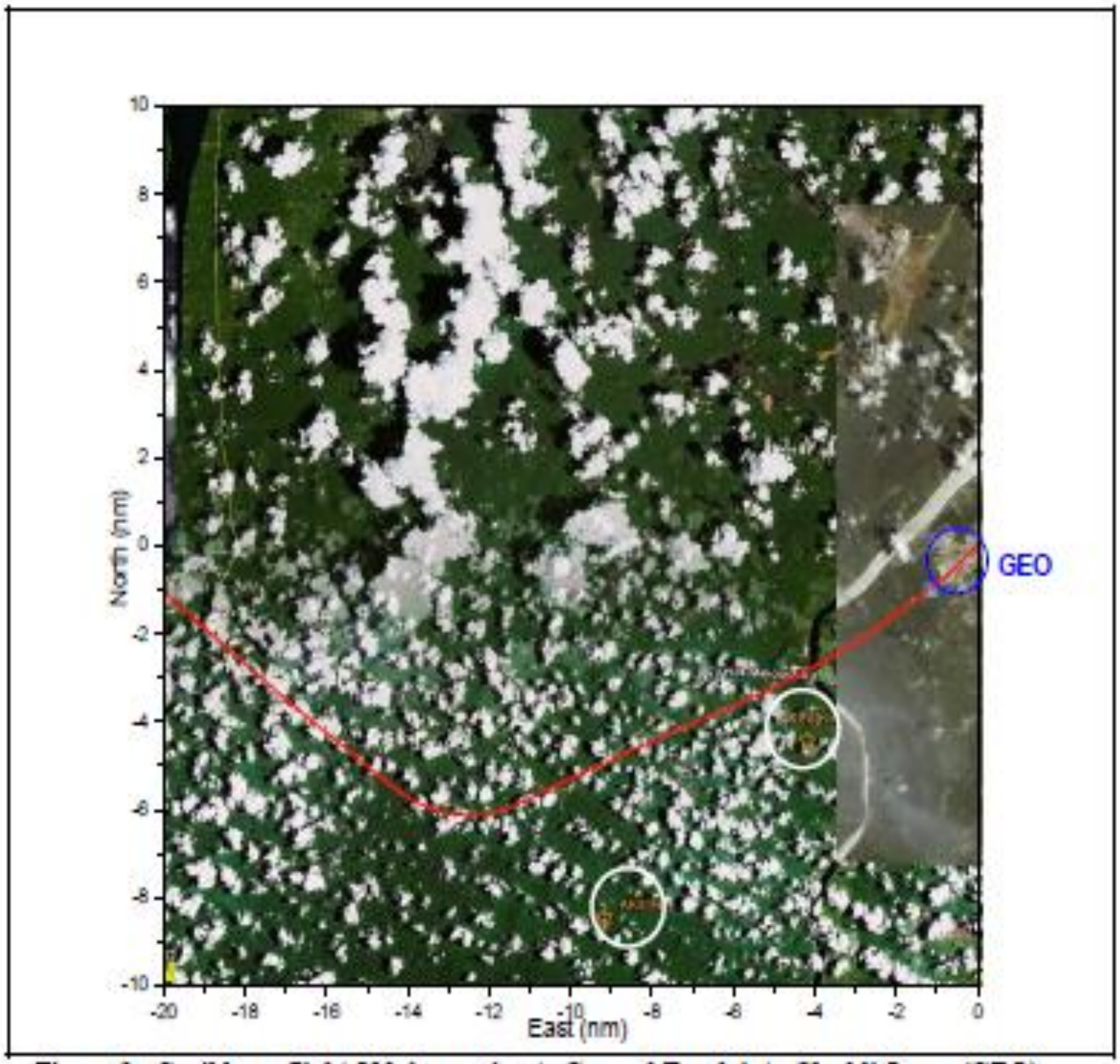


Figure 2: Caribbean flight 523 Approximate Ground Track into Cheddi Jagan (GEO)

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

Figure 3: Caribbean flight 523 Stopped Approximately 130 ft Off of the End and 64 ft Left

