AIRCRAFT ACCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/2/3/9704		
Aircraft Registration	**ZS-DEX**	**Date of Accident**	3 May 2018		**Time of Accident**	0608Z	
Type of Aircraft	Falcon 900EX (Aeroplane)		**Type of Operation**		Private (Part 91)		
Pilot-in-command Licence Type	Airline Transport		**Age**	46	**Licence Valid**	Yes	
Pilot-in-command Flying Experience	Total Flying Hours		6 362.2		Hours on Type	186.8	
Last Point of Departure	Cape Town International Aerodrome (FACT), Western Cape Province						
Next Point of Intended Landing	Rand Aerodrome (FAGM), Gauteng Province						
Location of the accident site with reference to easily defined geographical points (GPS position)							
Upon landing on Runway 17 at FAGM (GPS position: S26º14'14.00" E028º08'55.44"), elevation 5 448ft							
Meteorological Information	Wind: 190ºC at 12 kts; Temperature: 12ºC; Visibility: CAVOK and Dew Point 7ºC						
Number of people On-board	2 + 10	**No. of People Injured**	0	**No. of People Killed**	0		
Synopsis							

The Falcon 900EX aircraft was engaged in a non-scheduled domestic flight from Cape Town International Aerodrome (FACT) to Rand Aerodrome (FAGM). An instrument flight rules (IFR) flight plan was filed at 04:34:27; the aircraft took-off from Runway 19 at FACT and climbed to flight level (FL) 410. On-board the aircraft were two crew members and 10 passengers. The crew performed a visual approach for Runway 17 while still under IFR at FAGM, and the air traffic control (ATC) cleared the aircraft to land with the prevailing surface wind reported as southerly at 10 kts. At 06:08:35, which was seven seconds before runway contact, the right bank angle was captured at 35˚. At 06:08:38, the roll control position increased from 11.6˚ left bank to 9˚ right bank in 4 seconds. At 06:08:42, the aircraft's left landing gear was on the runway surface, with the left roll at 10˚ left bank.

During the roll-out, the first officer (FO), who was the pilot monitoring (PM), mentioned to the pilot-in-command (PIC), who was the pilot flying (PF), that he thought they may have hit something, possibly a tree, on short final approach. After the aircraft was parked on the apron, the post-flight walk-around inspection indicated that the right wing had impacted with trees, while the lower left wingtip, the slat and aileron had scraped the runway surface. The damage to the aircraft entailed the replacement of the slats, ailerons and wingtips on both wings. No one was injured on-board the aircraft.

The investigation determined that the crew continued with an unstable approach for landing on Runway 17, resulting in the right-wing colliding with trees in the approach path and the left wing making contact with the runway surface during landing.

SRP date	11 June 2019	Publication date	19 June 2019

ABBREVIATION	DEFINITION
AIID	Accident and Incident Investigation Division
AGL	Above ground level
AMO	Aircraft maintenance organisation
AMSL	Above mean sea level
ATC	Air traffic controller
ATIS	Automatic terminal information service
ATZ	Air traffic zone
AWOS	Automated weather observing system
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CVR	Cockpit voice recorder
CAR	Civil Aviation Regulation
DME	Distance measuring equipment
ETA	Estimated time of arrival
FDR	Flight data recorder
FL	Flight level
FO	First officer
ft	Feet
hPa	hectoPascal
ICAO	International Civil Aviation Organisation
IFR	Instrument flight rules
kts	Knots
lt	Litres
m	Metres
nm	Nautical miles
NOTAM	Notice to airmen
PF	Pilot flying
PIC	Pilot in command
PM	Pilot monitoring
QNH	Atmospheric pressure at mean sea level
SACAA	South African Civil Aviation Authority
SAWS	South African Weather Services
STC	Supplemental type certificate
TAWS	Terrain awareness and warning system
TCAS	Traffic alert and collision avoidance system
TMA	Terminal control area
UTC	Universal time coordination
VMC	Visual metrological conditions

Reference number	**:** CA18/2/3/9704
Name of Owner	**:** Blueport Trade 121 (Pty) Ltd
Name of Operator	**:** Corporate Aviation Operation (Part 93)
Manufacturer	**:** Dassault Aviation
Model	**:** Falcon 900EX
Nationality	**:** South African
Registration markings	**:** ZS-DEX
Place	**:** Rand Aerodrome (FAGM)
Date	**:** 3 May 2018
Time	**:** 0608Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011 this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and not to apportion blame or liability.

Investigations process:

The accident was reported to the Accident and Incident Investigations Division (AIID) on 3 May 2018. The investigators went to Rand Aerodrome on 3 May 2018. The investigators coordinated with all authorities on site by initiating the accident investigation process according to CAR Part 12 and investigation procedures. AIID of the South Africa Civil Aviation Authority (SACAA) is leading the investigation as the Republic of South Africa is the State of Occurrence.

Notes:
1. Whenever the following words are mentioned in this report, they shall mean the following:

- *Accident – this investigated accident;*
- *Aircraft – the Falcon 900EX involved in this accident;*
- *Investigation – the investigation into the circumstances of this accident;*
- *Pilot – the pilot involved in this accident;*
- *Report – this accident report.*

2. Photos and figures used in this report are taken from different sources and may be adjusted from the original for the sole purpose of improve the clarity of the report. Modifications to images used in this report are limited to cropping, magnification, file compression, or enhancement of colour, brightness, contrast, or addition of text boxes, arrows or lines.

Disclaimer:

This report is produced without prejudice to the rights of the CAA, which are reserved.

1. FACTUAL INFORMATION

1.1 History of flight

1.1.1 On 3 May 2018 at 0434Z, the Falcon 900EX aircraft departed from Runway 19 at FACT on a domestic non-scheduled flight to the FAGM on an IFR flight plan. On-board the aircraft were two crew members and 10 passengers. The PIC was the PF and the FO was the pilot monitoring (PM).

1.1.2 After take-off, the aircraft was cleared by radar control at FACT to climb to cruising altitude of 41 000 feet (ft) above mean sea level (AMSL) and FL 410. At 0543Z, the PM established radio contact with the FAGM tower where he provided the ATC with their estimated time of arrival (ETA), which was 0610Z. He also requested the latest surface data at FAGM, which the ATC indicated as follows: *"Surface wind is south-westerly at 15 knots, Runway 17 is in use".* The PF was listening to the Johannesburg automatic terminal information service (ATIS). He then remarked: *"Now everything is all ... (inappropriate language was used) up".* The PM then asked him: *"What happened now?"* To which the PF replied: *"The short runway is in use."*

1.1.3 At 0547Z, the PM requested descent clearance and the aircraft was cleared to descend to FL 360 by radar control at Johannesburg area control (FAJA); and at 0550Z, the aircraft was cleared to descend further to FL 160. The crew started to discuss the length of Runway 17 which, according to the PF, was 4 895ft (1 492m) long; and they required 3 179ft (969m) to land. The PM then asked the PF: *"Do you want to approach for Runway 17 and then break off for a right-hand turn for Runway 29, or do you want to land on Runway 17?"* At 0551Z, the PF then replied: *"Yah let's get a bit closer and then we will make a decision; I might switch it to Runway 29."*

1.1.4 At 0558Z, the aircraft was cleared by radar control to descend to 8 000ft. A pressure altitude setting (QNH) of 1026 hPa was given to the crew. At 0603Z, radar control was terminated and the crew were instructed to contact the Rand Aerodrome tower on the VHF frequency 118.70 MHz.

1.1.5 The PM established radio contact with the ATC at FAGM and the aircraft was cleared to join the circuit at 6 500ft on a right downwind for Runway 17 for a visual approach. There was slower traffic ahead of them (a Cessna 172) which was cleared for a touch-and-go landing. See Figures 1 and 2 show the track flown by ZS-DEX (red dotted line) and that of the Cessna 172 (yellow dotted line).

1.1.6 At 0605Z, the PF disconnected the autopilot. According to the flight data recorder (FDR), the aircraft commenced with a right turn for 44 seconds. The aircraft was at a maximum bank angle of 39.7º and the heading changed from 001º to 141º. It was also observed that during this time the pitch control position increased to a nose up attitude of 9º for a period of 30 seconds at an indicated airspeed (IAS) of 179 kts.

1.1.7 At 0605Z, the ATC asked the crew of ZS-DEX: *"Confirm you have the aircraft in sight"*, to which the PM replied: *"Negative at this stage, but we have him on traffic collision and avoidance system (TCAS)."* At 0605Z, during communication with ATC, the following audible warning could be heard on the cockpit voice recording (CVR): *"Caution terrain, caution terrain."* Five seconds later, a second audible warning followed: *"Terrain, terrain."* This was followed two seconds later by another audible warning: *"Pull up, pull up, pull up."* Neither of the crew members acted on these warnings, which came from the terrain avoidance warning system (TAWS); they continued with the approach and subsequent landing.

1.1.8 Between 0605Z and 0608Z, the crew members were discussing the location of the runway between themselves. At 0606Z, the ATC advised them: *"I have you in sight, report finals 17, you are number two, number one is on finals."* At this stage, neither of the crew members had the runway visual. At 0608Z, the PM said to the PF: *"There you go, right here"* and he replied: *"Yah, I see it."* Six seconds later, the ATC asked the crew: *"Confirm you will be able to land on Runway 17",* to which the PM replied: *"Affirmative, sorry mam, Affirm."* Six seconds later, the ATC cleared the aircraft to land on Runway 17 with the wind from the south at 10 kts, where after, the PM acknowledged the clearance.

1.1.9 Eight seconds later, the audible warning provided a radio altimeter height readout of 200ft. Nine seconds later, the audible warning could be heard: *"Bank angle, bank angle, bank angle, bank angle."* This warning was associated with a right bank angle of 35.2º, which was captured 12 seconds before the aircraft touched down on the runway.