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

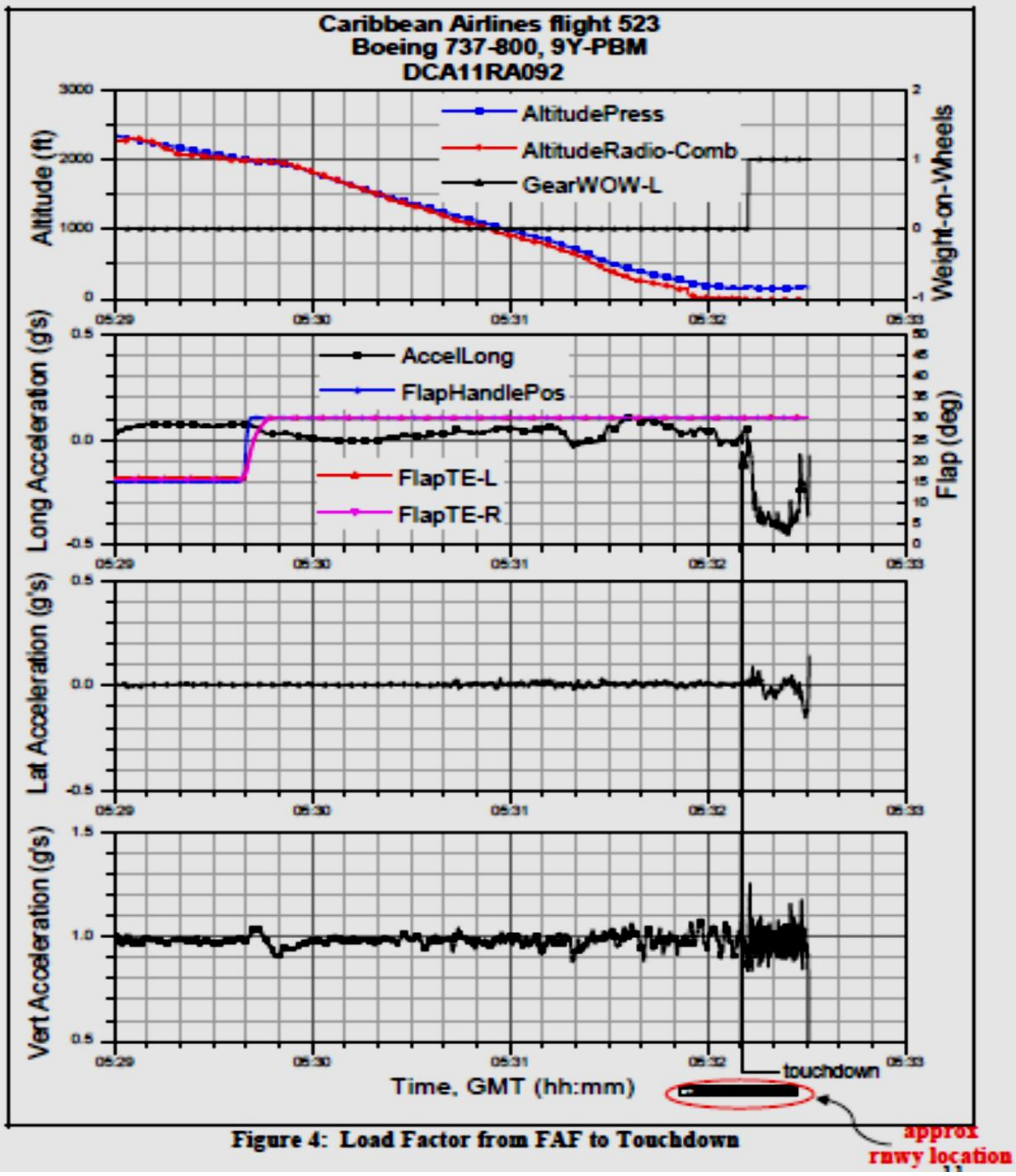


Figure 4: Load Factor from FAF to Touchdown

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

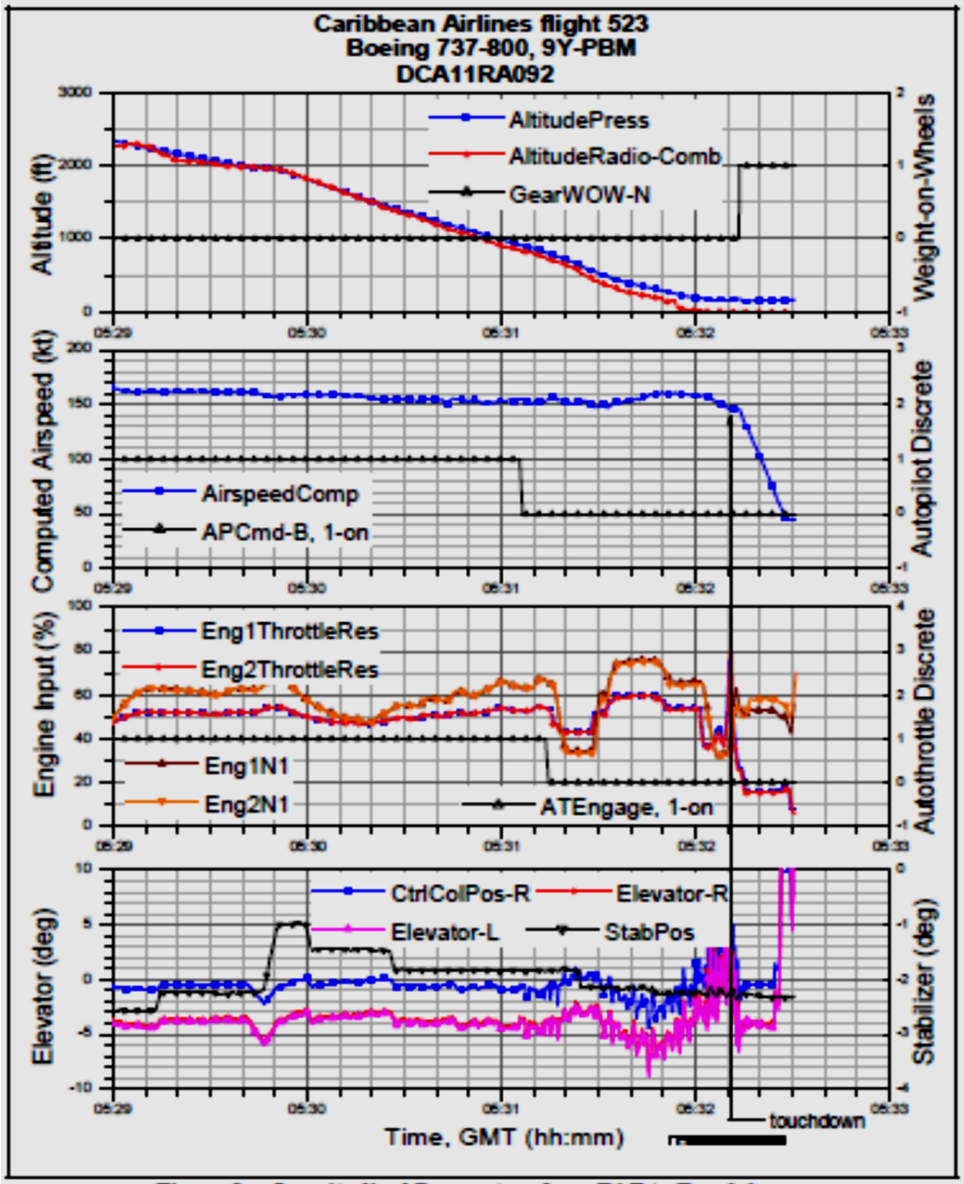


Figure 5a: Longitudinal Parameters from FAF to Touchdown

12

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

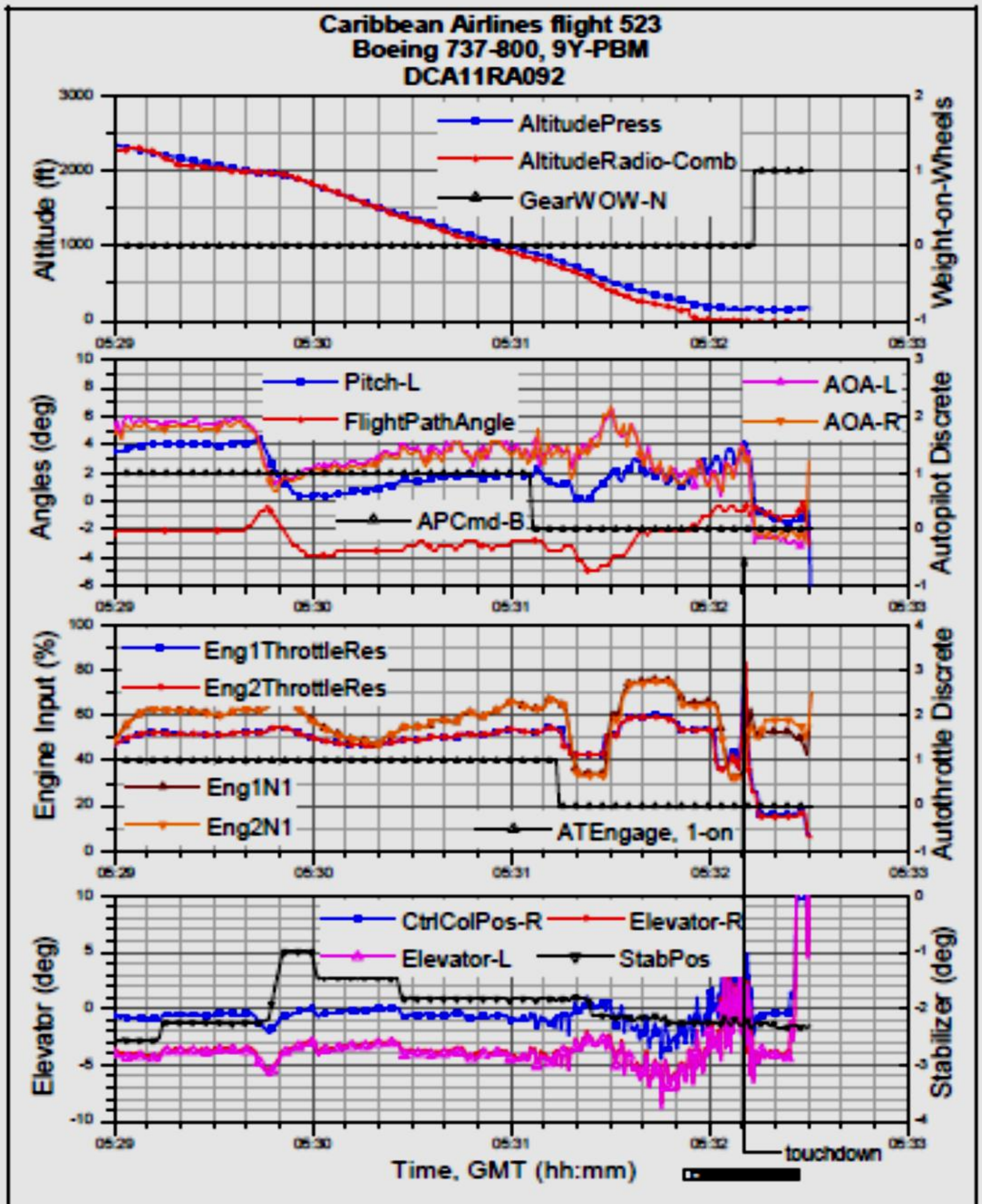


Figure 5b: Longitudinal Parameters from FAF to Touchdown

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

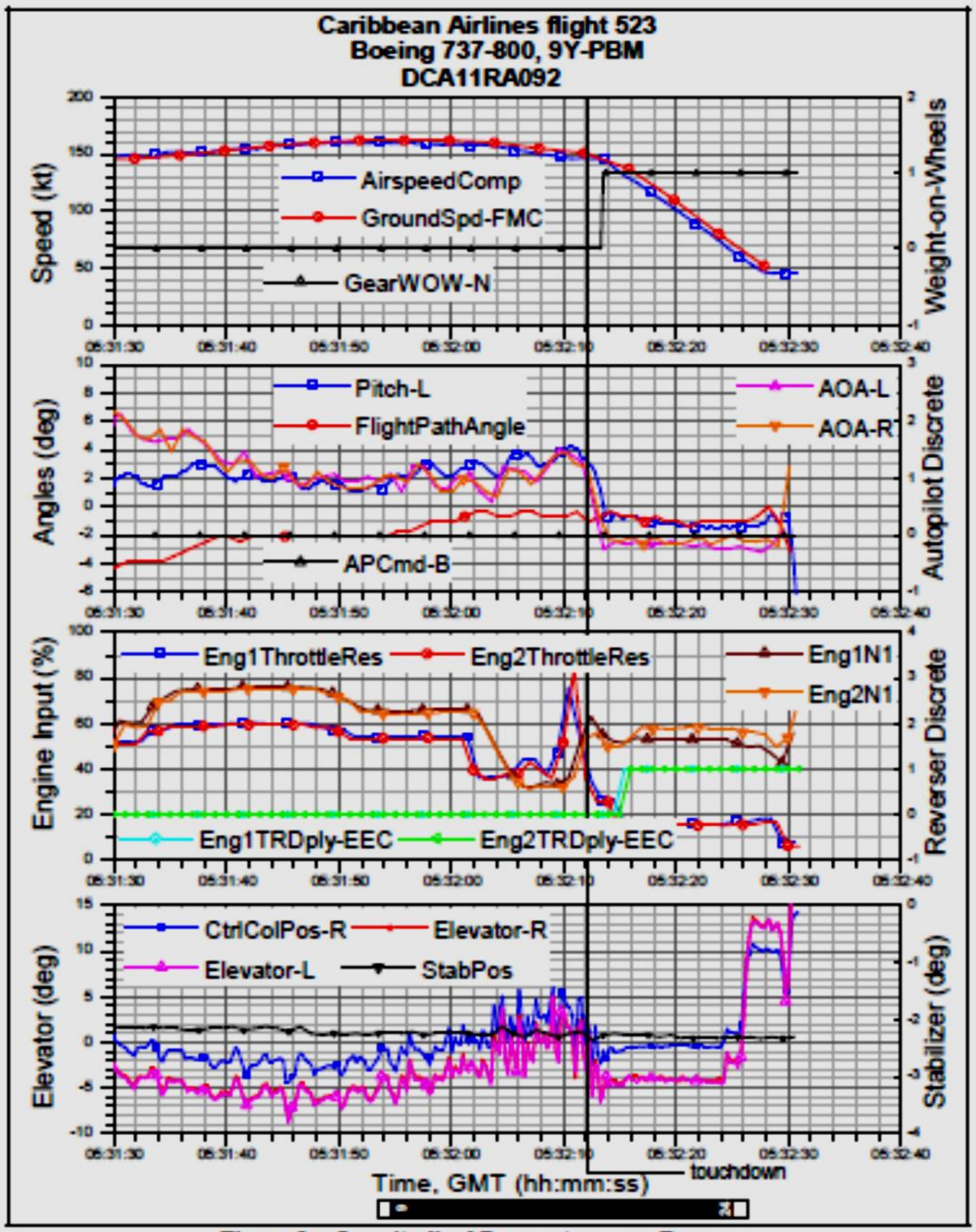


Figure 5c: Longitudinal Parameters over Runway

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

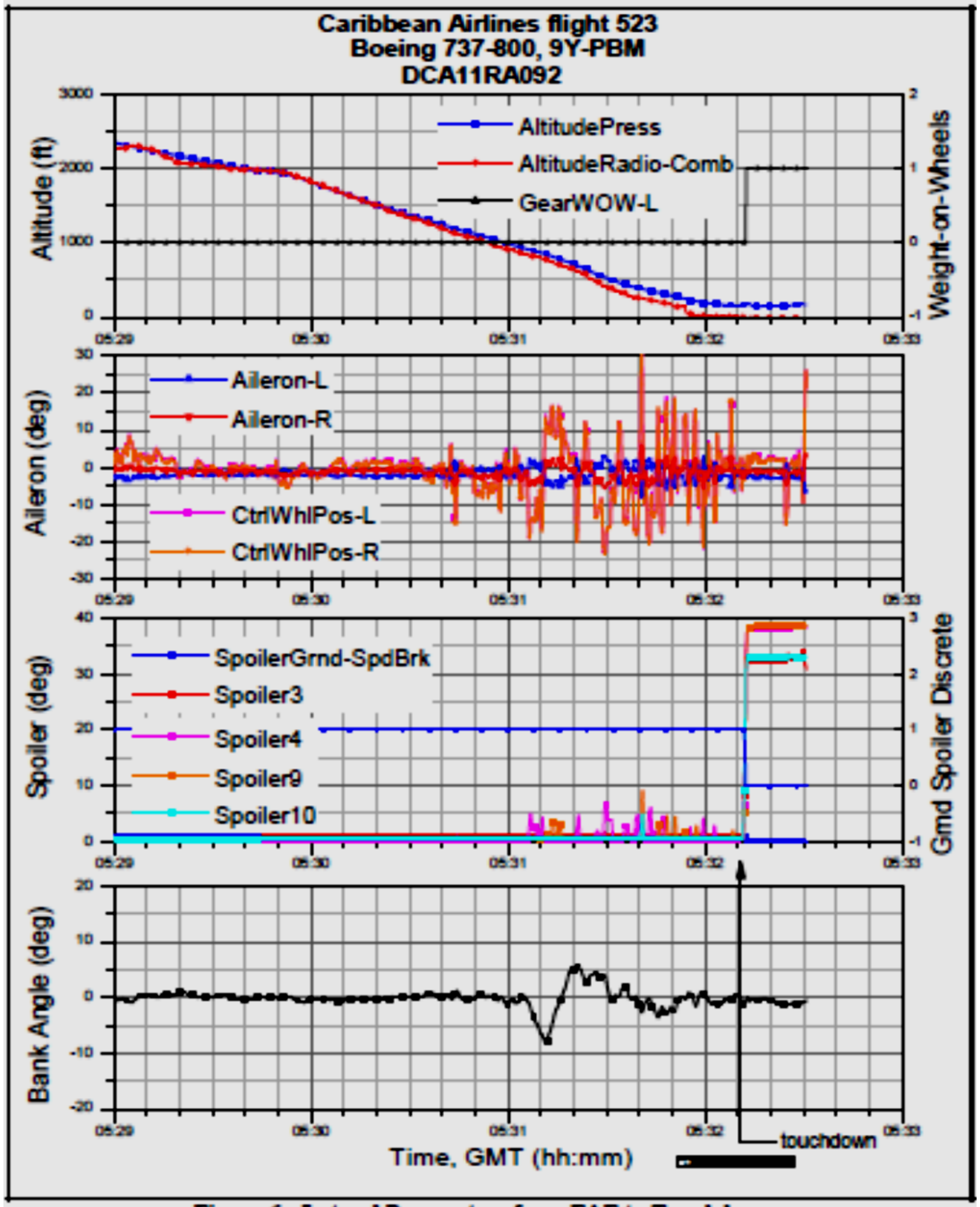


Figure 6: Lateral Parameters from FAF to Touchdown

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

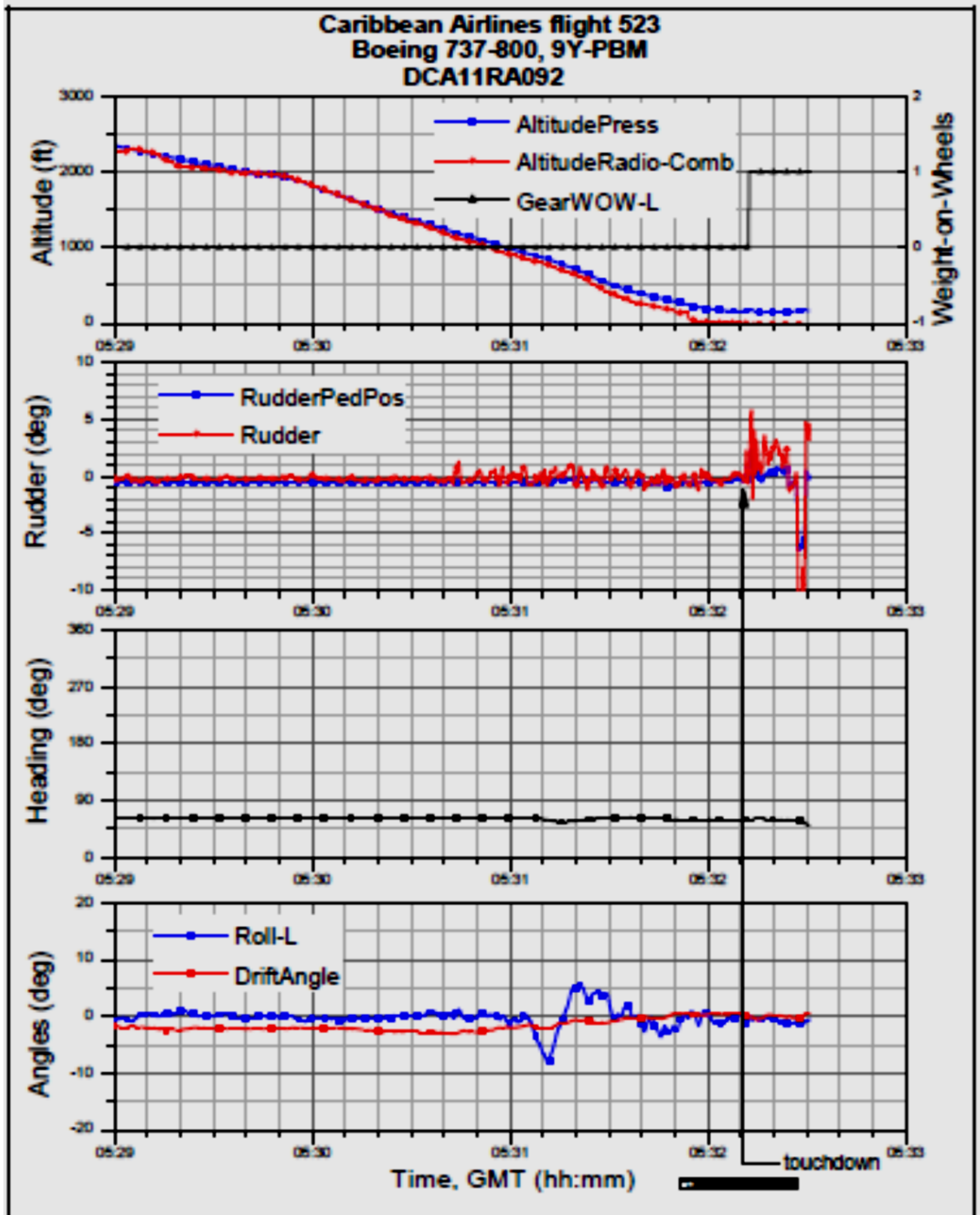


Figure 7: Directional Parameters from FAF to Touchdown

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

Axis	Bias (g)
X	-0.002421
Y	-0.005207
Z	-0.017142

Figure 8: Accelerometer Biases Used in Integration

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

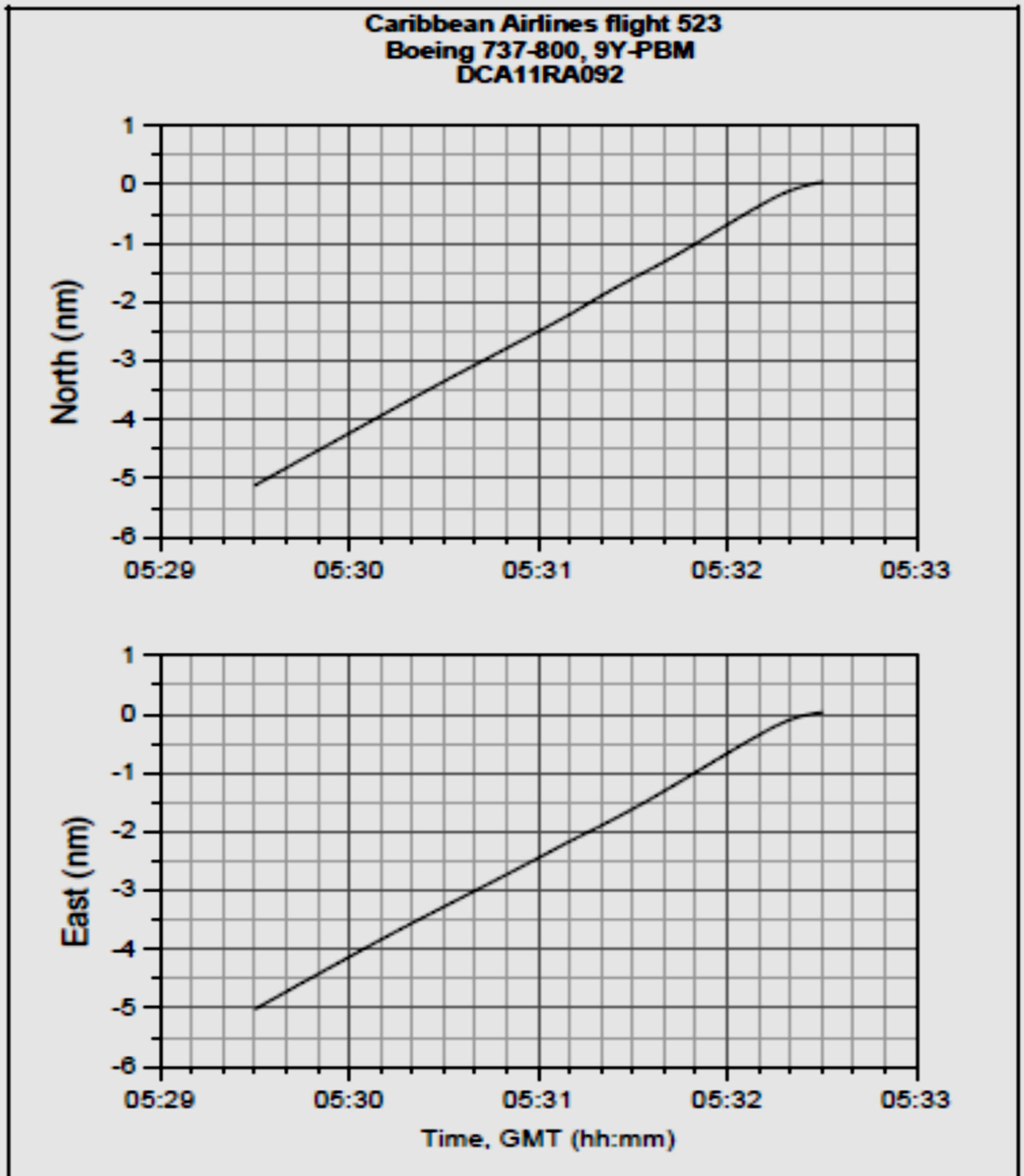


Figure 9: True North and East Relative to Airport Origin from FAF to Touchdown

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

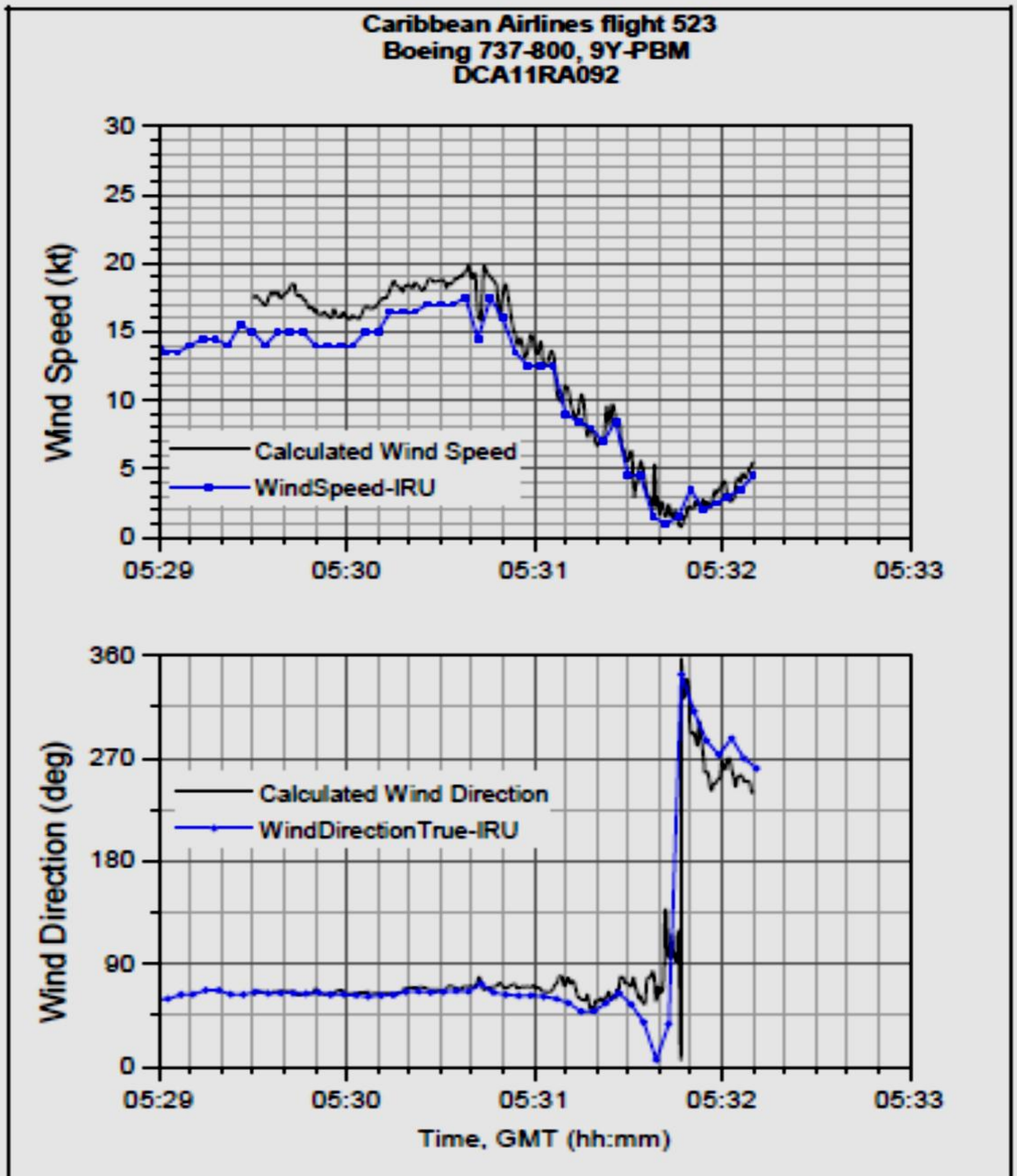


Figure 10a: FDR and Calculated Wind during Approach and Landing

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

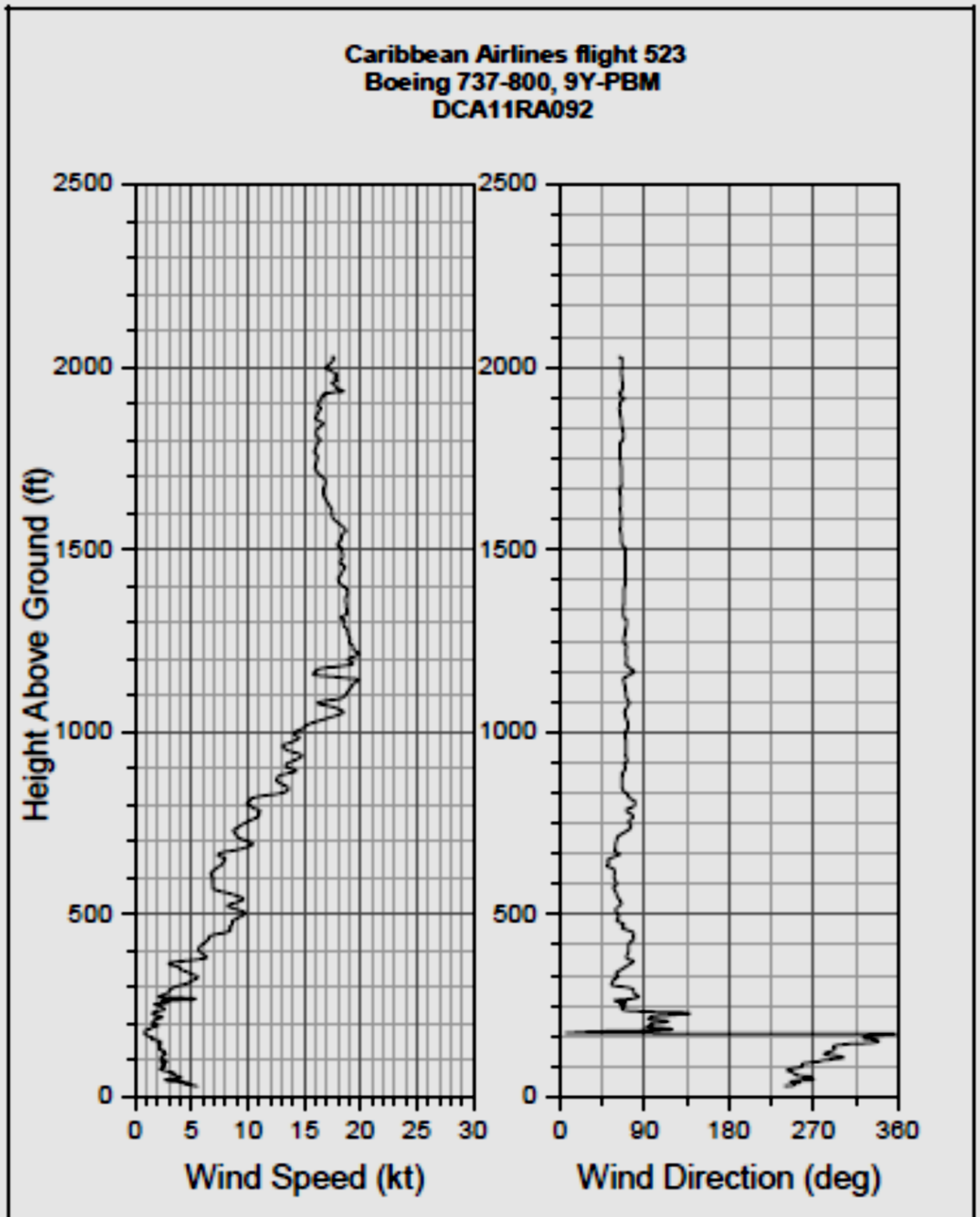


Figure 10b: Calculated Wind during Approach and Landing

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

Figure 11: Increasing Terrain Elevation as the Jungle Disappears Approaching Runway