1.1.10 Five seconds after that, a height readout from the audible warning followed: *"30, 20"* and two seconds later the TAWS audible warning prompt was heard: *"Bank angle, bank angle."* A second later, the roll control position changed from 11.6˚ left bank to 9˚ right bank. At four seconds, the left landing gear was on the ground; the pitch was 8˚ nose up, and the roll was 10˚ left bank. The yaw control position decreased from 17º left to 2º left yaw during a period of four seconds. Two seconds later, all three landing gears were on the ground (weight on wheels) and the PF called out: *"Brakes, brakes, brakes."* Annexure A is a summarised version of essential data

pertaining to the flight as extracted from the FDR and the CVR.

1.1.11 The aircraft ZS-DEX's flight track in Figures 1 and 2 can be seen as indicated by the red dotted line as it approached FAGM from the south-west. The green circle is the FAGM air traffic zone (ATZ), and the yellow dotted line within the green circle is the track flown by the Cessna 172 that was in the circuit at the time. The crew members of the ZS-DEX flew a very wide right downwind for Runway 17, which took the aircraft in proximity to the Johannesburg central business district (CBD) from where the PF executed several turns before the aircraft touched down on Runway 17. The downwind leg was flown outside of FAGM's controlled airspace in terms of the special rules, South Sector.

1.1.12 The accident occurred during daylight conditions at a geographical position that was determined to be S26º14'14.00" E028º08'55.44" at an elevation of 5 448ft AMSL.

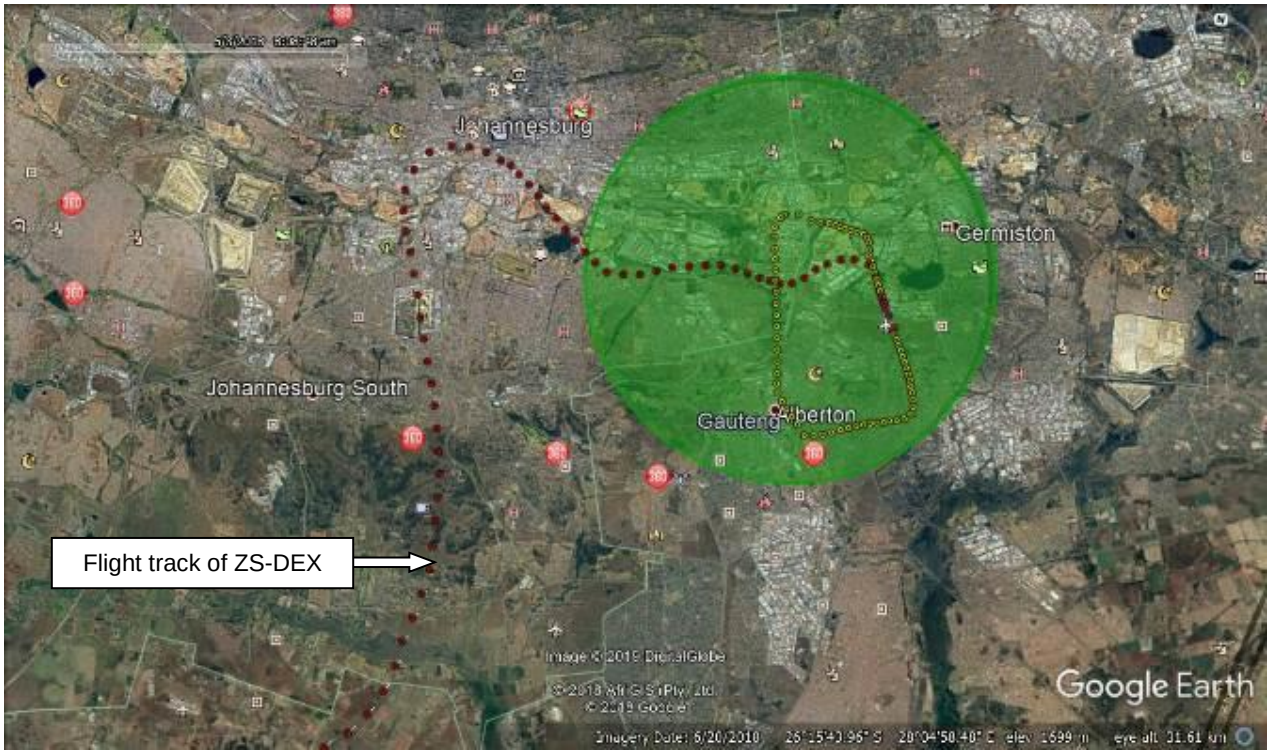


Figure 1: Overlay of the approach path that was flown by ZS-DEX (red dotted line) (Source: Google Earth)

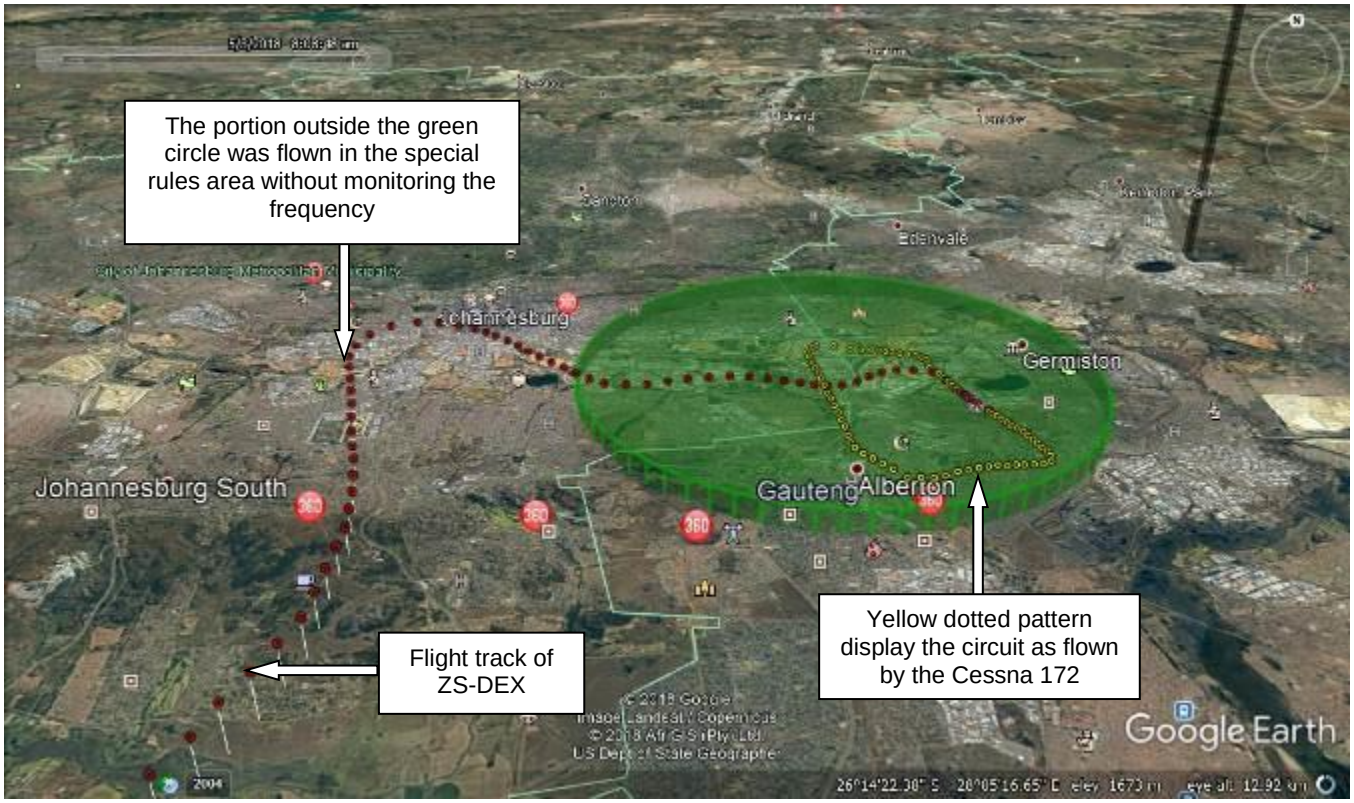


Figure 2: Overlay of the approach path that was flown by ZS-DEX (red dotted line) (Source: Google Earth)

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	2	-	10	-

1.3 Damage to Aircraft

1.3.1 The aircraft sustained substantial damage.

1.4 Other Damage

1.4.1 Damage to the trees on the Germiston Golf Course and to the runway surface of the airport.

1.5 Personnel Information

1.5.1 Pilot Flying (PF)

Nationality	South African	Gender	Male	Age	46
Licence Number	027 028 4441	Licence Type	Airline Transport		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument				
Medical Expiry Date	31 May 2018				
Restrictions	Must wear corrective lenses				
GNSS/GPS, RNAV	15 January 2013				
Previous Accidents	None on record with the SACAA				

Flying Experience:

Total Hours	6 362.2
Total Past 90 Days	68.0
Total on Type Past 90 Days	58.3
Total on Type	186.8

1.5.2 Pilot Monitoring (PM)

Nationality	South African	Gender	Male	Age	38
Licence Number	027 046 0751	Licence Type	Airline Transport		
Licence Valid	Yes	Type endorsed	Yes		
Ratings	Instrument				
Medical Expiry Date	31 May 2018				
Restrictions	None				
Previous Accidents	None on record with the SACAA				

Flying Experience:

Total Hours	4 370.9
Total Past 90 Days	76.6
Total on Type Past 90 Days	58.3
Total on Type	161.8

1.6 Aircraft Information

1.6.1 Aircraft Description – Falcon 900EX

The Dassault Falcon 900EX is a private jet with a range of over 5 000NM. It has a comfortable cabin with standard seating for between eight and 12 passengers in a double-club configuration and a three-person divan. The aircraft in question was equipped with Honeywell's Primus 2000 integrated avionics system. The system is enhanced by installing the Honeywell Elite II avionics upgrade under the supplemental type certificate (STC) ST029669NY.