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

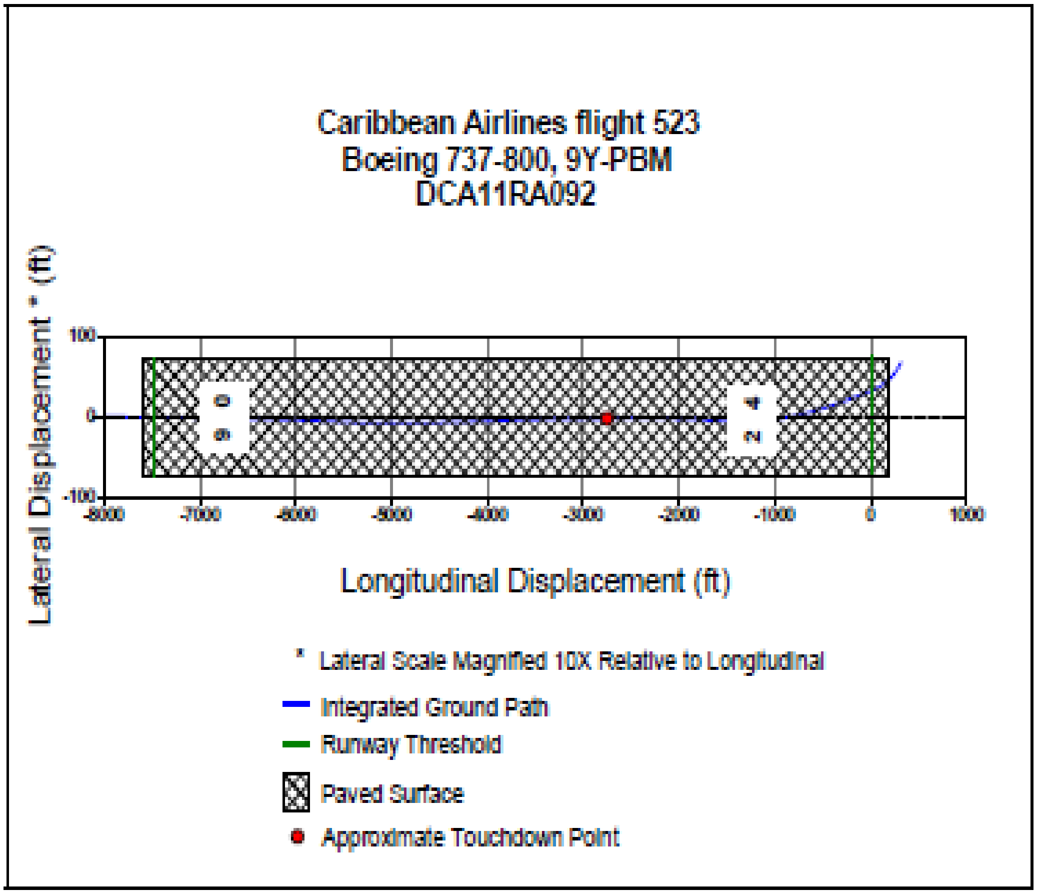


Figure 12: Integrated Ground Path over Runway

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

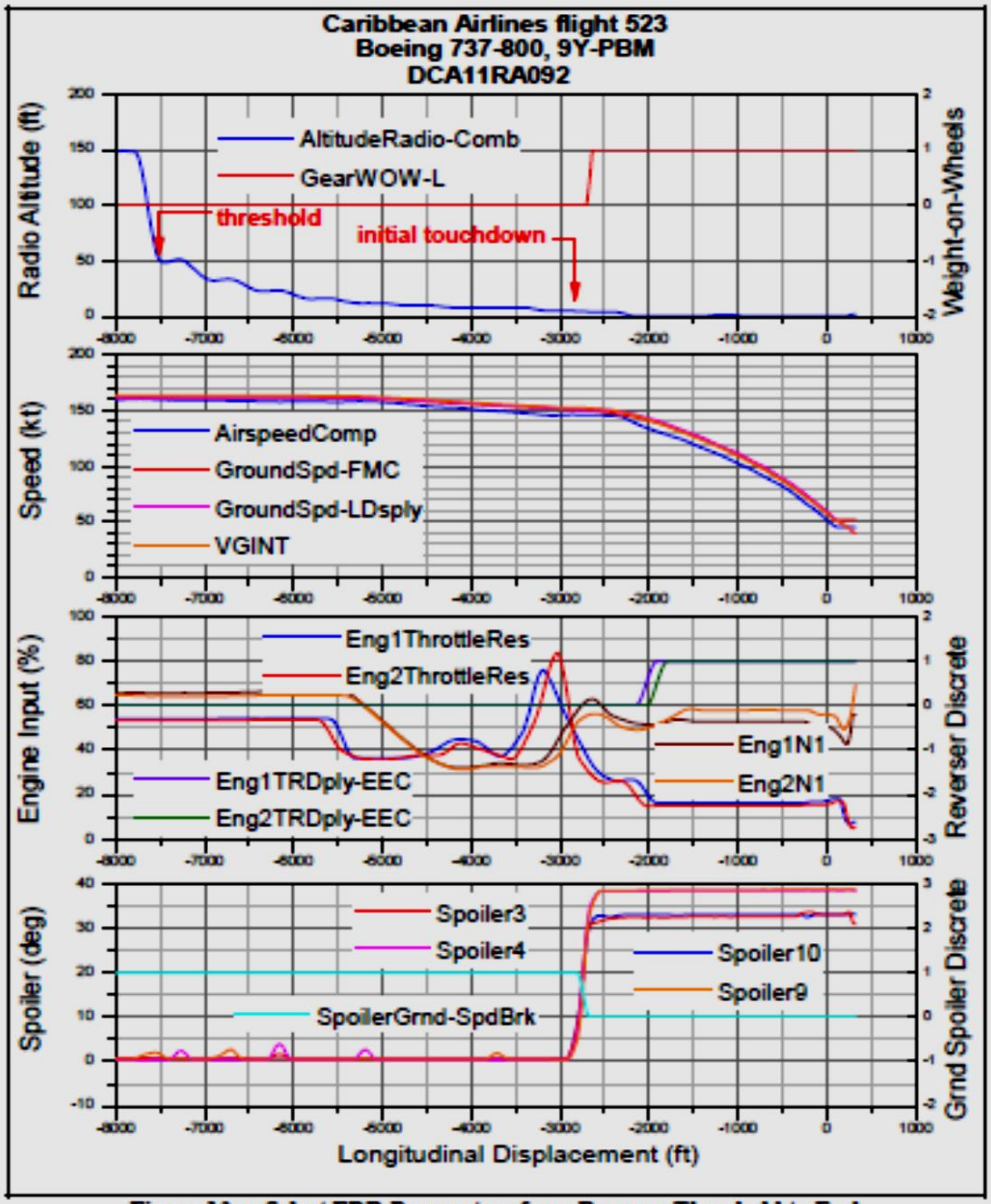


Figure 13a: Select FDR Parameters from Runway Threshold to End

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

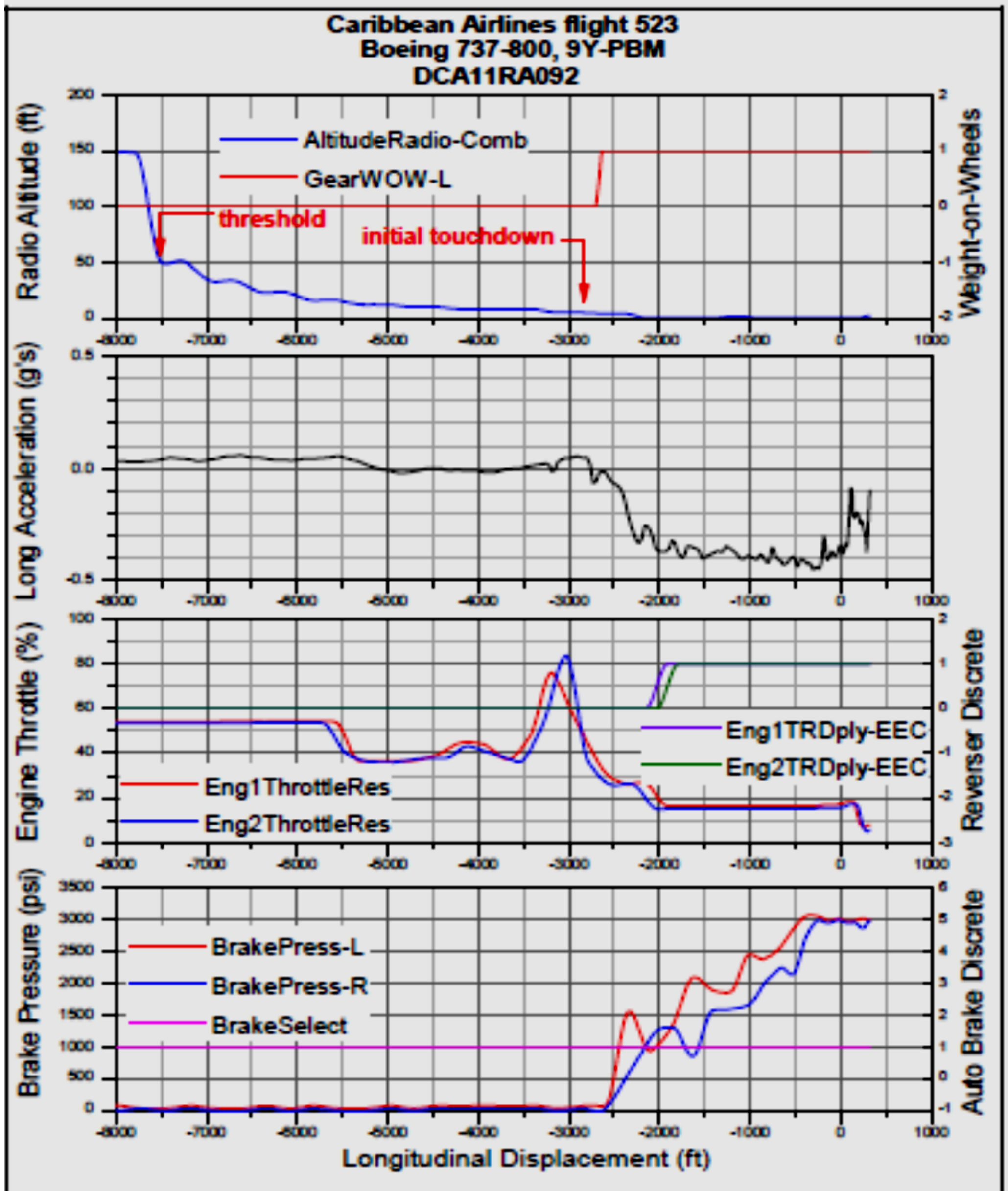


Figure 13b: Select FDR Parameters from Runway Threshold to End

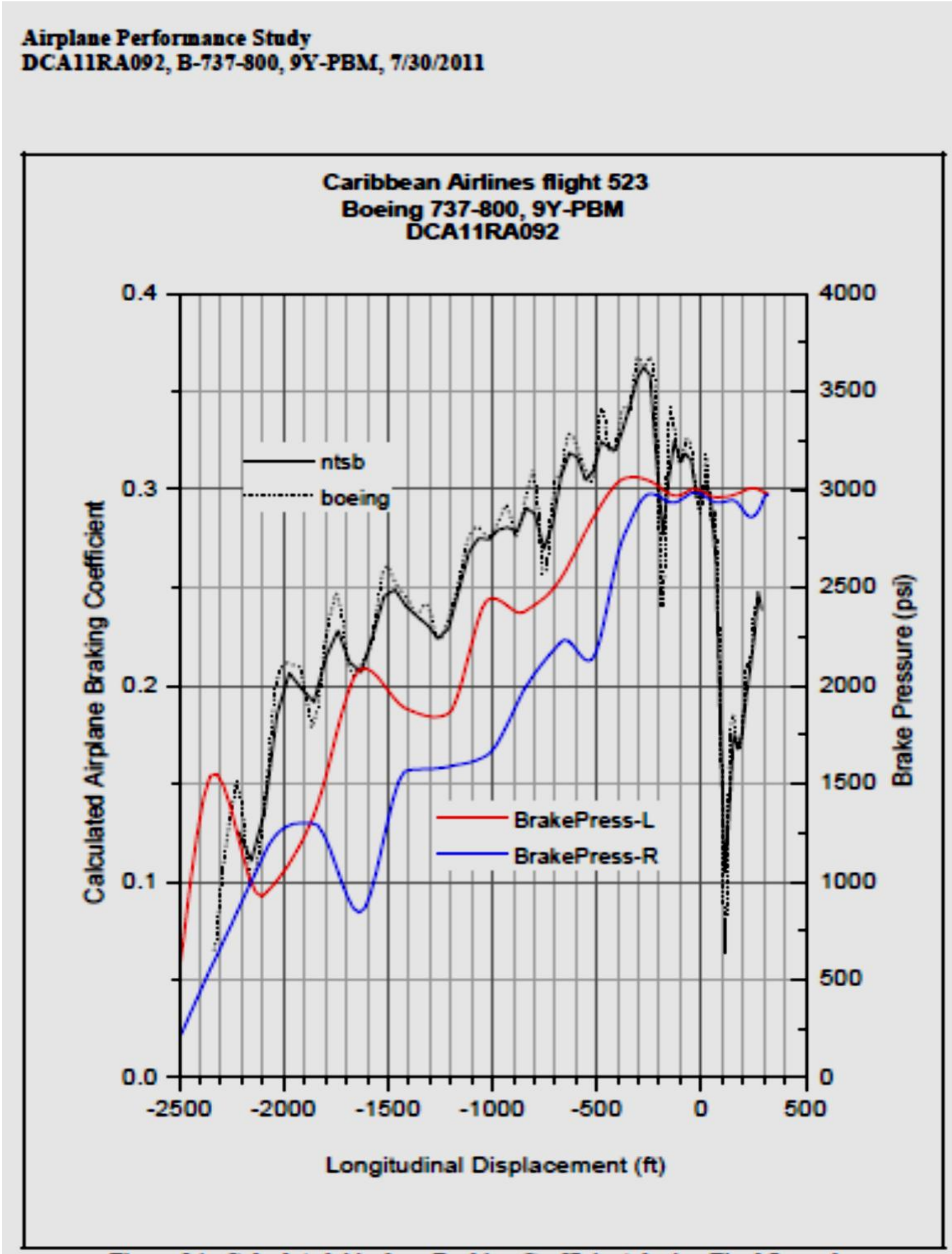


Figure 14: Calculated Airplane Braking Coefficient during Final Seconds

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

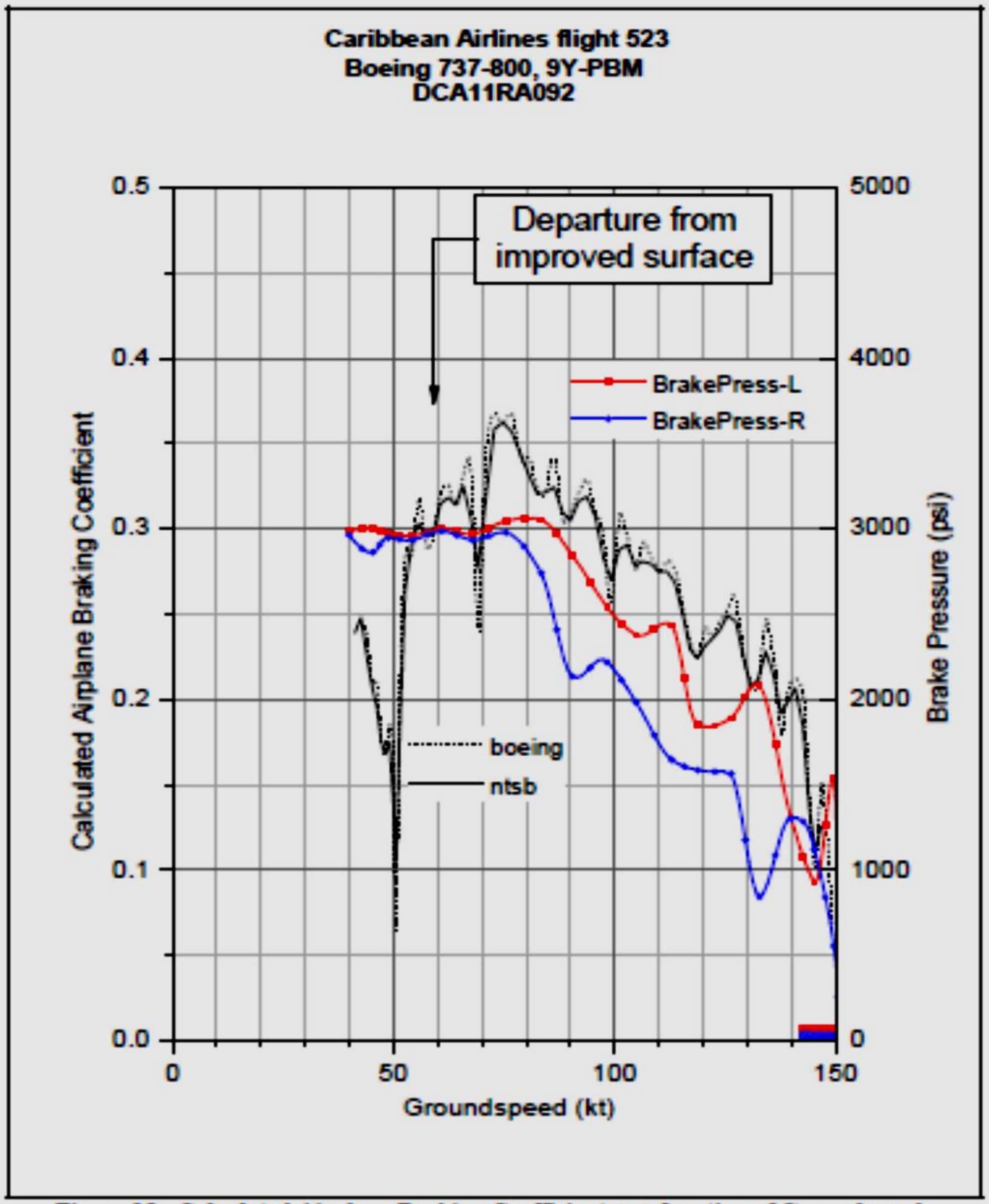


Figure 15: Calculated Airplane Braking Coefficient as a function of Groundspeed

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

	All reversers operating (FT)	One reverser operating (FT)	No reversers (FT)
Dry Runway			
Max Manual	3250	3316	3381
Autobrake 3	5861	5861	5861
Good Reported Braking Action			
Max Manual	4550	4779	5058
Autobrake 3	5867	5883	5916
Medium Reported Braking Action			
Max Manual	6266	6889	7742
Autobrake 3	6620	7079	7965

Figure 16a: FAA Advisory Landing Distances for the 737-800 with Winglets from QRH[10]

	All reversers operating (FT)	One reverser operating (FT)	No reversers (FT)
Dry Runway			
Max Manual	3250	3316	3381
Autobrake 3	5861	5861	5861
Good Reported Braking Action			
Max Manual	5232	5494	5823
Autobrake 3	6757	6773	6806
Medium Reported Braking Action			
Max Manual	7207	7929	8913
Autobrake 3	7624	8149	9166

Figure 16b: JAA Advisory Landing Distances for the 737-800 with Winglets from QRH[11]

[10] air distance = 1000 ft for dry, good, and medium braking action
[11] air distance = 1000 ft for dry and 1150 ft for good and medium braking action

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

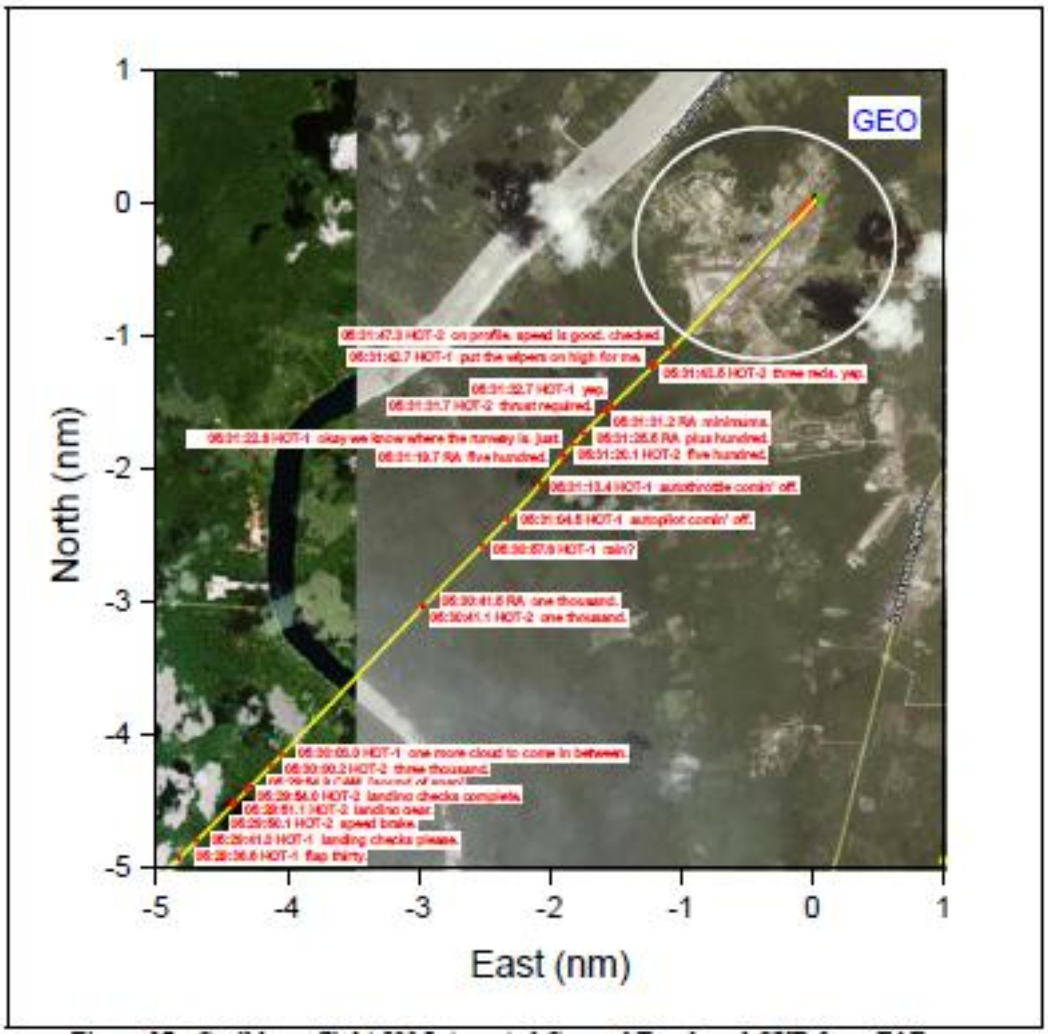


Figure 17: Caribbean flight 523 Integrated Ground Track and CVR from FAF

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

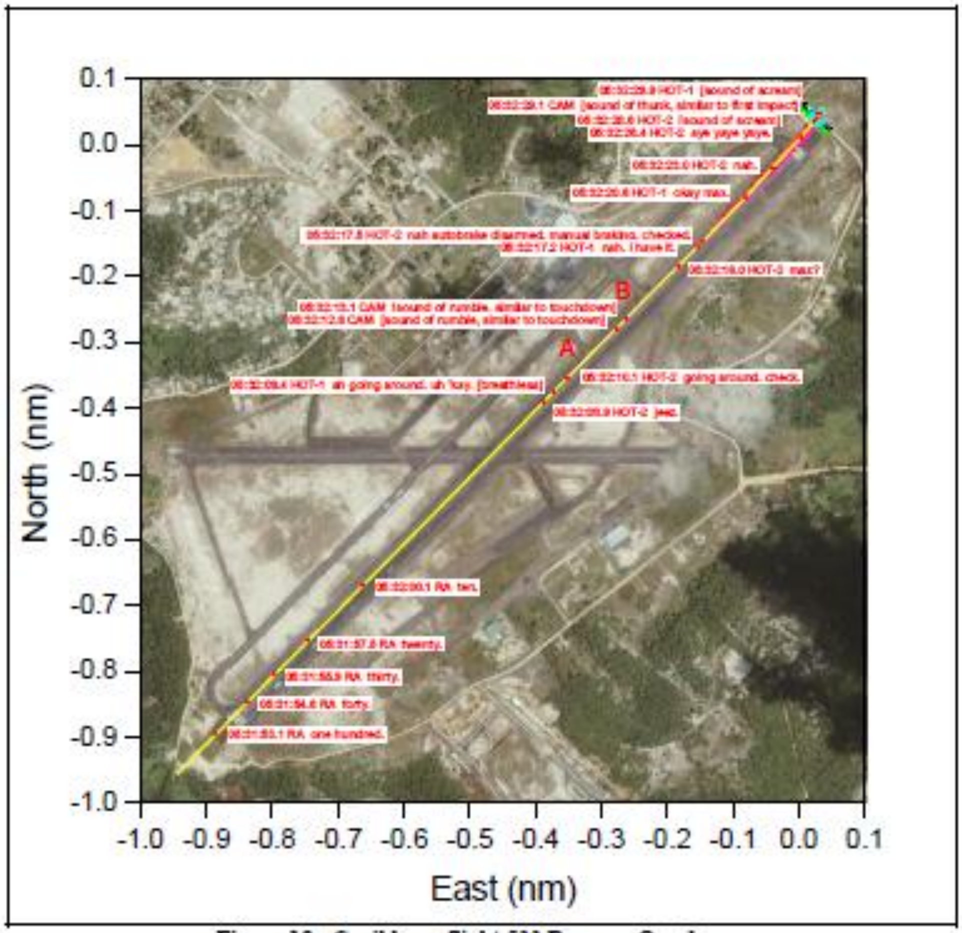


Figure 18: Caribbean flight 523 Runway Overlay

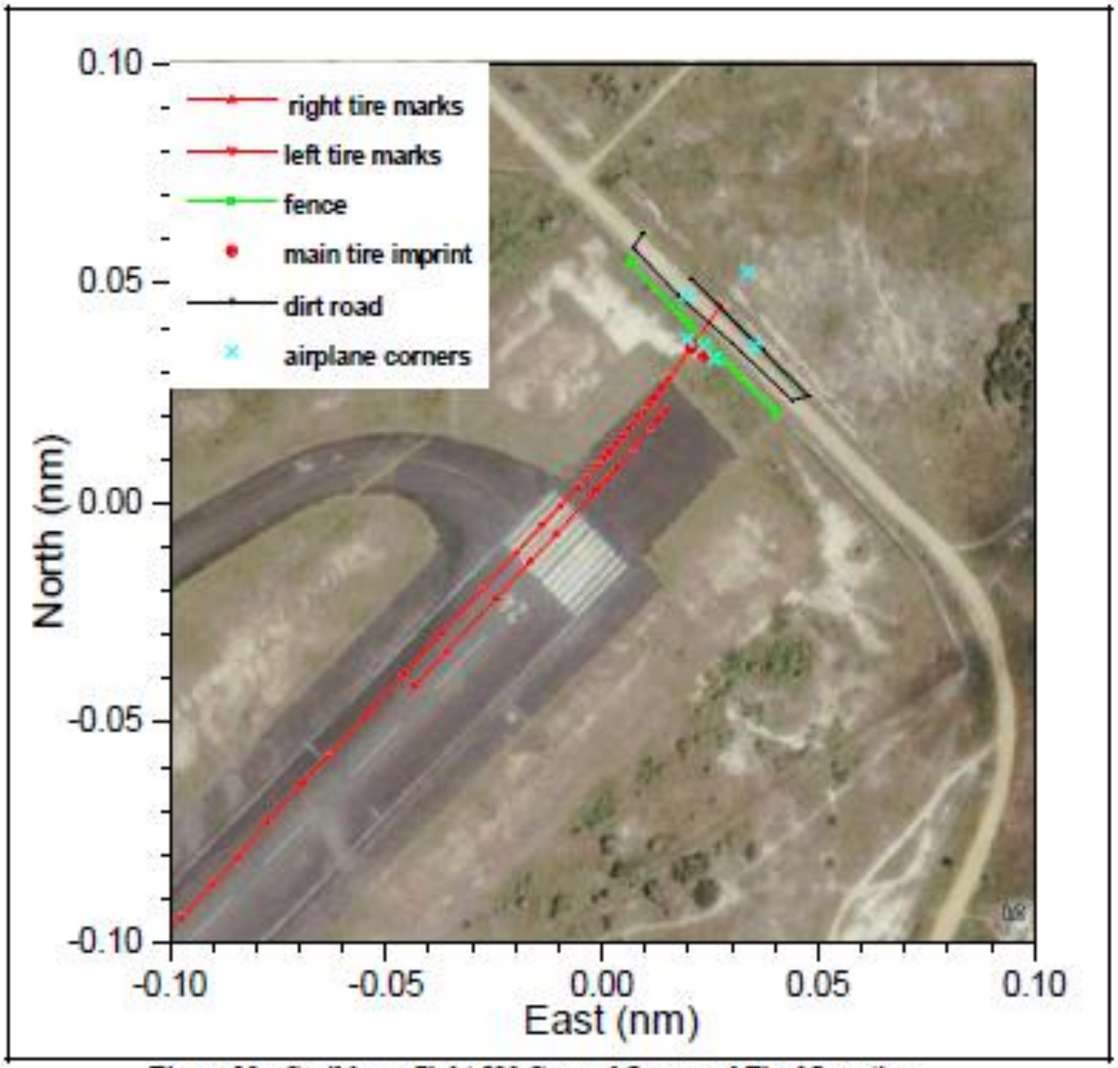


Figure 19: Caribbean flight 523 Ground Scars and Final Location

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

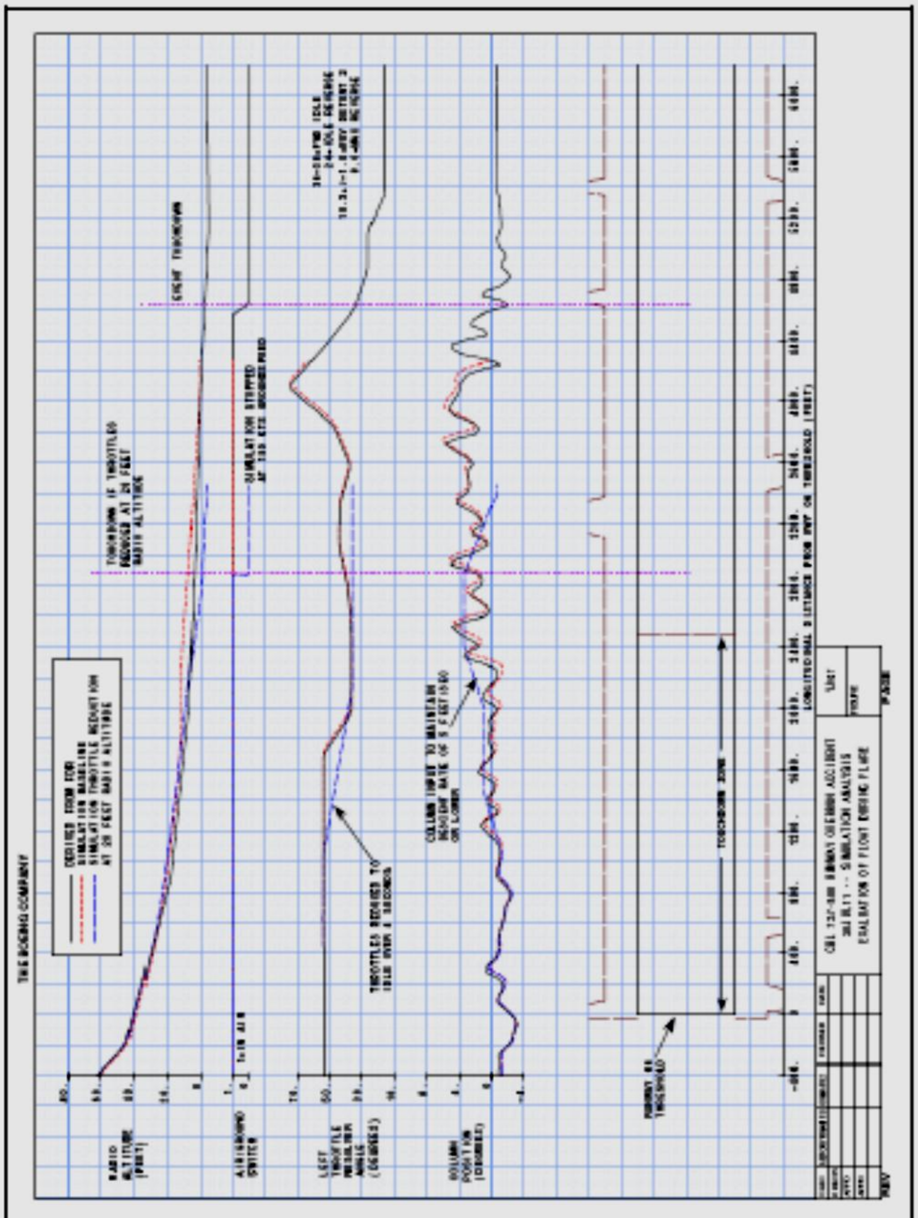


Figure 20: B-737 simulation with Idle Throttles at 20 ft agl Touches Down 1700 ft Sooner

Airplane Performance Study
DCA11RA092, B-737-800, 9Y-PBM, 7/30/2011

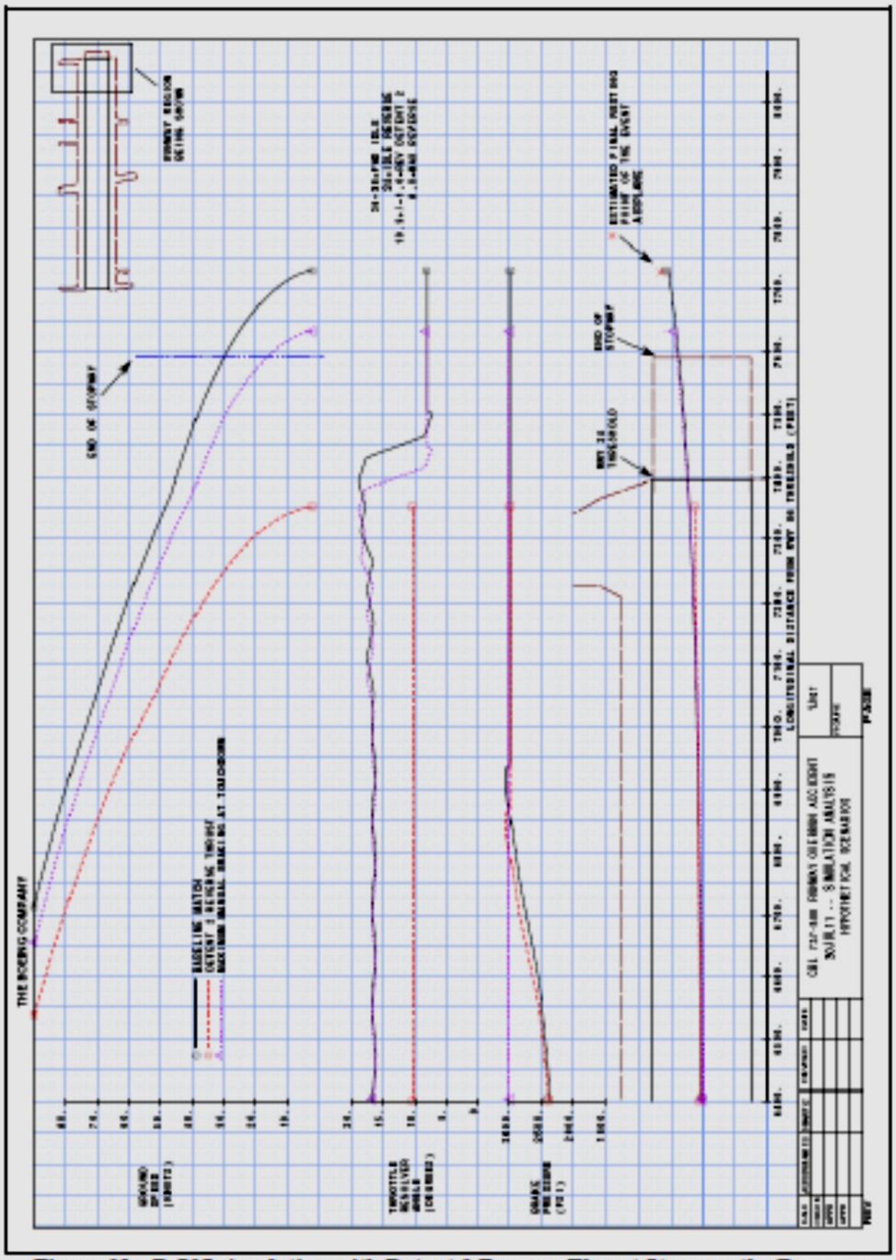


Figure 21: B-737 simulation with Detent 2 Reverse Thrust Stops on the Runway

APPENDIX – 5

9th August 2011

Report on the Friction Characteristics at The Cheddi Jagan International Airport August 3rd – 5th 2011

09th August 2011

Report on the Friction Characteristics at The Cheddi Jagan International Airport August 3rd - 5th 2011

Technical personnel from the Grantley Adams International Airport Inc. (GAZA Inc.) conducted Friction Testing Services on the runways of the Cheddi Jagan International Airport, most specifically Runways 06-24 in order to determine the frictional characteristics of these surfaces. This report sets out findings of these test as well as observations during the testing period of Thursday 4th August 2011.

The surface conditions of a runway have a major safety impact on aircraft operations, in particular on an aircraft's landing performance. Differences in the runway surfaces being operated by differing operating authorities requires individual aerodrome operators to closely monitor the friction levels. This monitoring assist in ensuring that the runway friction levels are kept to an acceptable level and assist in the planning of preventative maintenance activities. Low friction levels as well as contaminated runway surfaces can result in aircraft overruns and run-off incidents. The runway testing regime is conducted under controlled conditions using self wetting equipment to establish the friction characteristics of that runway as well as to identify any area on the runway which may require some remedial attention. The conditions under which the controlled testing is conducted can be found in the International Civil Aviation Organization (ICAO) Annex 14 Aerodromes (Aerodrome design and operations) Volume 1, 4th edition as well as the Airport Services Manual Part 2, 4th edition. These conditions are included within this document as appendix No.5 for ease of reference. These tests are conducted under standard conditions on a dry runway as prescribed in the attached ICAO documents.

The times indicated on these test are the times of testing in Guyana (GMT - 4hrs.). The friction tester being used in this survey is the Findley Irvine Mark 2 Grip Tester serial number GT 289 registered to The Grantley Adams International Airport Inc. All graphs and friction values were obtained from the data base of this test instrument and cannot be altered by the user.

The tables and graphs included in appendices 1-4 show the data summaries for the ICAO as well as non ICAO standard friction runs at the speeds and offsets from the runway centerline as indicated. The tables in appendix No.2 and data tables No. 5-7 in appendix No.3 show the non standard friction test as carried out to simulate rainy conditions on the runway. Graphical displays of these test can be found in appendix No.4, graphs 2011/08/04 12:06, 2011/08/04 12:26 and 2011/08/04 12:40. No historical friction data was available at the time of testing to compare with the current results and as a result this analysis is based solely on the frictional analysis done on the 4th of August 2011.

A total of seven test runs were completed on the Runways of the Cheddi Jagan International Airport on Thursday 4th August 2011. Four of these runs were standard test, as set out by the ICAO regulatory authority. The final three were done under conditions which simulated heavy shower activity.

The Runways of 06-24 are grooved along their entire operating length, as shown in photo No.3, this grooving is intended to increase the frictional forces between the tires of an aircraft and the runway's surface. It was noted that the grooves showed no signs of significant build up of rubber deposits during the periods of testing. The aggregate was visible and showed no signs of significant polish or being obscured by rubber deposits. The runways showed friction values above the ICAO's recommended maintenance level of 0.42, for most of its surface length. Friction value of 0.48 at offset 3m from centerline and 0.58 at offset 6m from centerline was recorded for runways 06-24. In the tests runs done in conditions to simulate heavy rainfall these values were 0.45 and 0.48 respectively. The runways showed consistency in the repeatability of the performance of its surfaces during both sets of test as well as the test done to familiarize the new operators to the testing regime. These runs were not recorded for this document. One area of concern in the analysis of the friction data was noted for further study, this being the area on runway 06 in the 200-300 meter section. This area is highlighted in red print in the friction tables as the values fall below the recommended minimum ICAO maintenance level of 0.42. This may be caused by damage to the asphalt surface by wide bodied aircraft prior to takeoff, applying braking forces in this area, after exiting the main taxiway. Remedial action is recommended to return this area to higher friction levels.

It was noted from the friction data that most wide bodied aircraft landed to the left of the center line on runway 06. However no major loss of friction was noticed in the touchdown zone area when compared to the values obtained for the entire runway length. No noticeable frictional losses were detected in the turn area of the high speed exit off the runway at the time of testing.

Should you have any questions relating to this report please don't hesitate to contact the Engineering Department of the Grantley Adams International Airport, it is further recommended that this test be repeated within the next twelve months.

Roger O'B Best

Engineering Services Supervisor

Grantley Adams International Airport

Photo No.1 Shows threshold of runway 06 off main taxiway

Photo No.2 shows runway 06 (Discoloration of paint markings)

Photo No.3 Transverse grooving on the 06-24 runways (pen is to establish scale)

Photo No.4 Runway 06 showing the touchdown zone

Photo No.5 Touchdown zone of runway 24

Appendix No.1

(Friction Data Tables (Sectional Thirds))

1.0 ICAO Standard Test Runs

Sectional Friction Averages

Standard Sectional Friction Averages

3m from c/l	Friction Run 1	Friction Run 2	Section Average
Section A	0.49	0.59	0.54
Section B	0.47	0.49	0.48
Section C	0.45	0.47	0.46
Run Average	0.47	0.51	0.49

6m from c/l	Friction Run 1	Friction Run 2	Section Average
Section A	0.73	0.63	0.68
Section B	0.56	0.52	0.54
Section C	0.55	0.53	0.54
Run Average	0.61	0.56	0.59

3m from c/l	Friction Run 1	Friction Run 2	Section Average
Section A	0.53	0.56	0.55
Section B	0.52	0.49	0.50
Section C	0.48	0.48	0.48
Run Average	0.51	0.51	0.51

3 m from c/l	Friction Run 1	Friction Run 2	Section Average
Section A	0.49	0.53	0.51
Section B	0.48	0.49	0.49
Section C	0.45	0.46	0.45
Run Average	0.47	0.49	0.48

Appendix No.2

(Friction Data Tables (Sectional Thirds))

2.0 ICAO Non Standard Test Runs

Sectional Friction Averages with Water Film in Excess of 0.50mm.

Non Standard Sectional Friction Averages

3m from c/l	Friction Run 1	Friction Run 2	Section Average
Section A	0.51	0.49	0.50
Section B	0.50	0.47	0.48
Section C	0.46	0.45	0.45
Run Average	0.49	0.47	0.48

3m from c/l	Friction Run 1	Friction Run 2	Section Average
Section A	0.50	0.48	0.49
Section B	0.48	0.46	0.47
Section C	0.53	0.45	0.49
Run Average	0.50	0.46	0.48

3m from c/l (Left)	Friction Run 1
Section A	0.48
Section B	0.46
Section C	0.43
Run Average	0.45

Appendix No.3

(Raw Friction Test Table Data)

ICAO Standard Test Tables

Non Standard Test Tables

FRICTION DATA TABLE No.1 ICAO STANDARD TEST RUN

3m L&R

	Run #1 Data		Run #2 Data	
Distance (m)	Avg. Speed (Km/h)	A vg. Friction	Avg. Speed (Km/h)	A vg. Friction
00 - 100	32	0.59	64	0.50
100 - 200	53	0.44	63	0.52
200 - 300	63	**0.40**	63	0.69
300 - 400	63	0.43	63	0.63
400 - 500	65	0.51	63	0.65
500 - 600	66	0.55	64	0.58
600 -700	64	0.53	64	0.55
700 - 800	65	0.56	63	0.51
800 - 900	63	0.51	64	0.46
900 - 1000	63	**0041**	63	0.51
1000 - 1100	63	0.42	63	0.48
1100 - 1200	66	0.46	63	0.51
1200 - 1300	67	0.49	64	0.48
1300 - 1400	69	0.44	64	0.48
1400 - 1500	63	0.47	63	0.50
1500 - 1600	62	0.48	64	0.51
1600 - 1700	64	0.52	64	0.46
1700 - 1800	64	0.45	66	0.44
1800 - 1900	63	0.43	66	0.44
1900 - 2000	65	0.45	62	0.43
2000 - 2100	63	0.42	62	**0.41**
2100 - 2200	62	0.43	52	0.47
2200 - 2270	64	0.42	32	0.64
Average	62	0.47	62	0.51

Overall Friction Average 0.49

FRICTION DATA TABLE No.2 ICAO STANDARD TEST RUN

6mL&R

Distance (m)	Run #1 Data Avg. Speed (KmIh)	Run #1 Data Avg. Friction	Run #2 Data Avg. Speed (KmIh)	Run #2 Data Avg. Friction
00 -100	34	0.76	63	0.57
100 - 200	49	0.77	63	0.66
200 - 300	60	0.74	63	0.69
300 - 400	67	0.73	63	0.63
400 - 500	66	0.73	64	0.64
500 - 600	66	0.71	63	0.60
600 -700	67	0.70	64	0.61
700 - 800	68	0.71	63	0.57
800 - 900	68	0.67	62	0.51
900 -1000	67	0.60	62	0.50
1000 -1100	66	0.55	64	0.49
1100 -1200	67	0.51	64	0.49
1200 -1300	69	0.52	64	0.50
1300 -1400	70	0.49	63	0.52
1400 -1500	68	0.47	64	0.56
1500 -1600	68	0.55	64	0.52
1600 -1700	69	0.55	64	0.52
1700 -1800	70	0.48	64	0.49
1800 -1900	69	0.53	68	0.50
1900 - 2000	69	0.57	68	0.51
2000 - 2100	71	0.60	64	0.49
2100 - 2200	65	0.57	54	0.60
2200 - 2270	63	0.52	35	0.65
Average	65	0.61	63	0.56

Overall Friction Average 0.58

FRICTION DATA TABLE No.3 ICAO STANDARD TEST RUN

3m L&R

	Run #1 Data		Run #2 Data	
Distance (m)	Avg. Speed (Km/h)	A vg. Friction	Avg. Speed (Km/h)	Avg. Friction
00 - 100	37	0.62	61	0.46
100 -200	57	0.47	64	0.48
200 -300	65	**0.41**	64	0.58
300 - 400	65	0.47	63	0.62
400 - 500	62	0.55	64	0.62
500 - 600	63	0.60	65	0.61
600 -700	64	0.58	66	0.55
700 - 800	64	0.59	65	0.48
800 - 900	63	0.55	64	0.46
900 -1000	65	0.49	65	0.48
1000 -1100	66	0.49	66	0.49
1100 -1200	67	0.51	66	0.48
1200 -1300	64	0.51	65	0.48
1300 -1400	63	0.49	64	0.51
1400 -1500	65	0.50	64	0.51
1500 -1600	64	0.52	65	0.49
1600 -1700	63	0.52	66	0.45
1700 -1800	63	0.51	65	0.44
1800 -1900	64	0.49	65	0.45
1900 -2000	64	0.45	65	0.42
2000 -2100	64	0.46	66	0.43
2100 - 2200	64	0.44	56	0.48
2200 - 2270	64	0.43	36	0.72
Average	62	0.51	63	0.51
Overall Friction Average 0.51				

FRICTION DATA TABLE No.4 ICAO STANDARD TEST RUN

	Run #1 Data		Run #2 Data	
Distance (m)	Avg. Speed (Km/h)	A vg. Friction	Avg. Speed (Km/h)	A vg. Friction
00 -100	37	0.61	65	0.44
100 - 200	55	0.42	65	0.46
200 - 300	64	**0.38**	64	0.56
300 - 400	66	0.44	64	0.59
400 - 500	66	0.48	65	0.59
500 - 600	66	0.52	65	0.56
600 -700	67	0.56	64	0.51
700 - 800	66	0.58	63	0.47
800 - 900	63	0.52	64	0.47
900 -1000	63	0.42	64	0.48
1000 -1100	62	0.42	64	0.50
1100 -1200	63	0.46	64	0.49
1200 -1300	64	0.47	64	0.49
1300 -1400	65	0.48	64	0.53
1400 -1500	66	0.52	64	0.48
1500 -1600	66	0.52	66	0.50
1600 -1700	65	0.47	66	0.43
1700 -1800	63	0.46	65	0.43
1800 -1900	63	0.43	65	0.43
1900 - 2000	65	0.45	66	0.40
2000 - 2100	64	0.46	62	0.43
2100 - 2200	65	0.43	51	0.48
2200 - 2270	65	0.42	32	0.67
Average	63	0.47	63	0.49
Overall Friction Average 0.48				

Friction Data Table No.5 NON STANDARD TEST

	Run #1 Data		Run #2 Data	
Distance (m)	Avg. Speed (KmIh)	Avg. Friction	Avg. Speed (Km/h)	Avg. Friction
00 -100	36	0.66	65	0.43
100 - 200	55	0.52	66	0.45
200 - 300	65	0.42	65	0.52
300 - 400	67	0.44	64	0.54
400 - 500	67	0.51	65	0.50
500 - 600	64	0.51	65	0.49
600 -700	64	0.52	66	0.49
700 - 800	65	0.52	66	0.45
800 - 900	65	0.53	66	0.46
900 -1000	64	0.52	65	0.46
1000 -1100	65	0.48	65	0.48
1100 -1200	65	0.48	65	0.50
1200 -1300	64	0.50	65	0.46
1300 -1400	63	0.48	65	0.49
1400 -1500	63	0.50	65	0.47
1500 -1600	64	0.47	66	0.47
1600 -1700	64	0.47	66	0.47
1700 -1800	65	0.48	66	0.43
1800 -1900	65	0.44	66	**0.41**
1900 -2000	66	0.45	66	**0.41**
2000 - 2100	66	0.45	64	**0.40**
2100 - 2200	66	0.45	54	0.46
2200 - 2270	66	0.44	32	0.67
Average	63	0.49	64	0.47
Overall Friction Average 0.48				

Friction Data Table No.6 NON STANDARD TEST

	Run #1 Data		Run #2 Data	
Distance (m)	Avg. Speed (Km/h)	Avg. Friction	Avg. Speed (Km/h)	Avg. Friction
00 -100	39	0.64	65	0.42
100 - 200	60	0.51	65	0.44
200 - 300	66	**0.41**	65	0.44
300 - 400	66	0.46	65	0.50
400 - 500	65	0.48	65	0.50
500 - 600	64	0.50	66	0.52
600 -700	66	0.50	65	0.50
700 - 800	64	0.49	64	0.45
800 - 900	64	0.50	65	0.42
900 -1000	66	0.53	65	0.47
1000 -1100	66	0.48	66	0.52
1100 -1200	67	0.47	66	0.47
1200 -1300	67	0.47	65	0.43
1300 -1400	65	0.44	65	0.44
1400 -1500	65	0.45	65	0.45
1500 -1600	66	0.46	65	0.46
1600 -1700	66	0.47	65	0.43
1700 -1800	66	0.49	65	0.43
1800 -1900	67	0.48	65	**0.41**
1900 - 2000	65	0.46	65	**0.40**
2000 -2100	63	0.45	65	**0.40**
2100 - 2200	65	0.56	54	0.45
2200 - 2270	63	0.93	33	0.65
Average	64	0.50	64	0.46
Overall Friction Average 0.48				