The aircraft is fitted with three Honeywell TFE731-60 engines, which are flat-rated to 5 000 pounds of thrust a piece. It has a very light, tough frame, which is manufactured from titanium and Kevlar.

Figure 3: The aircraft ZS-DEX, Falcon 900EX (Source: www.aviationphotos.net)

Airframe

Type	Falcon 900EX	
Serial Number	065	
Manufacturer	Dassault Aviation	
Year of Manufacture	2000	
Total Airframe Hours (at time of accident)	9 699.3	
Last Phase Inspection (hours & date)	9 658.7	28 February 2018
Hours Since Last Phase Inspection	40.6	
C of A (Issue Date)	15 August 2017	
C of A (Expiry Date)	14 August 2018	
C of R (Issue Date) (Present Owner)	22 June 2017	
RVSM Certificate (Issue Date)	23 June 2017	
Operating Categories	Standard Normal (Aeroplane)	
Maximum Take-off Weight (MTOW)	21 908kg (48 300lbs)	

Engine No. 1

Type	Honeywell TFE 731-60
Serial Number	P112330
Hours Since New	9 642.3

Engine No. 2

Type	Honeywell TFE 731-60
Serial Number	P112332
Hours Since New	9 703.3

Engine No. 3

Type	Honeywell TFE 731-60
Serial Number	P112333
Hours Since New	9 702.3

1.7 Meteorological Information

1.7.1 The weather information entered in the table below was obtained from OR Tambo Airport (FAOR).

Wind direction	190º	Wind speed	16kts	Visibility	CAVOK
Temperature	12ºC	Cloud cover	Nil	Cloud base	Nil
Dew point	7 ºC				

1.7.5 Johannesburg Automatic terminal information service (ATIS):

The definition of ATIS according to ICAO Annex 11 is as follows:

Automatic terminal information service (ATIS). The automatic provision of current, routine information to arriving and departing aircraft throughout 24 hours or a specified portion thereof.

"What is ATIS?

ATIS is a continuous broadcast of recorded aeronautical information in busier terminal areas, i.e. airports and their immediate surroundings. ATIS broadcasts contain essential information, such as current weather information, active runways, available approaches, and any other information required by the pilots, such as important notice to airmen (NOTAM). Pilots usually listen to an available ATIS broadcast before contacting the local control unit, which reduces the controllers' workload and relieves frequency congestion. The recording is updated in fixed intervals or when there is a significant change in the information, e.g. a change in the active runway."

The PIC, who was also the pilot flying (PF), was listening to the Johannesburg ATIS at 05:40:00Z as they approached FAGM. This information was obtained from the CVR. The ATIS, at the time, contained the following information:

Confirm Johannesburg Information Alpha on first contact, Johannesburg Alpha 0531, expect SIDs and STARs in use, Zone VMC, Runway 21L for arrival and Runway 21R for departure, transition level 90, Wind 190º at 4 knots, CAVOK, Temperature 12ºC, Dew point 7ºC, QNH 1025, NOSIG

The aircraft was also equipped with the following:

Data link-automatic terminal information service (D-ATIS). The provision of receiving ATIS via a data link.

Voice-automatic terminal information service (Voice-ATIS). The provision of ATIS by means of continuous and repetitive voice broadcasts.

1.8 Aids to Navigation

1.8.1 The aircraft was equipped with standard navigational equipment as required by the Regulator. There were no defects reported with the navigational equipment prior to the flight.

1.8.2 Approach facility at FAGM NOTAM:

The VOR/DME (RAV) 117.7 MHZ/CH at FAGM was not serviceable at the time of this accident. The VOR provided a non-precision approach for Runway 35.

A NOTAM was first issued on 10 January 2017 - C0098/17. It was continuously extended.
NOTAM C1695/18 was issued on 20 April 2018 and was valid from 20 April to 29 June 2018.
The NOTAM was in force on 3 May 2018.

1.8.3 The following navigational equipment were installed in this aircraft:

(i) Standby Attitude Indicator
(ii) Non-Stabilised Magnetic (Standby) Compass
(iii) VHF Navigation Systems (VOR/ILS)
(iv) Attitude and Heading System (IRS)
(v) Altitude Alerting System
(vi) Flight Management System (FMS)
(vii) Navigation Databases
(viii) Marker Beacon System
(ix) Distance Measuring Equipment (DME)
(x) ATC Transponder and Automatic Altitude Reporting System
(xi) Radio Compass System (ADF) C
(xii) Weather Radar System

(xiii) Class A Terrain Awareness Warning System (TAWS) Equipment Required
(xiv) Ground Proximity Warning System (GPWS)
(xv) Advisory Callouts
(xvi) Windshear Mode (Reactive)
(xvii) Terrain System – Forward Looking Terrain Avoidance (FLTA) and Premature Descent Alert (PDA) Functions
(xviii) Runway Awareness and Advisory System (RAAS)
(xix) Traffic Alert and Collision Avoidance System (TCAS)
(xx) Resolution Advisory (RA) Display System(s)
(xxi) Radio Altimeter
(xxii) Stormscope/Lighting Sensor
(xxiii) Electronic Flight Instrument System (EFIS) Displays

1.9 Communication

1.9.1 The aircraft was equipped with standard communication equipment as required by the Regulator. There were no defects reported with the communication equipment prior to the flight.

1.9.2 The following communication equipment was installed in this aircraft:

(i) Communication System (VHF x 2)
(ii) Passenger Address System (PA)
(iii) AFIS System (VHF and Satellite)
(iv) High Frequency (HF) Communication System

1.9.3 The FO, who was the pilot monitoring was in radio communication with Johannesburg radar on the VHF frequency 124.50 prior to the hand-over to ATC and FAGM. The crew members were advised by the radar controller to remain clear of OR Tambo airspace in order to avoid an airspace infringement.

1.9.4 The PM then communicated with the ATC at Rand tower on the very high frequency (VHF) 118.70. The aircraft was cleared by the ATC to land on Runway 17, with the prevailing wind being reported as southerly at 10 kts. During the approach phase of the flight, the ATC asked the ZS-DEX crew: *"Confirm you will be able to land on Runway 17."* The PM replied: *"Yes."*

1.9.5 The automated weather observation system (AWOS) screen in the control tower

of FAGM was inoperative at the time. A NOTAM was issued with reference number C1828/18 in this regard on 1 May 2018.

1.10 Aerodrome Information

Aerodrome	Rand Aerodrome (FAGM)	
Aerodrome Coordinates	S26º14'31.12" E028º09'04.88"	
Aerodrome Elevation	5 483 feet above mean sea level	
Runway Designations	11/29	17/35
Runway Dimensions	1 579 x 15 m	1 197 x 15 m
Runway Used	17	
Runway Surface	Asphalt	
Runway Slope	+0.71% uphill slope	
Approach Facilities	Runway lights, PAPI, VOR/DME (RAV)	
Aerodrome Status	Licensed	
Aerodrome Rescue & Fire Fighting	ARFF services were available at the aerodrome.	

The aerodrome chart (see Annexure B) lists the following essential information with regard to Runway 17 as a NOTE on the top right-hand corner of the page.

(i) High-tension power lines on approach for RWY 17, marked with red/white spheres
(ii) High trees on approach RWY 17

Further to the above, the chart indicates that a VOR/DME (RAV) was available at the aerodrome. At the time of this flight, the VOR/DME was inoperative. A NOTAM, with reference number C1695/18, was issued in this regard on 20 April 2018 and was valid until 29 June 2018.

The aerodrome declared distances (AD 2.13) information, as contained in the table below, was obtained from the Aeronautical Information Publication (AIP) for FAGM (AD 2-FAGM-5), effective 15 October 2017 as published by the SACAA.

RWY	*TORA (M)*	*TODA (M)*	*ASDA (M)*	*LDA (M)*	*Remarks*
17	1376	1376	1492	1313	Nil
35	1313	1313	1492	1376	Nil

Figure 4: On short final approach for Runway 17 at FAGM

Figure 5: An aerial view of the approach path for Runway 17

Figure 6: The high-tension wires and high trees on the final approach path for Runway 17

1.11 Flight Recorders

1.11.1 The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR), as they were required to be installed in this aircraft, according to the regulations.

1.11.2 The cockpit voice recorder (CVR) and flight data recorder (FDR) were removed from the aircraft, both units were in a good condition and were downloaded with the assistance of the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) in France during the week of 4 to 8 June 2018.

1.11.3 The aircraft was equipped with a Honeywell CVR, model number 6044, part number 980-6044-003 and serial number 010-02709. The unit was found to be in a good condition and it was subjected to a read out with the manufacturer's official download equipment. The audio relative to the flight was extracted and characterised as good to excellent. The entire flight from start-up at FACT until engine shut-down and doors-open at FAGM was recorded. The last 33 minutes of the CVR was transcribed as it contained important information to this accident, consisting of the descent, the approach and the landing phases of the flight.

The CVR download was successful from where audio files from the CVR.DT1 binary file, and four audio files in the wav format were extracted. These files were: the pilot's speech activity, the FO's speech activity, the cockpit area microphone and passenger address. The duration of the CVR recording was 6 hours 18 minutes and 4 seconds (6h18min04s).