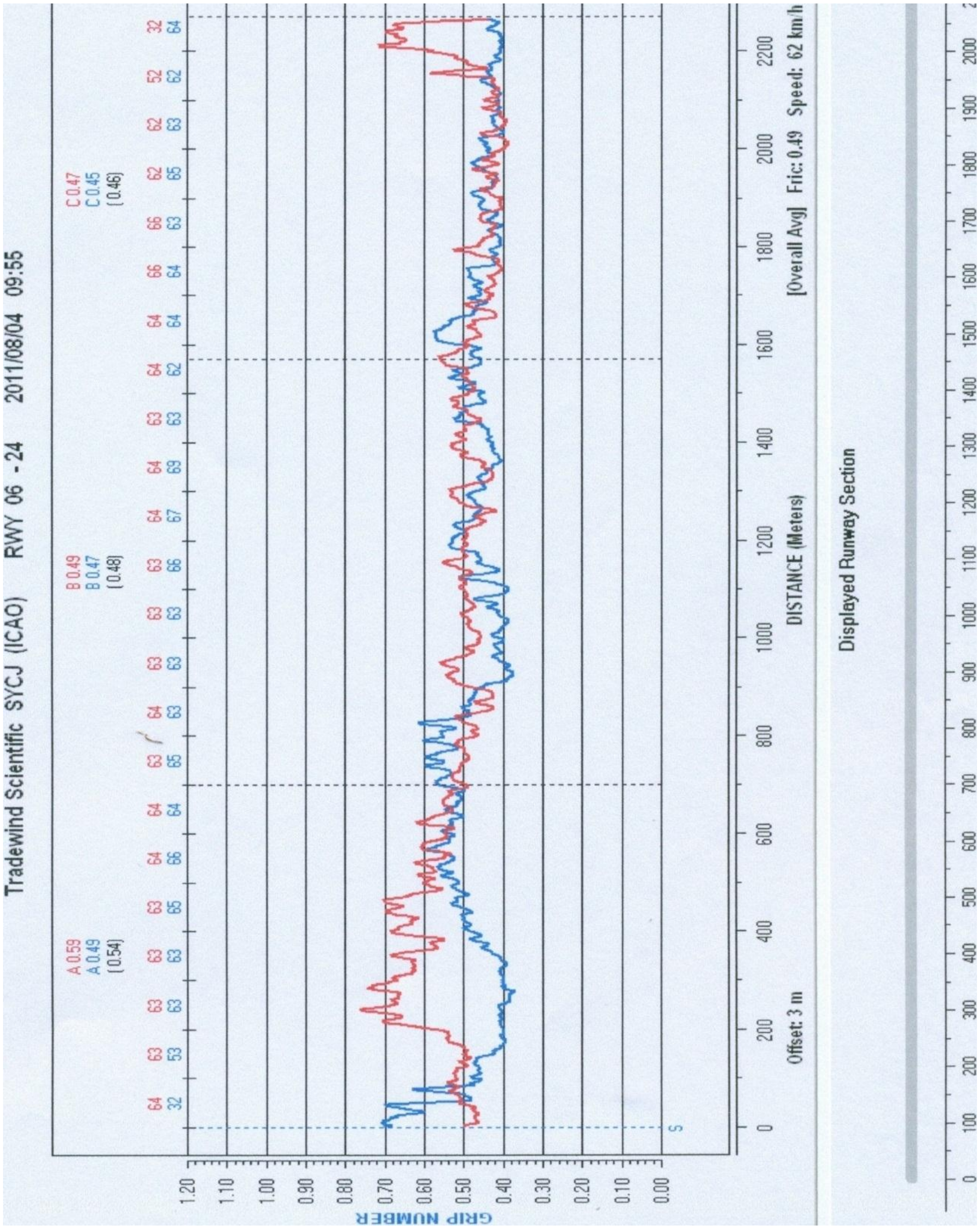
Friction Data Table No.7 NON STANDARD TEST

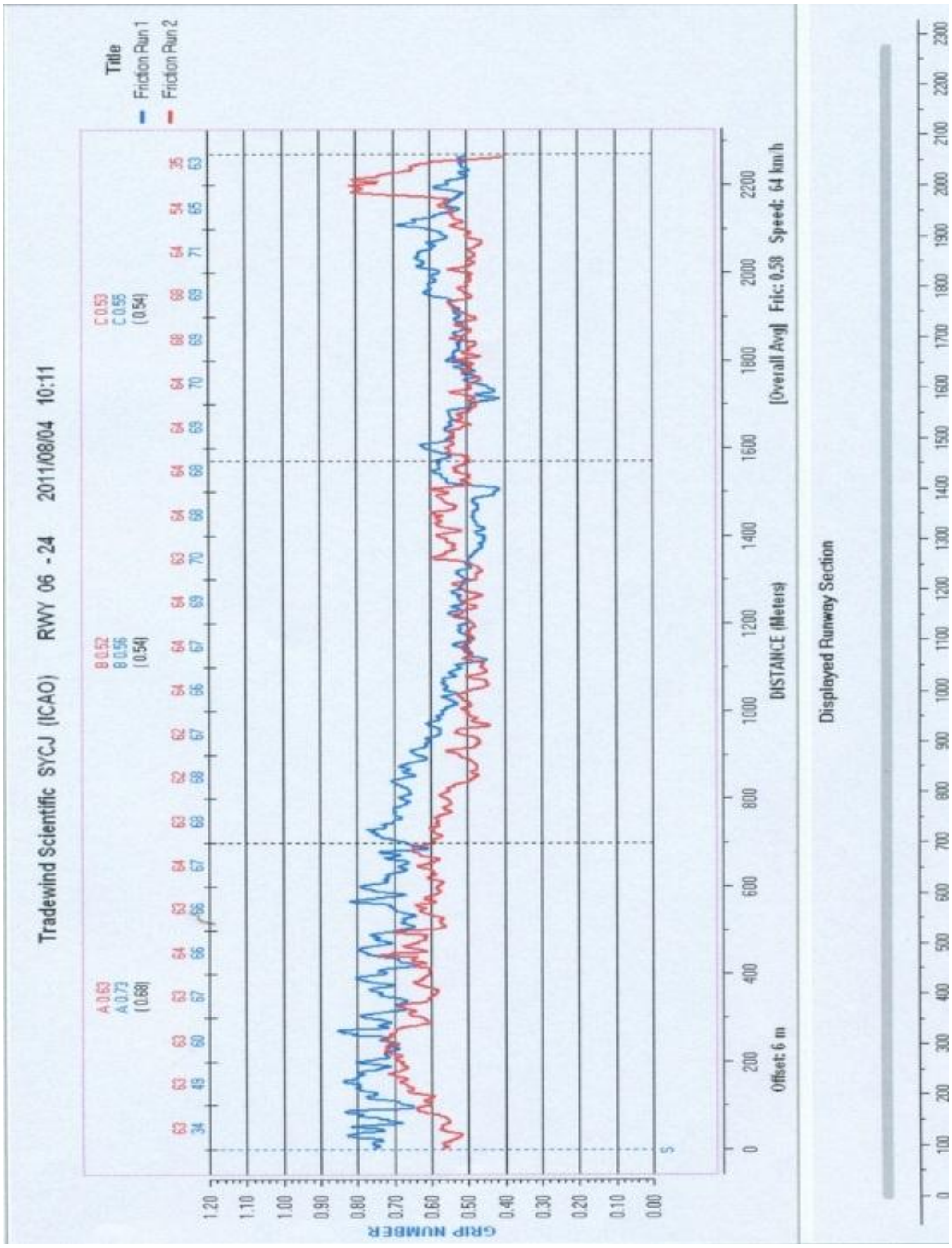
	Run #1 Data	
Distance (m)	Avg. Speed (Km/h)	A vg. Friction
00 -100	31	0.66
100 - 200	41	0.48
200 - 300	62	**0.40**
300 - 400	66	0.43
400 - 500	65	0.46
500 - 600	66	0.47
600 -700	65	0.44
700 - 800	65	0.46
800 - 900	66	0.46
900 -1000	66	0.46
1000 -1100	66	0.45
1100 -1200	66	0.46
1200 -1300	67	0.46
1300 -1400	66	0.48
1400 -1500	64	0.46
1500 -1600	65	0.43
1600 -1700	66	0.46
1700 -1800	65	0.45
1800 -1900	64	0.43
1900 - 2000	65	**0.41**
2000 - 2100	66	0.40
2100 - 2200	64	**0.41**
2200 - 2270	64	0.43
Average	63	0.45
Overall Friction Average 0.45		

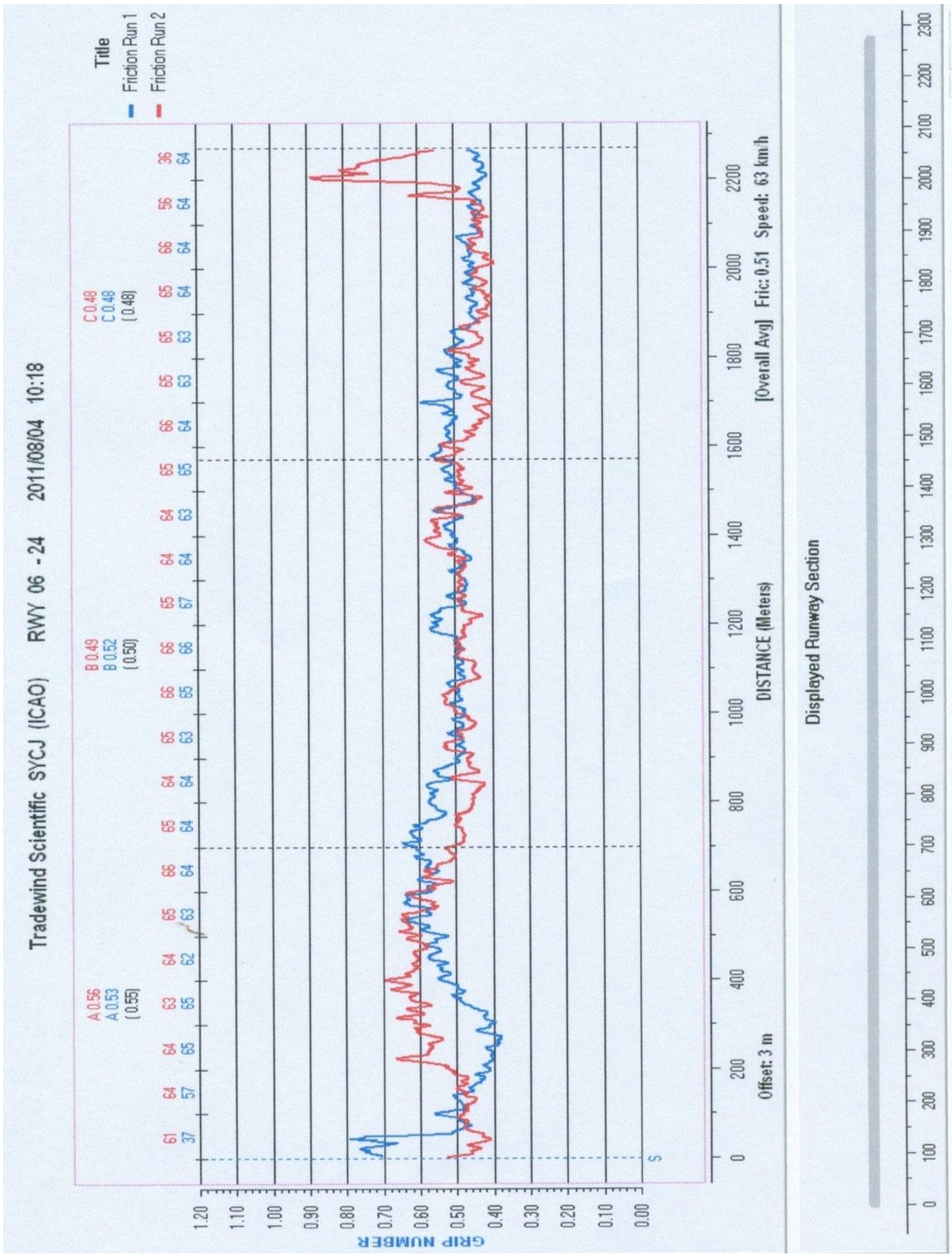
Appendix 4 Friction Graphs

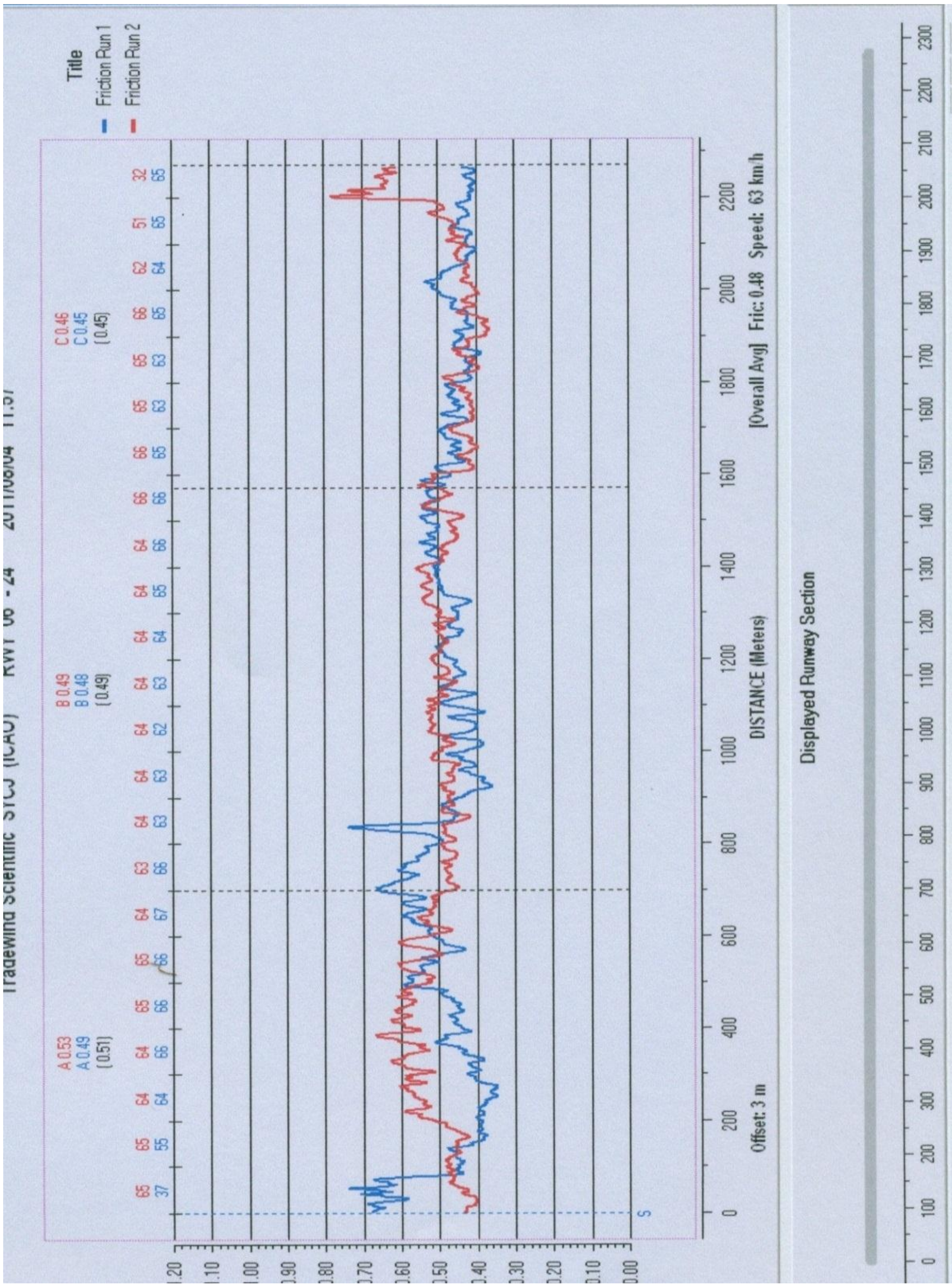
4.0 Standard Friction Graphs

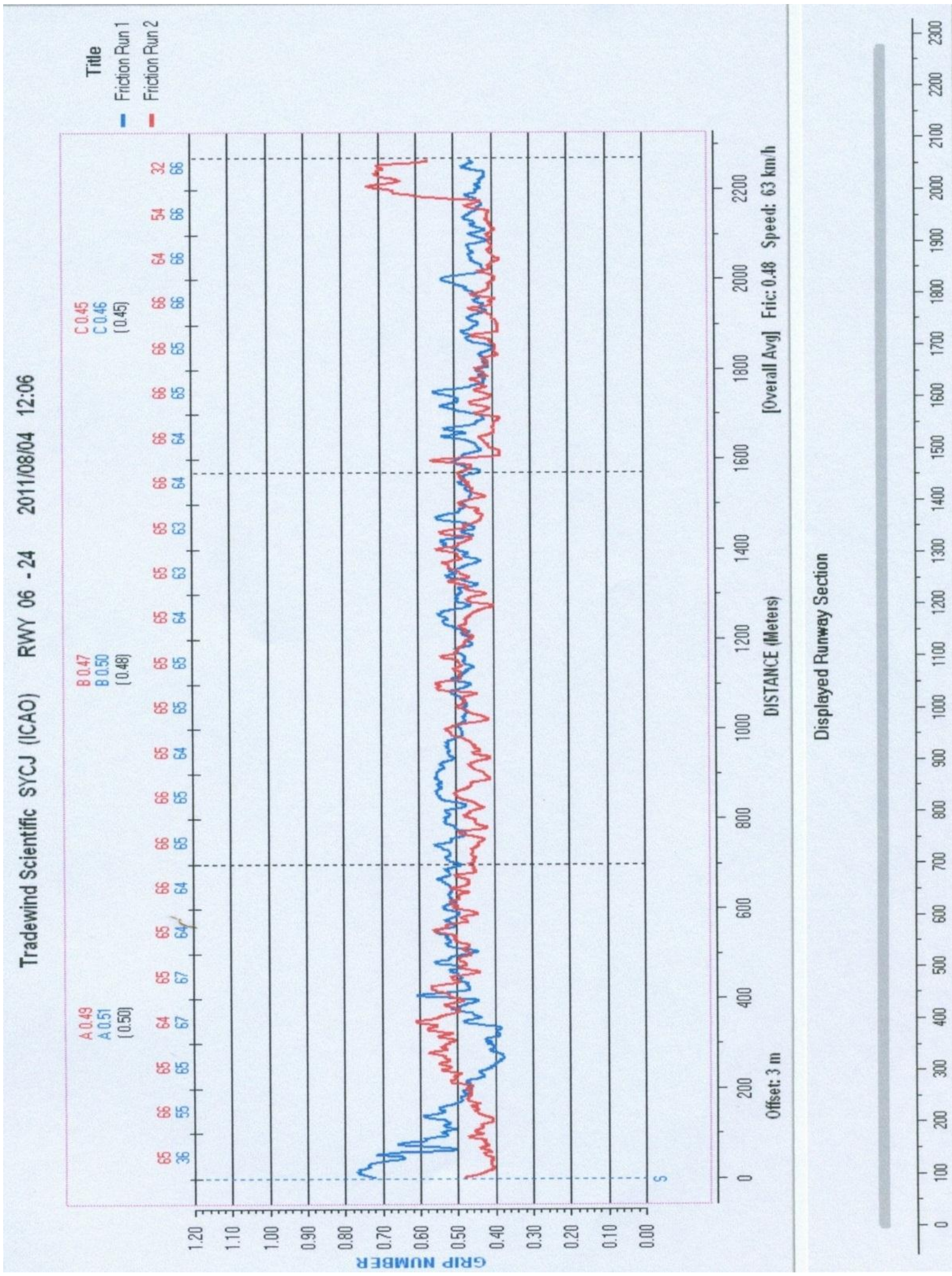
4.1 Non Standard Friction Graphs

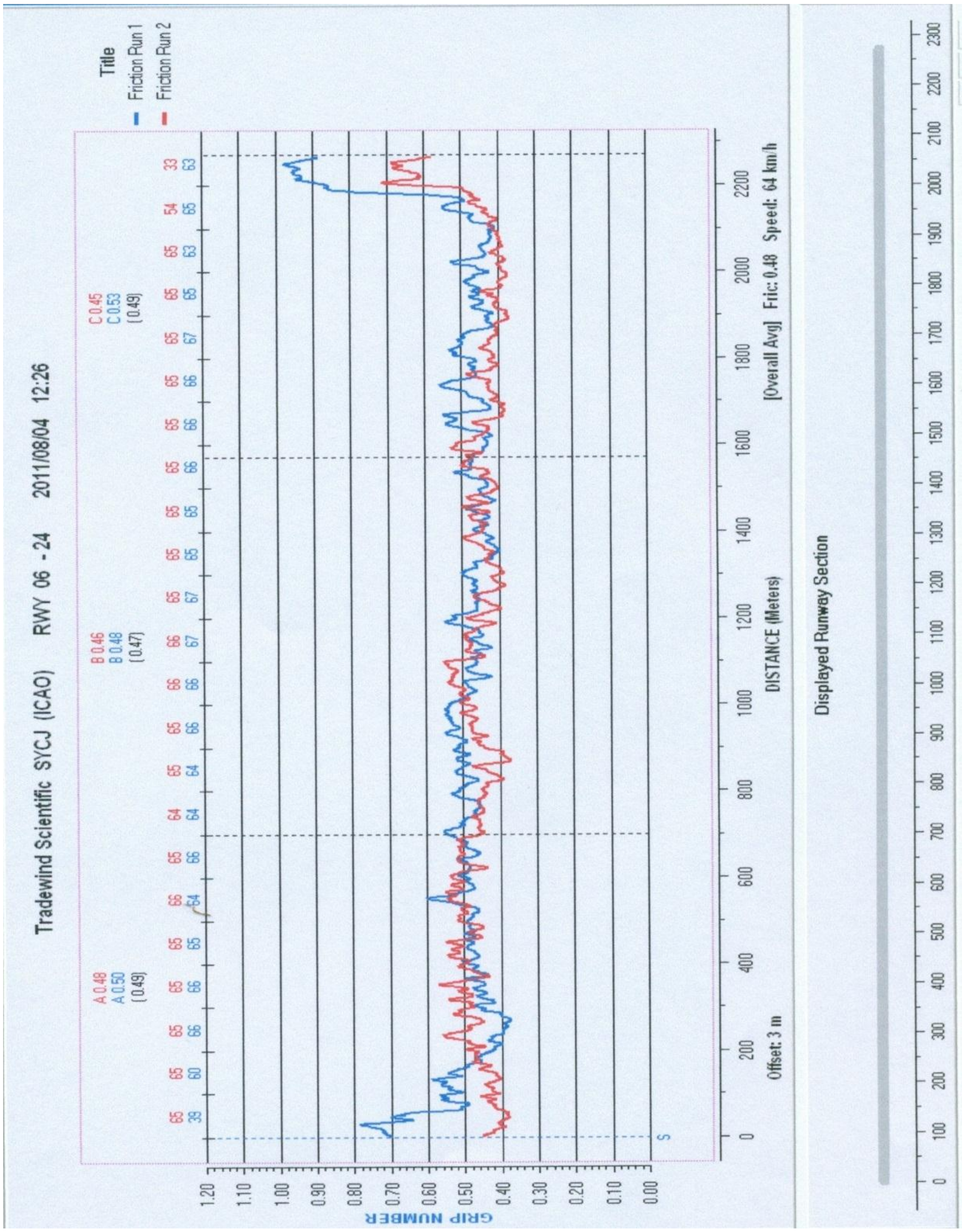

Tradewind Scientific SYCJ (ICAO) RWY 06 - 24 2011/08/04 09:55
A 0.59
A 0.49
(0.54)
B 0.49
B 0.47
(0.48)
C 0.47
C 0.45
(0.46)
GRIP NUMBER
DISTANCE (Meters)
Offset: 3 m
[Overall Avg] Fric: 0.49 Speed: 62 km/h
Displayed Runway Section

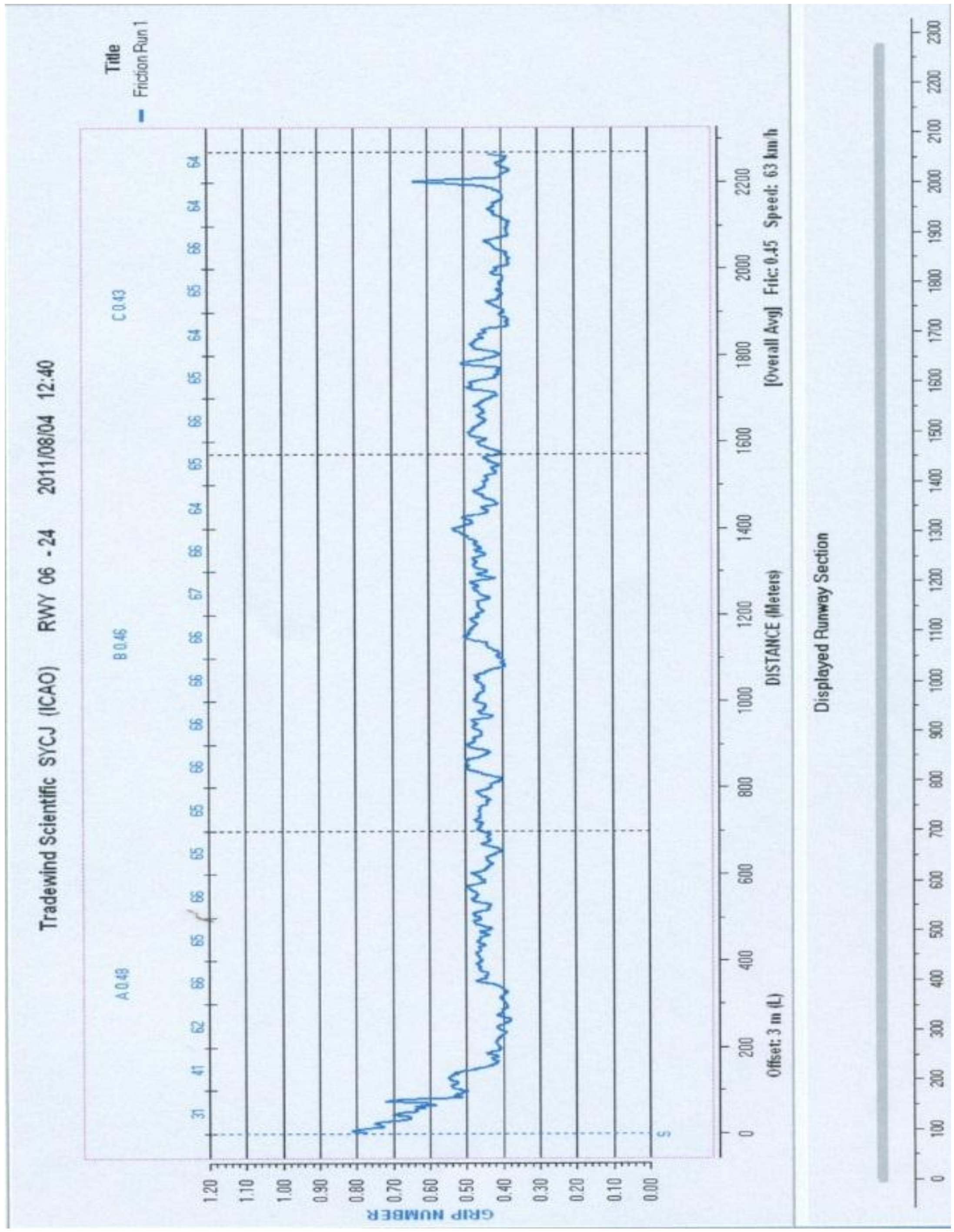

Tradewind Scientific SYCJ (ICAO) RWY 06 - 24 2011/08/04 10:11
Title
Friction Run 1
Friction Run 2
GRIP NUMBER
DISTANCE (Meters)
Offset: 6 m
[Overall Avg] Fric: 0.58 Speed: 64 km/h
Displayed Runway Section


Tradewind Scientific SYCJ (ICAO) RWY 06 - 24 2011/08/04 10:18
Title
Friction Run 1
Friction Run 2
A 0.56
A 0.53
(0.55)
B 0.49
B 0.52
(0.50)
C 0.48
C 0.48
(0.48)
GRIP NUMBER
Offset: 3 m
DISTANCE (Meters)
[Overall Avg] Fric: 0.51 Speed: 63 km/h
Displayed Runway Section


Title
Friction Run 1
Friction Run 2
DISTANCE (Meters)
Offset: 3 m
[Overall Avg] Fric: 0.48 Speed: 63 km/h
Displayed Runway Section


Tradewind Scientific SYCJ (ICAO) RWY 06 - 24 2011/08/04 12:06
Title
Friction Run 1
Friction Run 2
GRIP NUMBER
DISTANCE (Meters)
Offset: 3 m
[Overall Avg] Fric: 0.48 Speed: 63 km/h
Displayed Runway Section


Tradewind Scientific SYCJ (ICAO) RWY 06 - 24 2011/08/04 12:26
Title
Friction Run 1
Friction Run 2
A 0.48
A 0.50
(0.49)
B 0.46
B 0.48
(0.47)
C 0.45
C 0.53
(0.49)
GRIP NUMBER
DISTANCE (Meters)
Offset: 3 m
[Overall Avg] Fric: 0.48 Speed: 64 km/h
Displayed Runway Section


Tradewind Scientific SYCJ (ICAO) RWY 06 - 24 2011/08/04 12:40
Title
Friction Run 1
A 0.48
B 0.46
C 0.43
GRIP NUMBER
DISTANCE (Meters)
Offset: 3 m (L)
[Overall Avg] Fric: 0.45 Speed: 63 km/h
Displayed Runway Section

Appendix No. 5 (ICAO Documentation)

ICAO Aerodrome Design and Operations Volume 1, 4th Edition

ICAO Airport Services Manual, Part 2, Pavement Surface Conditions

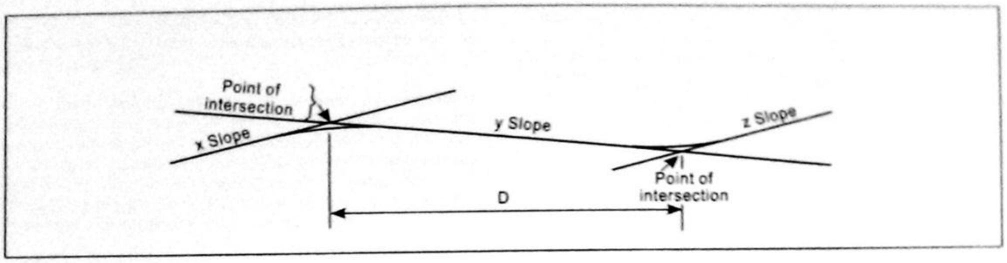


Figure A-2. Profile on centre line of runway

5.4 Deformation of the runway with time may also increase the possibility of the formation of water pools. Pools as shallow as approximately 3 mm in depth, particularly if they are located where they are likely to be encountered at high speed by landing aeroplanes, can induce aquaplaning, which can then be sustained on a wet runway by a much shallower depth of water. Improved guidance regarding the significant length and depth of pools relative to aquaplaning is the subject of further research. It is, of course, especially necessary to prevent pools from forming whenever there is a possibility that they might become frozen.

6. Determining and expressing the friction characteristics of snow- and ice-covered paved surfaces

6.1 There is an operational need for reliable and uniform information concerning the friction characteristics of ice- and snow-covered runways. Accurate and reliable indications of surface friction characteristics can be obtained by friction measuring devices; however, further experience is required to correlate the results obtained by such equipment with aircraft performance, owing to the many variables involved, such as: aircraft mass, speed, braking mechanism, tire and undercarriage characteristics.

6.2 The friction coefficient should be measured if a runway is covered wholly or partly by snow or ice and repeated as conditions change. Friction measurements and/or braking action assessments on surfaces other than runways should be made when an unsatisfactory friction condition can be expected on such surfaces.

6.3 The measurement of the friction coefficient provides the best basis for determining surface friction conditions. The value of surface friction should be the maximum value which occurs when a wheel is slipping but still rolling. Various friction measuring devices may be used. As there is an operational need for uniformity in the method of assessing and reporting runway friction conditions, the measurements should preferably be made with equipment which provides continuous measuring of the maximum friction along the entire runway. Measuring techniques and information on limitations of the various friction measuring devices and precautions to be observed are given in the *Airport Services Manual*, Part 2.

6.4 A chart, based on results of tests conducted on selected ice- or snow-covered surfaces, showing the correlation between certain friction measuring devices on ice- or snow-covered surfaces is presented in the *Airport Services Manual*, Part 2.

6.5 The friction conditions of a runway should be expressed as "braking action information" in terms of the measured friction coefficient μ or estimated braking action. Specific numerical μ values are necessarily related to the design and construction of each friction measuring device as well as to the surface being measured and the speed employed.

6.6 The table below with associated descriptive terms was developed from friction data collected only in compacted snow and ice and should not therefore be taken to be absolute values applicable in all conditions. If the surface is affected by snow or ice and the braking action is reported as "good", pilots should not expect to find conditions as good as on a clean dry runway (where the available friction may well be greater than that needed in any case). The value "good" is a comparative value and is intended to mean that aeroplanes should not experience directional control or braking difficulties, especially when landing.

Measured coefficient	*Estimated braking action*	*Code*
0.40 and above	Good	5
0.39 to 0.36	Medium to good	4
0.35 to 0.30	Medium	3
0.29 to 0.26	Medium to poor	2
0.25 and below	Poor	1

6.7 It has been found necessary to provide surface friction information for each third of a runway. The thirds are called

A, B and C. For the purpose of reporting information to aeronautical service units, section A is always the section associated with the lower runway designation number. When giving landing information to a pilot before landing, the sections are however referred to as first, second or third part of the runway. The first part always means the first third of the runway as seen in the direction of landing. Friction measurements are made along two lines parallel to the runway, i.e. along a line on each side of the centre line approximately 3 m or that distance from the centre line at which most operations take place. The objective of the tests is to determine the mean friction value for sections A, B and C. In cases where a continuous friction measuring device is used, the mean values are obtained from the friction values recorded for each section. The distance between each test point should be approximately 10 per cent of the usable length of the runway. If it is decided that a single test line on one side of the runway centre line gives adequate coverage of the runway, then it follows that each third of the runway should have three tests carried out on it. Test results and calculated mean friction values are entered in a special form (see *Airport Services Manual,* Part 2).

Note.— Where applicable, figures for stopway friction value should also be made available on request.

6.8 A continuous friction measuring device (e.g. Skiddometer, Surface Friction Tester, Mu-meter, Runway Friction Tester or Grip Tester), can be used for measuring the friction values for compacted snow- and ice-covered runways. A decelerometer (e.g. Tapley Meter or Brakemeter — Dynometer) may be used on certain surface conditions, e.g. compacted snow, ice and very thin layers of dry snow. Other friction measuring devices can be used, provided they have been correlated with at least one of the types mentioned above. A decelerometer should not be used in loose snow or slush, as it can give misleading friction values. Other friction measuring devices can also give misleading friction values under certain combinations of contaminants and air/pavement temperature.

6.9 The *Airport Services Manual,* Part 2 provides guidance on the uniform use of test equipment to achieve compatible test results and other information on removal of surface contamination and improvement of friction conditions.

7. Determination of friction characteristics of wet paved runways

7.1 The friction of a wet paved runway should be measured to:

a) verify the friction characteristics of new or resurfaced paved runways when wet (Chapter 3, 3.1.24);

b) assess periodically the slipperiness of paved runways when wet (Chapter 10, 10.2.3);

c) determine the effect on friction when drainage characteristics are poor (Chapter 10, 10.2.6); and

d) determine the friction of paved runways that become slippery under unusual conditions (Chapter 2, 2.9.8).