Figure 7: The cockpit voice recorder

1.11.3 The aircraft was equipped with a Honeywell solid state FDR, model number 4700, part number 980-4700-025 and serial number 04552. The synchronisation level was good and approximately 26 hours of flight data were recorded, which included a total of seven flights, including the accident flight.

Figure 8: The flight data recorder

1.12 Wreckage and Impact information

1.12.1 The aircraft was taxied to the main apron after landing where it was parked. It was only during the post-flight walk-around that the damage to both the wings and flight control surfaces were noted. The PM asked the PF during the landing roll if he was sure they had collided with a tree, which was confirmed to be the case during the walk-around. The scrape markings (see Figure 9) were caused by the left wing that had made contact with the runway surface during landing. These markings were at the threshold of runway 17.

Figure 9: Scrape markings from the left wing at the threshold of Runway 17

Figure 10: Scrape markings visible on the lower left wing-tip surface, as well as the aileron

Figure 11: Damage to the left-wing leading edge slat, lower surface

Figure 12: Damage to the aileron (left wing)

Figure 13: Damage to the right-wing slat, which was caused by vegetation (impact with trees)

Figure 14: Closer view of the damage to the right-wing slat

1.13 Medical and Pathological Information

1.13.1 None.

1.14 Fire

1.14.1 There was no evidence of pre- or post-impact fire.

1.15 Survival Aspects

1.15.1 The accident was survivable as there was no damage to the cabin and cockpit which could have caused injury to the occupants.

1.16 Tests and Research

1.16.1 Due to the FDR data not having any latitude and longitude parameters, it was not possible to obtain a virtual animation of the flight. Secondary surveillance radar (SSR) data was obtained for the flight, which provided the investigation team with the track the aircraft flew from FACT until landing at FAGM. It can be seen from the radar data that the aircraft flew a very wide right downwind for Runway 17 and, at the same time, extended the downwind by turning in proximity to the Johannesburg central business district (CBD). The aircraft came closely to some of the high-rise buildings, and the TAWS system prompted several audible warnings.

1.16.2 At 0605Z, the terrain awareness warning system (TAWS) issued or broadcast the following warning: *"Caution obstacle, Caution obstacle."* Thirty-five seconds later, another TAWS warning was activated: *"Caution terrain, caution terrain"* and five seconds later, another warning was activated: *"Terrain, terrain"* five seconds later, another TAWS warning was activated: *"Pull up, pull up, pull up.*" The aircraft was then observed to initiate a right turn; however, none of the crew members had acknowledged or had any comment(s) on any of these aural warnings.

1.16.3 The orange line (Figure 15b below) displays the aileron input during the flight. During the final approach phase of the flight, these control surfaces displayed substantial inputs, which included several noticeable deflections of 11˚ and more.

Figure 15a: FDR data for the last 2 minutes of the flight

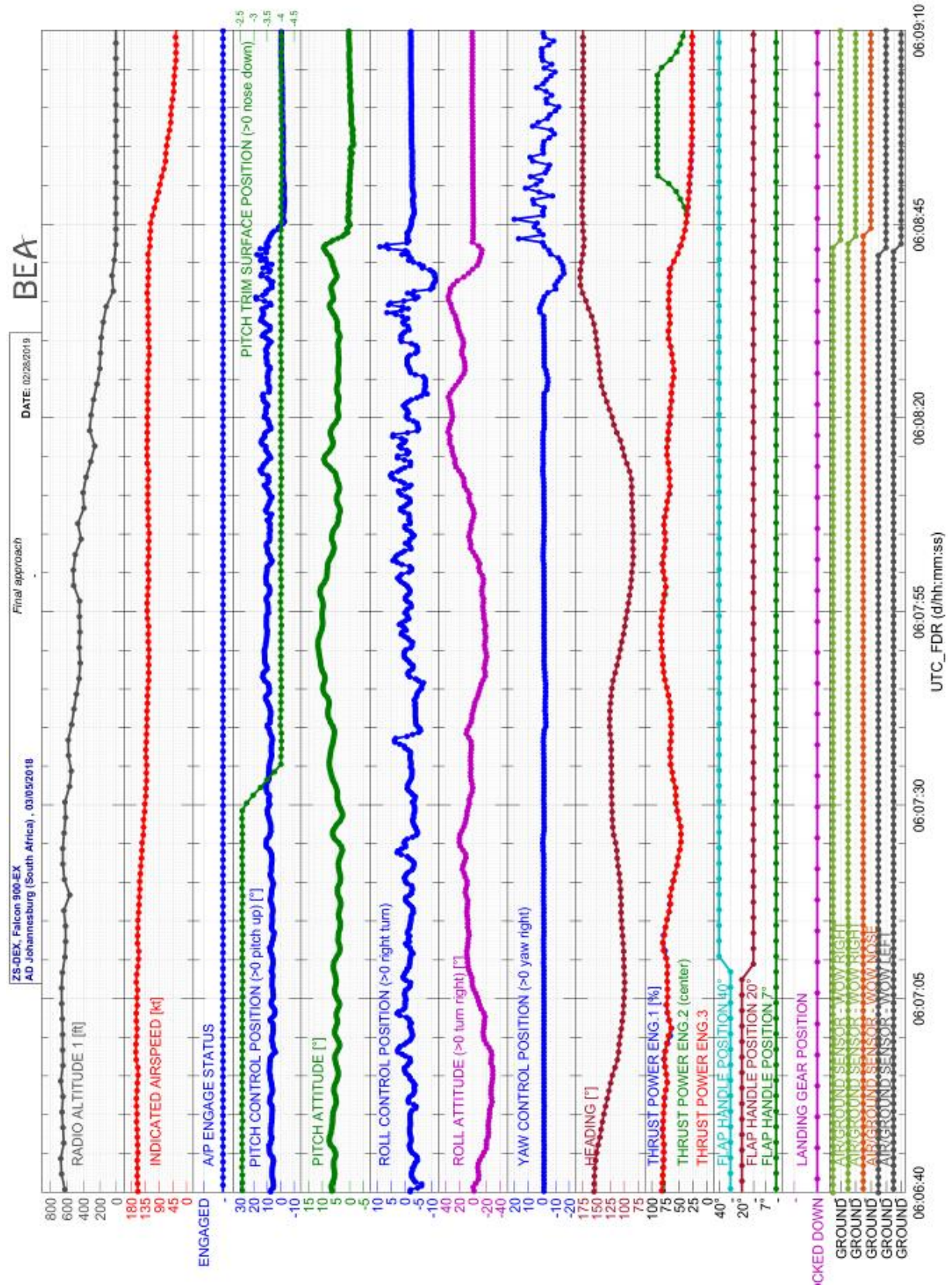


Figure 15a: FDR data for the last 2 minutes of the flight

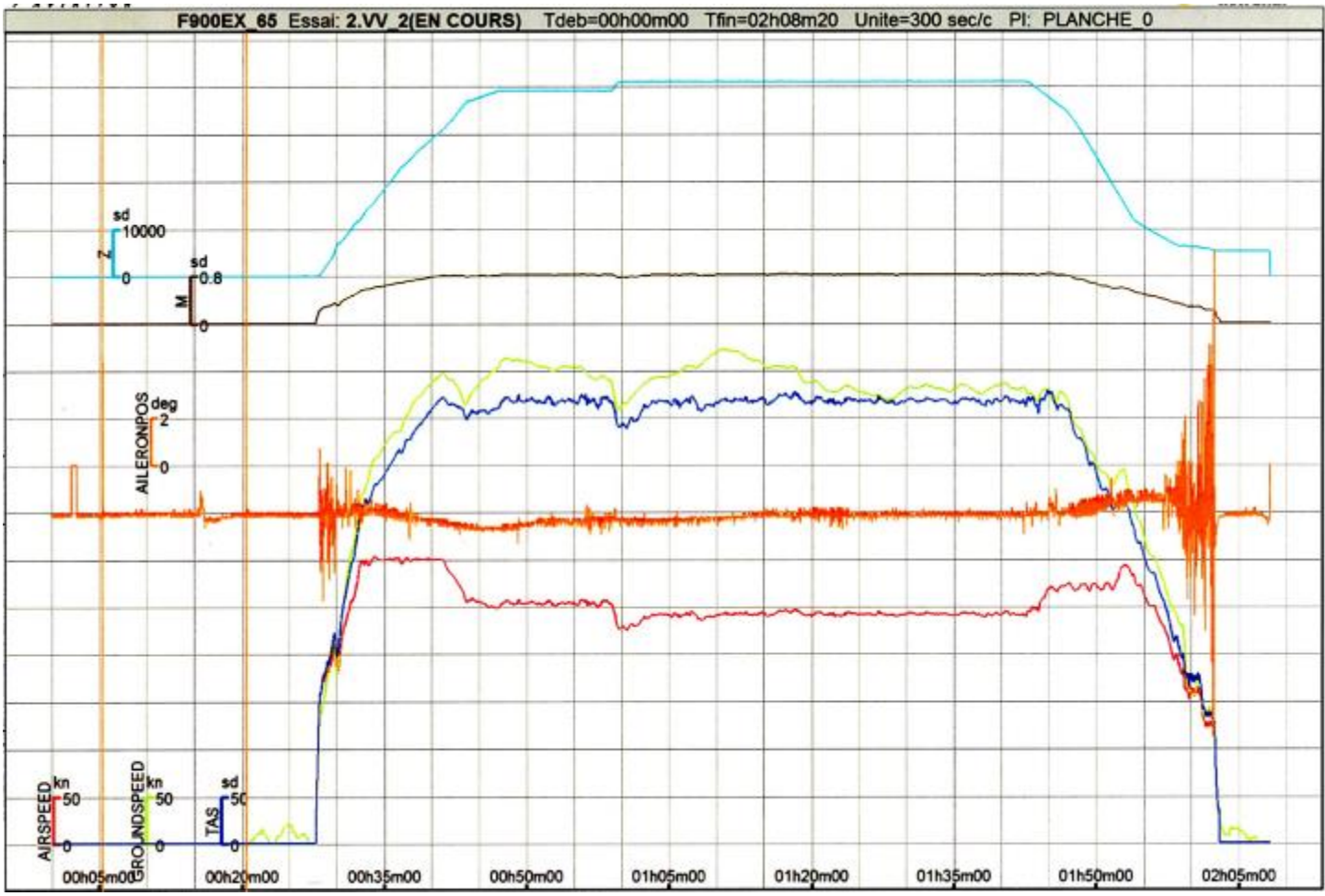


Figure 15b: The orange line displays the aileron position during the flight with substantial input noted during the approach

1.17 Organisational and Management Information

1.17.1 This aircraft was operated under Part 93 of the Civil Aviation Regulations of 2011 as amended at the time, which deals with Corporate Aviation Operations.