7.2 Runways should be evaluated when first constructed or after resurfacing to determine the wet runway surface friction characteristics. Although it is recognized that friction reduces with use, this value will represent the friction of the relatively long central portion of the runway that is uncontaminated by rubber deposits from aircraft operations and is therefore of operational value. Evaluation tests should be made on clean surfaces. If it is not possible to clean a surface before testing, then for purposes of preparing an initial report a test could be made on a portion of clean surface in the central part of the runway.

7.3 Friction tests of existing surface conditions should be taken periodically in order to identify runways with low friction when wet. A State should define what minimum friction level it considers acceptable before a runway is classified as slippery when wet and publish this value in the State's aeronautical information publication (AIP). When the friction of a runway is found to be below this reported value, then such information should be promulgated by NOTAM. The State should also establish a maintenance planning level, below which, appropriate corrective maintenance action should be initiated to improve the friction. However, when the friction characteristics for either the entire runway or a portion thereof are below the minimum friction level, corrective maintenance action must be taken without delay. Friction measurements should be taken at intervals that will ensure identification of runways in need of maintenance or special surface treatment before the condition becomes serious. The time interval between measurements will depend on factors such as: aircraft type and frequency of usage, climatic conditions, pavement type, and pavement service and maintenance requirements.

7.4 For uniformity and to permit comparison with other runways, friction tests of existing, new or resurfaced runways should be made with a continuous friction measuring device provided with a smooth tread tire. The device should have a capability of using self-wetting features to enable measurements of the friction characteristics of the surface to be made at a water depth of at least 1 mm.

7.5 When it is suspected that the friction characteristics of a runway may be reduced because of poor drainage, owing to inadequate slopes or depressions, then an additional test should be made, but this time under natural conditions representative of a local rain. This test differs from the previous one in that water depths in the poorly cleared areas are normally greater in a local rain condition. The test results are thus more apt to identify problem areas having low friction values that could induce aquaplaning than the previous test. If circumstances do not permit tests to be conducted during natural conditions representative of a rain, then this condition may be simulated.

7.6 Even when the friction has been found to be above the level set by the State to define a slippery runway, it may be known that under unusual conditions, such as after a long dry period, the runway may have become slippery. When such a condition is known to exist, then a friction measurement should be made as soon as it is suspected that the runway may have become slippery.

7.7 When the results of any of the measurements identified in 7.3 through 7.6 indicate that only a particular portion of a runway surface is slippery, then action to promulgate this information and, if appropriate, take corrective action is equally important.

7.8 When conducting friction tests on wet runways, it is important to note that, unlike compacted snow and ice conditions, in which there is very limited variation of the friction coefficient with speed, a wet runway produces a drop in friction with an increase in speed. However, as the speed increases, the rate at which the friction is reduced becomes less. Among the factors affecting the friction coefficient between the tire and the runway surface, texture is particularly important. If the runway has a good macro-texture allowing the water to escape beneath the tire, then the friction value will be less affected by speed. Conversely, a low macro-texture surface will produce a larger drop in friction with increase in speed. Accordingly, when testing runways to determine their friction characteristics and whether maintenance action is necessary to improve it, a speed high enough to reveal these friction/speed variations should be used.

7.9 Annex 14, Volume I requires States to specify two friction levels as follows:

a) a maintenance friction level below which corrective maintenance action should be initiated; and

b) a minimum friction level below which information that a runway may be slippery when wet should be made available.

Furthermore, States should establish criteria for the friction characteristics of new or resurfaced runway surfaces. Table A-1 provides guidance on establishing the design objective for new runway surfaces and maintenance planning and minimum friction levels for runway surfaces in use.

7.10 The friction values given above are absolute values and are intended to be applied without any tolerance. These values were developed from a research study conducted in a State. The two friction measuring tires mounted on the Mu-meter were smooth tread and had a special rubber formulation, i.e. Type A. The tires were tested at a 15 degree included angle of alignment along the longitudinal axis of the trailer. The single friction measuring tires mounted on the Skiddometer, Surface Friction Tester, Runway Friction Tester and TATRA were smooth tread and used the same rubber formulation, i.e. Type B. The GRIPTESTER was tested with a single smooth tread tire having the same rubber formulation as Type B but the size was smaller, i.e. Type C. The specifications of these tires (i.e. Types A, B and C) are contained in the *Airport Services Manual,* Part 2. Friction measuring devices using rubber formulation, tire tread/groove patterns, water depth, tire pressures, or test speeds different from those used in the programme described above, cannot be directly equated with the friction values given in the table. The values in columns (5), (6) and (7) are averaged values representative of

Table A-1.

Test equipment	Test tire: Type	Test tire: Pressure (kPa)	Test speed (km/h)	Test water depth (mm)	Design objective for new surface	Maintenance planning level	Minimum friction level
(1)	(2)		(3)	(4)	(5)	(6)	(7)
Mu-meter Trailer	A A	70 70	65 95	1.0 1.0	0.72 0.66	0.52 0.38	0.42 0.26
Skiddometer Trailer	B B	210 210	65 95	1.0 1.0	0.82 0.74	0.60 0.47	0.50 0.34
Surface Friction Tester Vehicle	B B	210 210	65 95	1.0 1.0	0.82 0.74	0.60 0.47	0.50 0.34
Runway Friction Tester Vehicle	B B	210 210	65 95	1.0 1.0	0.82 0.74	0.60 0.54	0.50 0.41
TATRA Friction Tester Vehicle	B B	210 210	65 95	1.0 1.0	0.76 0.67	0.57 0.52	0.48 0.42
GRIPTESTER Trailer	C C	140 140	65 95	1.0 1.0	0.74 0.64	0.53 0.36	0.43 0.24

the runway or significant portion thereof. It is considered desirable to test the friction characteristics of a paved runway at more than one speed.

7.11 Other friction measuring devices can be used, provided they have been correlated with at least one test equipment mentioned above. The *Airport Services Manual*, Part 2 provides guidance on the methodology for determining the friction values corresponding to the design objective, maintenance planning level and minimum friction level for a friction tester not identified in the above table.

8. Strips

8.1 Shoulders

8.1.1 The shoulder of a runway or stopway should be prepared or constructed so as to minimize any hazard to an aeroplane running off the runway or stopway. Some guidance is given in the following paragraphs on certain special problems which may arise, and on the further question of measures to avoid the ingestion of loose stones or other objects by turbine engines.

8.1.2 In some cases, the bearing strength of the natural ground in the strip may be sufficient, without special preparation, to meet the requirements for shoulders. Where special preparation is necessary, the method used will depend on local soil conditions and the mass of the aeroplanes the runway is intended to serve. Soil tests will help in determining the best method of improvement (e.g. drainage, stabilization, surfacing, light paving).

8.1.3 Attention should also be paid when designing shoulders to prevent the ingestion of stones or other objects by turbine engines. Similar considerations apply here to those which are discussed for the margins of taxiways in the *Aerodrome Design Manual*, Part 2, both as to the special measures which may be necessary and as to the distance over which such special measures, if required, should be taken.

8.1.4 Where shoulders have been treated specially, either to provide the required bearing strength or to prevent the presence of stones or debris, difficulties may arise because of a lack of visual contrast between the runway surface and that of the adjacent strip. This difficulty can be overcome either by providing a good visual contrast in the surfacing of the runway or strip, or by providing a runway side stripe marking.

8.2 Objects on strips

Within the general area of the strip adjacent to the runway, measures should be taken to prevent an aeroplane's wheel, when sinking into the ground, from striking a hard vertical face. Special problems may arise for runway light fittings or other objects mounted in the strip or at the intersection with a taxiway or another runway. In the case of construction, such as runways or taxiways, where the surface must also be flush with the strip surface, a vertical face can be eliminated by chamfering from the top of the construction to not less than 30 cm below the strip surface level. Other objects, the functions of which do not require them to be at surface level, should be buried to a depth of not less than 30 cm.

8.3 Grading of a strip for precision approach runways

Chapter 3, 3.4.8 recommends that the portion of a strip of an instrument runway within at least 75 m from the centre line should be graded where the code number is 3 or 4. For a precision approach runway, it may be desirable to adopt a greater width where the code number is 3 or 4. Figure A-3 shows the shape and dimensions of a wider strip that may be considered for such a runway. This strip has been designed using information on aircraft running off runways. The portion to be graded extends to a distance of 105 m from the centre line, except that the distance is gradually reduced to 75 m from the centre line at both ends of the strip, for a length of 150 m from the runway end.

9. Runway end safety areas

9.1 Where a runway end safety area is provided in accordance with Chapter 3, consideration should be given to providing an area long enough to contain overruns and undershoots resulting from a reasonably probable combination of adverse operational factors. On a precision approach runway, the ILS localizer is normally the first upstanding obstacle, and the runway end safety area should extend up to this facility. In other circumstances and on a non-precision approach or non-instrument runway, the first upstanding obstacle may be a road, a railroad or other constructed or natural feature. In such circumstances, the runway end safety area should extend as far as the obstacle.

9.2 Where provision of a runway end safety area may involve encroachment in areas where it would be particularly prohibitive to implement, and the appropriate authority considers a runway end safety area essential, consideration may have to be given to reducing some of the declared distances.

10. Location of threshold

10.1 General

10.1.1 The threshold is normally located at the extremity of a runway, if there are no obstacles penetrating above the

Chapter 3

Determining and Expressing Friction Characteristics of Wet Paved Surfaces

3.1 GENERAL

3.1.1 There is an operational need for information on paved runways that may become slippery when wet. To this end, there is a need to measure periodically the friction characteristics of a paved runway surface to ensure that they do not fall below an agreed level. An indication of the friction characteristics of a wet paved runway can be obtained by friction-measuring devices; however, further experience is required to correlate the results obtained by such devices with aeroplane braking performance due to the many variables involved, such as runway temperature, tire inflation pressure, test speed, tire-operating mode (locked wheel, braked slip), anti-skid system efficiency, and measuring speed and water depth.

3.1.2 The measurement of the friction coefficient has been found to provide the best basis for determining surface friction conditions. The value of the surface friction coefficient should be the maximum value that occurs when a wheel is braked at a specified percentage of slip but is still rolling. Various methods may be used to measure the friction coefficient. Operational considerations will generally determine the most suitable method to be used at a particular airport. As there is an operational need for uniformity in the method of assessing the runway friction characteristics, the measurement should preferably be made with devices that provide continuous measuring of the maximum friction (between 10 and 20 per cent slip) along the entire runway.

3.1.3 Present technology cannot provide a direct and immediate correlation of runway surface friction measurements, taken with a friction-measuring device, with aeroplane braking performance on wet runways. It has been found, however, that the wet runway friction characteristics of a surface remain relatively constant and deteriorate slowly over long periods of time, depending on frequency of use. This finding is important because it eliminates the need to continually measure the friction characteristics of a wet runway. Test results have shown that comparisons between measurements made by friction devices and the effective braking friction developed by aeroplanes under similar contaminated runway surface conditions do not correlate directly but can be related indirectly. By conducting many tests at several speeds on pavements that had various types of microtextural/macrotextural surfaces, it was also found that friction-measuring devices did provide the airport authority with the capability to distinguish between runway surfaces that have good or poor surface friction characteristics. It is, therefore, concluded that instead of reporting, on an operational basis, the friction characteristics of a wet runway, the runway friction can be periodically measured to ensure that its friction characteristics are of an acceptable standard.

3.1.4 The periodic measurement serves two purposes. First, it identifies the sub-standard runways, the location of which should be made known to pilots. Second, it provides qualitative information to airport authorities on the condition of the runway surface, thus permitting the development of more objective maintenance programmes and justifying development of budgets.

3.1.5 Ideally, the distinction between good and poor runway surface friction characteristics when wet should be related to airworthiness criteria for the certification of aeroplanes. International agreement for certification of aeroplanes on wet runways, however, does not exist at this time. Nevertheless, a number of States have operational experience with particular friction-measuring devices that enable them to initiate programmes for identifying runways which have poor surface friction when wet. This experience can be used to advantage by other States to establish their own programmes. Though such programmes may be theoretically imprecise in their relationship to aeroplane performance, they are considered adequate to distinguish between good and poor runway surface friction characteristics.

3.1.6 The criteria used by a State for evaluating runway surfaces should be published in the State's aeronautical information publication (AIP). When a runway surface that does not meet the criteria is found, a NOTAM should be issued until such time as corrective action has been taken.

3.1.7 Furthermore, it is desirable to measure the friction/speed characteristics of a new or resurfaced runway in order to verify whether or not the design objective has been achieved. The measurements should be made with a friction-measuring device using self-wetting features at two or more different speeds. An average value at each test speed for the entire runway should be obtained when the runway is wet but clean. To this end, friction-measuring devices providing continuous measurements of runway friction characteristics are preferable to those providing only spot measurements, as the latter may give misleading information. This information is considered of operational value as it gives an overall indication of the available surface friction of the relatively long central portion of the runway that is not affected by rubber build-up.

3.2 MEASUREMENT

3.2.1 The reasons for the requirement to measure the friction characteristics of a wet paved runway are:

a) to verify the friction characteristics of new or resurfaced paved runways;

b) to assess the slipperiness of paved runways;

c) to determine the effect on friction when drainage characteristics are poor; and

d) to determine the friction of paved runways that become slippery under unusual conditions.

3.2.2 Runways should be evaluated when first constructed or after resurfacing to determine the wet runway surface friction characteristics. Although it is recognized that friction reduces with use, this value will represent the friction of the relatively long central portion of the runway that is uncontaminated by rubber deposits from aeroplane operations and is therefore of operational value. Evaluation tests should be made on clean surfaces. If it is not possible to clean a surface before testing, then for purposes of preparing an initial report, a test could be made on a portion of a clean surface in the central part of the runway.

3.2.3 The friction value should be obtained by averaging the results of measurements made with the test device. If the friction characteristics differ significantly along major portions of a runway, the friction value should be obtained for each portion of the runway. A portion of runway approximately 100 m long may be considered sufficient for the determination of the friction value.

3.2.4 Friction tests of existing surface conditions should be taken periodically in order to identify runways with low friction when wet. A State should define what minimum friction level it considers acceptable before a runway is classified as slippery when wet and should publish this value in the State's AIP. When the friction of a runway or a portion thereof is found to be below this reported value, then such information should be promulgated by a NOTAM. The State should also establish a maintenance planning level, below which appropriate corrective maintenance should be considered to improve the friction. However, when the friction characteristics for either the entire runway or a portion thereof are below the minimum friction level, corrective maintenance action must be taken without delay. Friction measurements should be taken at intervals that will ensure identification of runways in need of maintenance or special surface treatment before the condition becomes serious. The time interval between measurements will depend on factors such as aeroplane type and frequency of usage, climatic conditions, pavement type, and pavement service and maintenance requirements.

3.2.5 For uniformity and to permit comparison with other runways, friction tests of existing, new or resurfaced runways should be made with a continuous friction-measuring device having a smooth tread tire. The device should have the capability of using self-wetting features to enable measurements of the friction characteristics of the surface to be made at a water depth of at least 1 mm.

3.2.6 When it is suspected that the friction characteristics of a runway may be reduced because of poor drainage due to inadequate slopes or depressions, then an additional test should be made under natural conditions representative of local rain. This test differs from the previous one in that water depths in the poorly drained areas are normally greater in a local rain condition. The friction tests are thus more apt to identify those problem areas which will most likely experience low friction values that could induce aquaplaning than the previous friction test that used the self-wetting feature. If circumstances do not permit friction tests to be conducted during natural conditions representative of rain, then this condition may be simulated.

3.2.7 Even when friction has been found to be above the level set by the State to define a slippery runway, it may be known that under unusual conditions, the runway may have become slippery when wet. These conditions are known to occur at certain locations when the initial rainfall on a runway, following a prolonged dry spell, results in a

Table 3-1. Runway Surface Condition Levels

Test Equipment	Test tire: Type	Test tire: Pressure (kPa)	Test Speed (km/h)	Test Water Depth (mm)	Design Objective or New Surface	Maintenance Planning Level	Minimum Friction Level
(1)	(2)		(3)	(4)	(5)	(6)	(7)
Mu-meter Trailer	A	70	65	1.0	0.72	0.52	0.42
	A	70	95	1.0	0.66	0.38	0.26
Skiddometer Trailer	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.47	0.34
Surface Friction	B	210	65	1.0	0.82	0.60	0.50
Tester Vehicle	B	210	95	1.0	0.74	0.47	0.34
Runway Friction	B	210	65	1.0	0.82	0.60	0.50
Tester Vehicle	B	210	95	1.0	0.74	0.54	0.41
TATRA Friction	B	210	65	1.0	0.76	0.57	0.48
Tester Vehicle	B	210	95	1.0	0.67	0.52	0.42
RUNAR	B	210	65	1.0	0.69	0.52	0.45
Trailer	B	210	95	1.0	0.63	0.42	0.32
GRIPTESTER	C	140	65	1.0	0.74	0.53	0.43
Trailer	C	140	95	1.0	0.64	0.36	0.24

and have been correlated with at least one of the types mentioned in Chapter 5. A method of estimating the friction value when no friction-measuring devices are available at the airport is described in Appendix 6.

3.3 REPORTING

There is a requirement to report the -presence of water within the central half of the width of a runway and to make an assessment of water depth, where possible. To be able to report with some accuracy on the conditions of the runway, the following terms and associated descriptions should be used:

Damp — the surface shows a change of colour due to moisture.

Wet — the surface is soaked but there is no standing water.

Water patches — significant patches of standing water are visible.

Flooded — extensive standing water is visible.

3.4 INTERPRETATION OF LOW FRICTION CHARACTERISTICS

3.4.1 The information that, due to poor friction characteristics, a runway or portion thereof may be slippery when wet must be made available since there may be a signi-ficant deterioration both in aeroplane bra-king performance and in directional con-trol.

3.4.2 It is advisable to ensure that the landing distance required for slippery run-way pavement conditions, as specified in the Aeroplane Flight Manual, does not exceed the landing distance available. When the possibility of a rejected take-off is being considered, periodic investigations should be undertaken to ensure that the surface friction characteristics are adequate for braking on that portion of the runway which would be used for an emergency stop. A safe stop from V_1 (decision speed) may not be possible, and depending on the distance available and other limiting conditions, the aeroplane take-off mass may have to he reduced or take-off may need to be delayed awaiting improved conditions.