1.17.2 The aircraft was maintained in accordance with the approved maintenance schedule by a CAA-approved aircraft maintenance organisation (AMO).

1.18 Additional Information

1.18.1 An unstable approach

An unstable approach is an approach during which an aircraft does not maintain at

least one of the following variables stable: speed, descent rate, vertical/lateral flight path and in-landing configuration, or receive a landing clearance by a certain altitude. Unstable approaches account for most approach and landing accidents. For this reason, an approach should be stabilised at 1 000ft (305m) above the runway altitude. Otherwise, a go-around should be executed by the pilot.

1.18.2 Stabilised approach

Source: https://flightsafety.org/files/alar_bn7-1stablizedappr.pdf
Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force:

"All flights must be stabilised by 1 000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC).

An approach is stabilised when all of the following criteria are met:

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

"An approach that becomes unstable below 1 000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires

an immediate go-around."

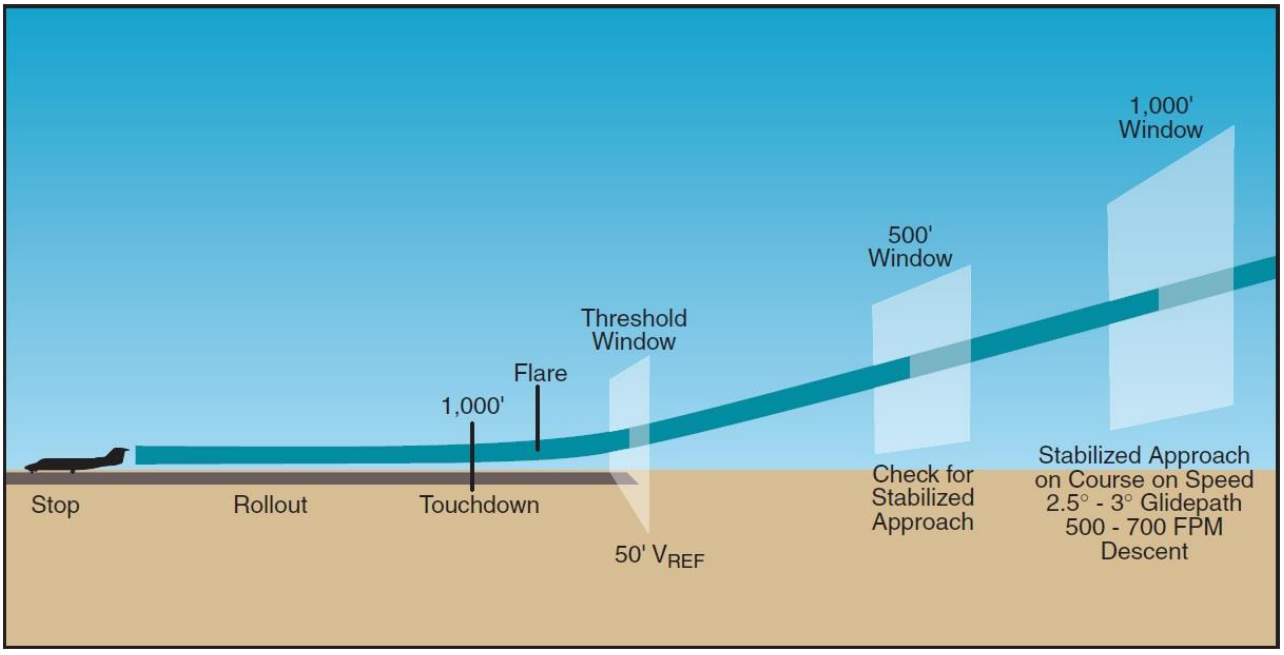


Figure 16: Illustration of the requirements to be met for a stabilised approach (Illustration, www.12charlie.com)

1.18.2 Falcon 900EX, Airplane Flight Manual, Performance, Wind

"Demonstrate crosswind

Satisfactory controllability during take-off and landing has been demonstrated with 90º crosswind component up to 30 kts.
Operation in strong gusty crosswinds is not recommended."

Supporting documentation pertaining to this sub-heading can be find attached to this report as Annexure C.

1.18.3 Falcon 900EX, Narrow runway operations

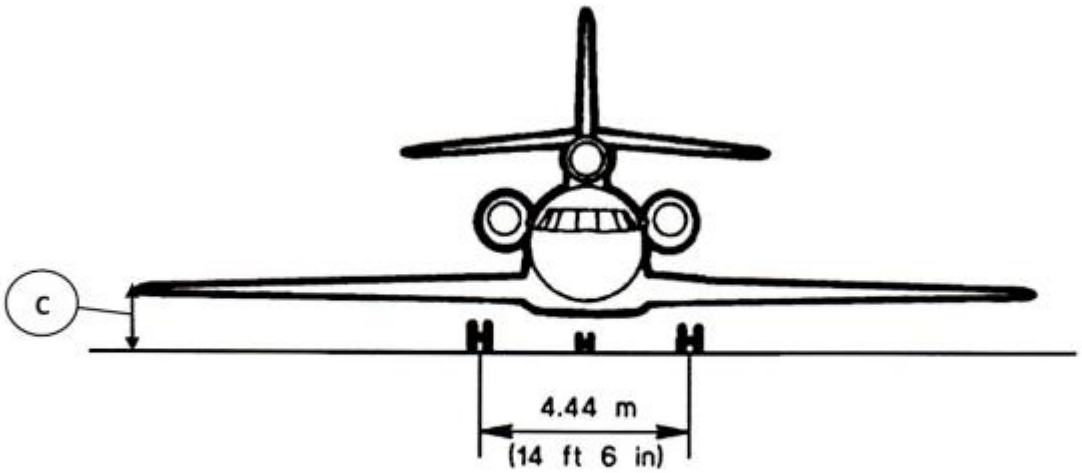
Both the runways at FAGM are 15m wide.
Dassault Aviation has published a special procedure – operation for narrow runway operations as it raises certain operational issues relevant to the lateral control of the aircraft. It should be noted that the AFM does not make reference to minimum runway width limitations as this was not a regulatory requirement during the certification of this aircraft. The narrow runway operations procedure states that when deviating from the recommended runway width of 30m, certain criteria should

be complied with.

(i) The crew should always exercise conservative judgement when considering an approach and landing.
(ii) A successful landing on a narrow runway depends on **a stabilised approach** and accurate tracking of the runway extended centreline on the final approach segment. Any late attempt to compensate for an incorrect runway alignment may result in severe hazards.
(iii) If overall landing conditions are considered as unsatisfactory: **go around**
(iv) Strictly hold the centreline.
(v) Be vigilant.

The crew accepted the clearance and continued with the approach and subsequent landing, which resulted in substantial damage to the aircraft.

Supporting documentation from Dassault Aviation pertaining to this sub-heading can be found attached to this report as Annexure D.



C = 130 cm

According to ICAO Annex 14, Chapter 3, paragraph 3.1.10 (Width of runways), the aircraft in question was categorised as a category 3B aircraft and, for this category of aircraft, the recommended runway width should be 30m (98ft). Attached for reader reference is ICAO doc 9157, Aerodrome Design Manual, Volume 1, Appendix 1, see Annexure E.

1.18.4 Optical Illusions

Source: http://www.flightlearnings.com/2012/09/30/optical-illusions

Of the senses, vision is the most important for safe flight. However, various terrain features and atmospheric conditions can create optical illusions. These illusions are primarily associated with landing. Since pilots must transition from reliance on instruments to visual cues outside of the flight deck for landing at the end of an instrument approach, it is imperative that they be aware of the potential problems associated with these illusions, and take appropriate corrective action. The major illusions leading to landing errors are as follows:

Runway Width Illusion

A narrower-than-usual runway can create an illusion that the aircraft is at a higher altitude than it actually is, especially when runway length-to-width relationships are comparable. The pilot who does not recognise this illusion will fly a lower approach, with the risk of striking objects along the approach path or landing short. A wider-than-usual runway can have the opposite effect, with the risk of levelling out high and landing hard, or overshooting the runway.

Runway and Terrain Slopes Illusion

An upsloping runway, upsloping terrain, or both, can create an illusion that the aircraft is at a higher altitude than it actually is. The pilot who does not recognise this illusion will fly a lower approach. Downsloping runways and downsloping approach terrain can have the opposite effect.

Featureless Terrain Illusion

An absence of surrounding ground features, as in an over water approach, over darkened areas, or terrain made featureless by snow, can create an illusion the aircraft is at a higher altitude than it actually is. This illusion, sometimes referred to as the "black hole approach", causes pilots to fly a lower approach than is desired.

Water Refraction

Rain on the windscreen can create an illusion of being at a higher altitude due to the horizon appearing lower than it is. This can result in the pilot flying a lower

approach.

Haze

Atmospheric haze can create an illusion of being at a greater distance and height from the runway. As a result, the pilot will have a tendency to be low on the approach. Conversely, extremely clear air (clear bright conditions of high attitude airport) can give the pilot the illusion of being closer than he or she actually is, resulting in a high approach, which may result in an overshoot or go-around. The diffusion of light due to water particles on the windshield can adversely affect depth perception. The lights and terrain features normally used to gauge height during landing become less effective for the pilot.

Figure 17: Narrow runway approach versus a wide runway approach (www.boldmethod.com)

1.18.5 Airspace Infringement Hotspots (OR Tambo area)

During the approach for FAGM, while still under radar control prior to the hand-over to the FAGM ATC, the crew members were advised to remain clear of the Johannesburg controlled traffic region (CTR) boundary. A map depicting these areas can be found attached to this report as Annexure F.

1.19 Useful or Effective Investigation Techniques

1.19.1 No new methods were used.

2. ANALYSIS

General

From the evidence available, the following analysis was made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

2.1 Man (Crew)

This was the first time the crew were going to land this aircraft at FAGM, as Lanseria Aerodrome (FALA) was the airport they normally utilised when they were flying to Gauteng. The passengers were to attend a business meeting in Soweto and, for logistical reasons, the crew members were requested to land at the nearest airport as the passengers wanted to return to Cape Town soon after the excursion.

During the approach for FAGM, the PF listened to the ATIS message, which provided the prevailing weather conditions for FAOR, as per the table below:

Confirm Johannesburg Information Alpha on first contact, Johannesburg Alpha 0531, expect SIDs and STARs in use, Zone VMC, Runway 21L for arrival and Runway 21R for departure, transition level 90, Wind 190º at 4 knots, CAVOK, Temperature 12ºC, Dew point 7ºC, QNH 1025, NOSIG

From the AFIS information, it was evident that the prevailing wind for FAOR was from the south (190˚ at 4 kts). At 05:43:23Z, which was 3½ minutes after the PF had listened to the AFIS, the PM established radio contact with the ATC at FAGM and asked them for the latest surface data. ATC reported that they were using FAOR QNH and the surface wind was south-westerly at 15 kts, and Runway 17 was in use. The PF then expressed his dismay and, when asked by the PM what was the problem, he said: *"The short runway is in use."* As the flight progressed, they discussed the option of flying the approach for Runway 17 with the option to break off for a right-hand turn for Runway 29. At 05:51:43Z, the PF made the following remark: *"Yah let's get a bit closer and then we will make a decision; I*

might switch it around to Runway 29." However, the crew never discussed this option again at any stage during the flight.

According to the aircraft performance software, Runway 17 was long enough for a safe landing. They required 969m (3 178ft) to land, and they had available 1 197m (3 926ft). Both runways at FAGM were 15m wide. According to the recommendation as contained in ICAO Annex 14, Volume 1, paragraph 3.1.10, the runway width should not be less than 30m in order to ensure safety was not compromised for this category 3B aircraft. The crew was well aware of the fact that the two runways at FAGM were 15m wide. The runway width at their departing aerodrome (FACT), for example, was 61m and that of FALA, an aerodrome they were familiar with, was 45m wide. Both these runways met the recommended limitations with regard to the runway width required as contained in ICAO Annex 14. Reference to this requirement was also contained in a special procedure – narrow runway operations, issued by Dassault Aviation.

The crew were advised by the ATC that there was slower traffic ahead of them (Cessna 172) in the circuit, and the PF opted to fly a wider downwind circuit. The turn onto downwind and the remainder of the downwind leg were flown outside the FAGM CTR. This placed the aircraft in the Special Rules South airspace, which is an unmanned broadcast-type frequency. Other aircrafts in the area would not have been able to contact ZS-DEX nor did ZS-DEX do any position reporting to advise other aircrafts on this frequency. This placed them on a flight path with the aircraft flying towards the Johannesburg city centre. Once in proximity to the high-rise buildings, the TAWS gave them a "Caution obstacle, Caution obstacle" warning. The PF then commence with a right turn. FAGM ATC then asked them if they had the slower traffic ahead of them visually, to which the PM replied: *"Negative at this stage, but we have him on TCAS".* During the approach, the crew members were well aware of the circuit traffic, but never physically had the aircraft visual at any stage during the approach. The early right turn had deleted the graphical extended centreline from the FMS, but the PF opted not to have it reinserted. Both crew members lost visual contact with the runway at approximately 1 000ft above ground level (AGL), but the PF continued with the turn onto final approach in anticipation of re-establishing visual contact. The PM was the first to indicate that he had the runway visual, which was 38 seconds before touchdown. When the PF saw the runway, he realised that the aircraft was to the right of the runway centreline. At that stage, the aircraft was fully configured for landing with the auto throttle holding the Vref speed at 123 kts.

At 06:08:09Z, the ATC asked the crew: *"Delta Echo X-ray (DEX), confirm you will be able to land on Runway 17?"* To which the PM replied: *Affirmative, sorry mam, Affirm."* The crew acknowledge the communication and continued with the approach to land.

The PF then opted to execute a descending left turn, which was followed by a right turn to establish runway heading. During the right turn, which was associated with an angle bank of 35˚, they flew over some tall trees overhead the Germiston Golf Course, and the right wing collided with some of the trees. This was not known by the crew at that stage. Following the right turn, approximately 4 seconds before the left main gear made contact with the runway surface, the roll position increased to a maximum left bank of 11.6˚ and the yaw control position increased up to 17˚ left yaw. The left main gear first made contact with the runway surface and, at that stage, the aircraft was at a 10˚ left bank. The left wing most probably made contact with the runway surface during this period as the scrape markings on the runway surface were to the left of the runway designation '17'. This was also an indication that the aircraft was very low on the final approach segment.

During the landing roll out after touchdown, the PM mentioned that he thought they may have collided with trees, but the PF indicated that it felt to him like a possible hydraulic-related input on the flight controls. The PM mentioned his observation again while they were taxiing to the parking bay. After the aircraft was parked on the main apron and the occupants had disembarked, the crew members observed damage to both wings during the walk-around inspection.

The crew workload increased during the final approach phase of the flight and, as a result, they placed themselves under undue pressure by committing to the landing on Runway 17. At no time during the flight had either one of them mentioned the option of a go-around or called for a go-around. The crew's action should be regarded as a significant contributory factor to this accident as they deviated from standard operating procedures.

The fact that the crew opted to land the aircraft at FAGM was associated with a high risk factor even before they had departed FACT. They knew that the aircraft had the capability to land and being decelerated to a safe speed on the runway length available, for both runways at FAGM. What they could not plan for was the actual weather conditions, especially what the prevailing wind conditions would be prior to and during landing at FAGM. From the CVR data, it was evident that once the PF had listened to the ATIS and had realised that Runway 17 was the active runway,

the cockpit dynamics changed from a relaxed atmosphere to a much more alert state.

At no stage during the approach phase of the flight did any of the crew members mention anything about performing a go-around or even diverting to an alternate aerodrome, of which there were several in Gauteng. One can, therefore, draw the conclusion that unless something unforeseen happened en route and they had to divert, they were committed to land the aircraft at FAGM, even though neither of them had landed this type of aircraft there before.

Of fundamental importance was the fact that this approach was a visual approach, yet the crew had difficulty in physically seeing the runway due to the position of the sun, but they continued with the approach. The PM was the first crew member to report runway visual, which was 38 seconds before the aircraft touched down on Runway 17. When the PF got the runway visual, the aircraft was to the right of the runway centreline. At no stage, during the flight, did the PF handed control over to the PM to land the aircraft, seeing that he had seen/located the runway visual first.

2.2 Machine (Aircraft)

The aircraft was airworthy at the time of the flight and no mechanical malfunction was recorded during the flight that could have contributed or could have caused the accident. The aircraft was maintained by an approved AMO in accordance with the SACAA-approved maintenance schedule.

The FDR and CVR were removed from the aircraft and the data was downloaded. From the FDR data, it was evident that during the final phase of the flight, several aircraft control inputs were executed leading to high bank angles. It is the investigator's opinion that this was done in an attempt to align with the centreline of the runway and/or to correct the approach path. This was further supported by the CVR data where audible warnings were heard but not acted upon by the crew. Furthermore, it is also the investigator's opinion that the approach was unstable, which would demand that the crew executed a go-around and not continue with the landing.

2.3 Environment

Fine weather conditions prevailed at the time, with the surface wind at FAGM being reported by ATC to be southerly at 10 kts when clearing the aircraft to land on

Runway 17. Clear sky conditions also prevailed at the time. The 10 kts headwind was well within the operating limitations of the aircraft.

2.4 Aerodrome

The aerodrome is a licensed facility with two active runways, as well as a manned air traffic control tower and ARFF personnel to assist in any possible emergency situation at the aerodrome. The prevailing wind at the time was from the south at 10 kts and the active runway was 17. The aerodrome chart contained a NOTE whereby aviators were made aware of high-tension wires, as well as high trees on final approach for runway 17. Both runways at FAGM were 15m wide, which are considered narrow runways according to the recommendation in ICAO Annex 14, Volume 1, Chapter 3, paragraph 3.1.10 (see Annexure E), as well as the Falcon 900EX Operational Procedures Manual CODDE2, special procedures, narrow runway operations (see Annexure D) in the aircraft flight manual.

2.5 Conclusion

Both crew members were in possession of valid airline transport pilot licences and had the aircraft type endorsed on their licences. Neither of them had landed with a Falcon 900EX at FAGM before. During all their previous visits to Gauteng, they landed at FALA, which was also where the aircraft maintenance organisation (AMO) that maintained this aircraft was based. The runway at FALA was 2 996m (9 827ft) long and 45m (148ft) wide.

Twenty-one minutes before the aircraft landed on Runway 17 at FAGM, the PF had completed listening to the ATIS (weather information) and shared his dismay with the PM stating: *"Now everything is all … (inappropriate language was used) up."* The PM then asked: *"What happened now?"* Whereupon the PF responded: *"The short runway is in use."*

The crew continued with the approach and, during a further discussion, the PF mentioned that he might break off on the approach for Runway 17 and land on Runway 29. This option was, however, never discussed again as the flight progressed, which could have been due to the fact that (i) the PF was well aware that both runways at FAGM were only 15m wide, and (ii) would he have opted to land on either one of them, he would have been confronted with at least a 10 kts crosswind. The runway width did not allow any room for error should he have opted for a crosswind landing.

From the photographic evidence in Figures 5 and 6 and the evidence under sub-paragraph 1.10 (Aerodrome Information) in this report, it was evident that the aircraft must have been very low on the final approach segment for Runway 17 in order for the right wing to have collided with trees. An important thought to remember during this low approach and subsequent right bank where the right wing was damaged by trees is that should this right turn have been executed a few seconds earlier, the aircraft could have possibly impacted with the high-tension wires instead of the trees, which could have resulted in a totally different outcome to this accident.

The Dassault Aviation narrow runway operations procedure clearly states that *in order to execute a successful landing on a runway surface with a width less than 30m,*

- *(i) it is essential that the approach must be stablished;*
- (ii) *(ii) the runway extended centreline must be accurately tracked during the approach; and*
- (iii) *(iii) any late attempt to compensate for an incorrect runway alignment may result in severe hazards.*

In the light of the procedure outlined in the above paragraph, it was clear that the non-compliance actions by the crew members in which they created their own severe hazards, resulting in this accident. There was always the option to execute a go-around, but never during this entire flight was this word mentioned or the option discussed. There was also the option of trying to land again, following a go-around, or to divert to another aerodrome, for instance FALA, with which the crew was familiar.

3. CONCLUSION

3.1. General

From the evidence available, the following findings, causes and contributing factors were made with respect to this accident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

To serve the objective of this investigation, the following sections are included in the conclusions heading:

- **Findings –** are statements of all significant conditions, events or circumstances in this Accident. The findings are significant steps in this Accident sequence but they are not always causal or indicate deficiencies.
- **Causes –** are actions, omissions, events, conditions, or a combination thereof, which led to this Accident.
- **Contributing factors –** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the accident or incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2. Findings

The Crew

3.2.1 The PIC was the holder of a valid airline transport pilot licence and the aircraft type was endorsed in his licence. He had accumulated a total of 6 362.2 flying hours at the time, of which 186.8 was on the aircraft type.

3.2.2 The PIC was in possession of a valid class 1 aviation medical certificate with an expiry date of 31 May 2018.

3.2.3 The FO was the holder of a valid airline transport pilot and he had the aircraft type endorsed on his licence. He had accumulated a total of 4 370.9 flying hours at the time, of which 161.8 was on the aircraft type.

3.2.4 The FO was in possession of a valid class 1 aviation medical certificate with an expiry date of 31 May 2018.

3.2.5 The PIC was the pilot flying (PF). It was the first time the crew landed a Falcon 900EX at FAGM. The FO was the pilot monitoring (PM).

The ATC

3.2.6 The ATC on duty at FAGM held a valid licence and aviation medical certificate at the time of the accident.

3.2.7 The aircraft was cleared by the ATC to land on Runway 17 (number two), behind slower traffic, with a Cessna 172 ahead of them engaged in circuit work.

3.2.8 Prior to landing, the ATC asked the crew: *"Confirm you will be able to land on Runway 17."* The PM replied: *"Affirmative, sorry mam, Affirm."*

3.2.9 The AWOS screen in the control tower was inoperative at the time of the accident and the ATC had to revert to a physical look at the windsock for wind information.

3.2.10 After the handover from radar to FAGM tower, the aircraft had not actually entered the FAGM CTR but in fact remained in the Johannesburg South special rules area, which had an unmanned frequency. The duration of this was for the entire downwind and a portion of the base leg for Runway 17.

The Aircraft

3.2.11 The aircraft, with serial number 065, was manufactured in the year 2000 and had a valid Certificate of Airworthiness, which was issued on 15 August 2017, with an expiry date of 14 August 2018.

3.2.12 The aircraft was issued with a Certificate of Release to Service, lapsing at 10 058.7 airframe hours or 28 October 2018, whichever occurs first.

3.2.13 The last maintenance inspection carried out on the aircraft prior to the accident flight was certified on 28 February 2018 at 9 658.7 airframe hours. Since this inspection, the aircraft had flown a further 40.6 hours.

3.2.14 The aircraft sustained damage to both slats, ailerons and wing tips, which required replacement. The wing structure also needed to undergo a detailed structural inspection, which will include non-destructive testing on certain areas as prescribed by the manufacturer.

3.2.15 The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR). Both these units were not damaged in the accident and were removed from the aircraft and downloaded at an approved facility.

3.2.16 The FDR and CVR were removed from the aircraft and the data was downloaded. From the FDR data, it was evident that during the final phase of the flight, several aircraft control inputs were executed leading to high bank angles. It is the investigator's opinion that this was done in an attempt to align with the centreline of the runway and/or to correct the approach path.

3.2.17 This was further supported by the CVR data where audible warnings were heard but not acted upon by the crew. Furthermore, it is also the investigator's opinion that the approach was unstable, which would demand that the crew execute a go-around and not continue with the landing.

The Aerodrome

3.2.18 FAGM is a licensed aerodrome with two crossing asphalt runways. Both these runways are 15m (4 ft) wide. Runway 17 is 1 197m (3 926ft) long.

3.2.19 There was no precision/procedural approach facility at the aerodrome. The VOR/DME (RAV) was inoperative at the time and a NOTAM was issued in that regard.

3.2.20 The AWOS screen in the control tower was inoperative at the time and the ATC had made use of alternative resources to provide weather data to aircraft traffic.

3.2.21 The VOR break cloud procedure chart for Runway 35 had been withdrawn by the Regulating Authority at the time of the accident.

3.2.22 The SACAA-approved FAGM aerodrome chart (attached as Annexure A) contains a NOTE to all aviators that the approach path for Runway 17 has high tension wires, as well as high trees.

3.2.23 The recommended runway width for this aircraft type according to ICAO Annex 14, Volume 1, Chapter 3, paragraph 3.1.10 should not have been less than 30m.

Environment

3.2.24 Fine weather conditions prevailed at FAGM, with the surface wind being from the south at 10 kts, which was well within the operating limitations of the aircraft.

International Protocol/Assistance

3.2.25 The BEA in France, the state in which the aircraft was designed and manufactured, was notified of the accident; and they had appointed a non-travelling accredited representative for purposes of the investigation as per the provisions contained in ICAO Annex 13.

3.2.26 The CVR and FDR were downloaded by the BEA Engineering Department.

3.3. Probable Cause

3.3.1 The crew continued with an unstable approach for landing on Runway 17, resulting in the right-wing colliding with trees in the approach path and the left wing making contact with the runway surface during landing.

3.4 Contributory Factors

3.4.1 This was the first time the crew landed with this aircraft (Falcon 900EX) at FAGM.

3.4.2 The PF verbally pronounced his dismay with his fellow crew member when he became aware that Runway 17 was the active runway at FAGM. Having to cope with a stressful situation like this most probably placed additional pressure on the PF.

3.4.3 The crew was advised by radar control to remain clear of the Johannesburg CTR, which should be regarded as a significant contributory factor as it limited the available airspace for manoeuvring the aircraft before landing on Runway 17.

3.4.4 During the approach phase of the flight, the PF mentioned that he might opt to land on Runway 29, which was substantially longer. However, a 10 kts crosswind was a concern to him due to the narrow runway width of 15m. During the remainder of the flight, the crew never discussed this option again.

3.4.5 The PM was not assertive enough (which is an essential attribute required for effective crew performance), especially during the final approach phase of the flight. He never called for a go-around at any stage during the approach. The cockpit dynamics were noted to be very relaxed.

3.4.6 The PM was the first of the two crew members to indicate that he had the runway visual, which was 38 seconds before the aircraft touched down.

3.4.7 There were high-tension power lines and high trees on the final approach path for Runway 17, which was noted on the approved aerodrome chart.

3.4.8 Poor judgement and decision making by the crew to continue with the approach and subsequent landing contributed to the accident.

3.4.9 The narrow runway (15m wide) surface could have presented the PF with an optical illusion and, as a result, a low approach was flown.

3.4.10 There was limited airspace for a fast aircraft to manoeuvre and get into position on final approach for Runway 17 due to restricted airspace limitations being in proximity to FAOR.

3.4.11 The crew members had become over-reliant on the advanced cockpit technology, including instrumentation and automation, that was at their disposal.

4. SAFETY RECOMMENDATIONS

4.1. General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation, and are based on the conclusions listed in heading 3 of this report; the AIID expects that all safety issues identified by the Investigation are addressed by the receiving states and organisations.

4.2. Safety recommendation

4.2.1 It is recommended to the Director of Civil Aviation (DCA) to incorporate the requirements of Annex 14 discussed in paragraph 1.18 above under the section Civil Aviation Regulations (CAR).

4.2.2 It is recommended to the DCA to issue a Notice to Airman (NOTAM) alerting the airman of limitations requirements at aerodromes such as FAGM with regard to high performance aircraft (e.g business jets) being allowed to approach and land on Runway 17 at FAGM.

The following factors should be considered:

(i) The approach path has several obstructions/hazards associated with it, which, as we have seen in this accident, have resulted in damage to the aircraft, with the possibility of even much more severe damage that could have occurred.

(ii) High performance aircraft (i.e. business jets) have limited manoeuvring space for preventing an airspace infringement with the Johannesburg CTR, due to proximity between the two aerodromes, which put undue pressure on the crew that intended to land at FAGM, especially when Runway 17 is in use.

(iii) High performance aircraft, like the aircraft in question, should not be allowed to approach nor land on Runway 17 in order to eliminate the risk associated with the hazards on the approach path.

4.2.3 Since the revision on the CAR, the aircraft type and those similar to it were moved to CAR Part 91 operation should they be operated privately. This has resulted in less stringent oversight requirements; thus, operators do not consider safety operations as required by Part 93 operation. This has resulted in Part 91 operators of such aircraft going over flight and duty times, landing in aerodromes without considering the limitations, etc.

It is recommended that operations of these aircraft be considered for CAR Part 93 operations as this will reduce the risk of similar occurrences and, possibly, save lives.

5. APPENDICES

5.1 Annexure A (Summary of FDR and CVR data with reference to the approach)

5.2 Annexure B (FAGM Aerodrome Chart)

5.3 Annexure C (Wind limitations as contained in the Falcon 900EX AFM)

5.4 Annexure D (Special Procedure - Narrow Runway Operations, Falcon 900EX AFM)

5.5 Annexure E (ICAO Annex 14 reference page and ICAO doc 9157 reference page)

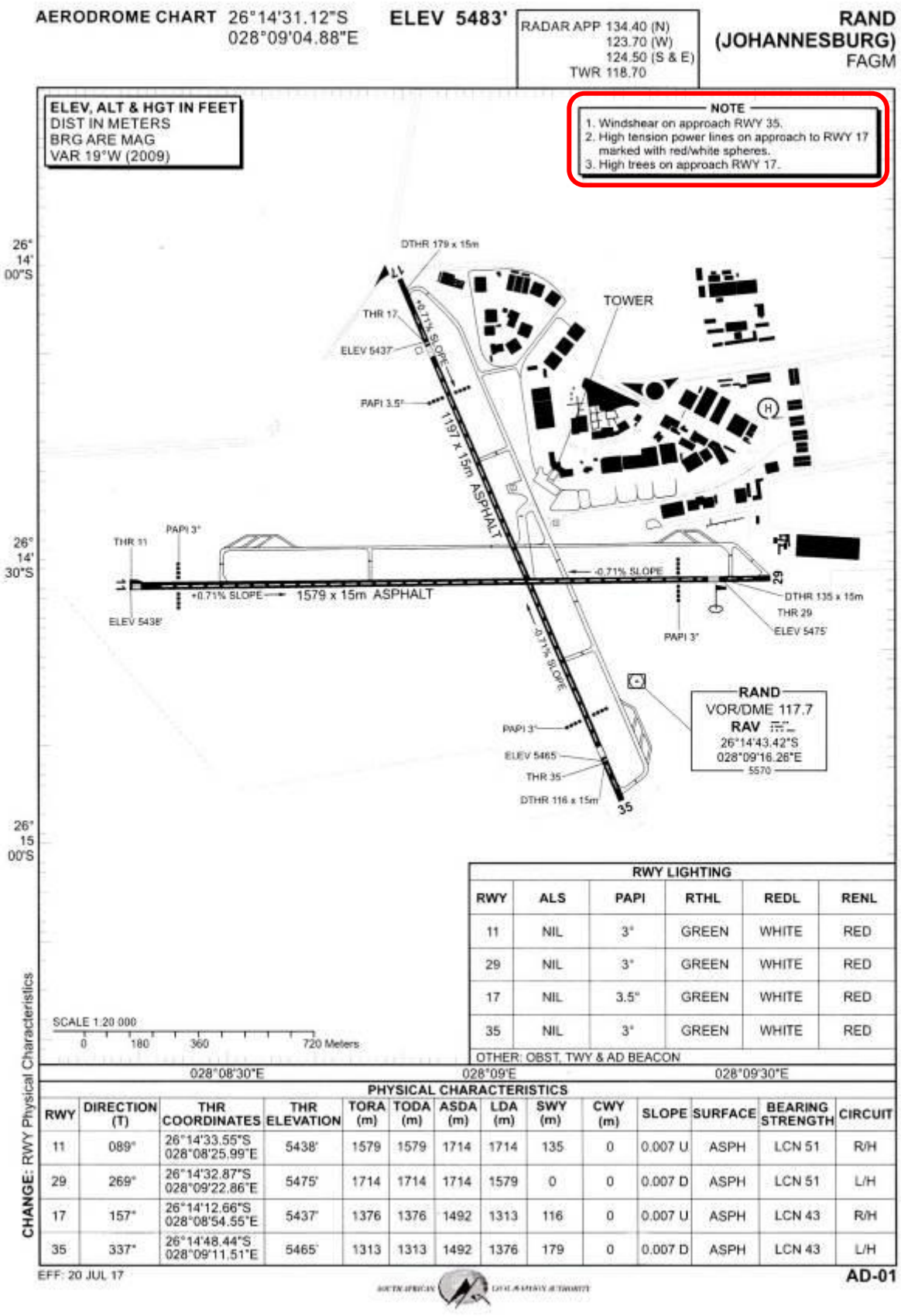
5.6 Annexure F (OR Tambo Area - Airspace Infringement Hotspots chart)

ANNEXURE A

UTC Time (hh:mm:ss)	Altitude (ft)	IAS (kts)	Event based on FDR data	CVR
04:34:27			Take-off from FACT on heading 189˚.	
04:39:17	13 879	299	Engagement of the Auto Pilot.	
05:06:43	41 403	226	Level off at cruise altitude FL410	
05:49:00	41 217	243	Beginning of descent.	
06:05:00	6 515	179	Flaps handle was set to flap 1 (7˚)	
06:05:11	6 521	179	Terrain caution was on for 8 seconds.	*TAWS Caution obstacle*
06:05:15	6 535	179	The Auto Pilot was disengaged. Beginning of right turn for 44 seconds. The right-bank angle increased to a maximum of 39.7˚. Heading increased from 001˚ to 141˚. The PFD 1 NAV source was FMS 1, the MFD 1 NAV format was MAP, the PFD 1 HIS mode was on COMPASS.	
06:05:18	6 537	179	The pitch control position increased to 9˚ nose up 30 seconds later.	
06:05:20	6 537	179	The MFD 1 range decreased from 25nm to 10nm.	
06:05:23	6 523	179	Flaps handle was set to flap 2 (20˚)	
06:05:41	6 557	163	The landing gear - down and locked.	
06:05:47	6 467	162	Terrain caution was on for 6 seconds.	*TAWS Caution terrain TAWS Caution terrain*
06:05:53	6 341	158	Terrain caution was on for 4 seconds.	*TAWS Caution terrain TAWS Pull up*
06:06:08	6 285	162	The MFD 1 range increased to 25 nm for 12 seconds and then decreased back to 10 nm.	
06:06:39	6 243	157	Beginning of left turn for 28 seconds: Left-bank angle with a maximum of 29.4˚. Heading decreased from 154˚ to 098˚.	
06:07:07	6 163	163	Beginning of right turn for 35 seconds: Right-bank angle to a maximum of 19.2˚ Heading increased from 100˚ to 125˚.	
06:07:10	6 139	156	Flaps handle was set to flaps 3 (40˚).	
06:07:27	6 029	139	The pitch trim surface decreased towards 0˚. Heading was almost constant around 122˚ for 18 seconds.	
06:07:29	6 031	135	The pitch trim surface decreased from -2.6˚ to -4.0˚ in 6 seconds, indicating more nose up trim.	*Sound similar to pitch trim with a duration of 6 seconds*
06:07:38	5 927	130	The pitch control position increased to nose	

			up. Pitch increased from 6˚ to a maximum of 11˚.	
06:07:42	5 893	128	Beginning of left turn for 20 seconds: Roll input with a maximum roll control position of 7.1˚ to the left. Left-bank angle with a maximum of 20˚. Heading decreased from 124˚ to 083˚	
06:08:00	5 879	124	Roll position was more at roll right, the left bank-angle decreased and heading was 085˚ for a period of 12 seconds.	
06:08:12	5 834	124	Bank angle continued to increase to the right, up to a maximum of 36˚. Heading increased to the right.	
06:08:23	5 743	125	Roll control to the left up to 8.4˚. The right-bank angle decreased, the yaw control position increased to the left and the heading continued to increase to the right up to 145˚.	
06:08:34	5 587	124	Roll control position indicated less right roll, and the yaw control increased to the left. Heading stabilised at 179˚.	
06:08:35	5 569	125	The pitch control position reached 18.1˚ nose up, and the roll control position increased to roll left and reached a minimum of 11.6˚ left bank 3 seconds later. Pitch was 7˚ nose up, roll was 35˚ right and heading was 169˚.	*TAWS Bank angle, bank angle for 6 seconds*
06:08:36	5 569	127	Roll control reached 33˚ right bank. Heading was 175˚. Roll control position continued to increase to left bank up to a maximum of 11.6˚ left and the yaw control position continued to increase to yaw left up to 11˚. It then continued to increase up to 17˚ left yaw.	
06:08:38	5 537	124	Roll control position increased from 11.6˚ left bank to 9.0˚ right bank in 4 seconds. Yaw control position decreased from 17˚ left yaw to 2˚ left yaw during this period. Roll was 6˚ right bank and was decreasing. Heading stabilised at 179˚.	
06:08:42	5 473	119	The left landing gear was on the ground and lateral acceleration increased and again rapidly decreased. The longitudinal acceleration decreased, indicating a reduction in speed. Pitch was 8˚ nose up, and roll was 10˚ left bank with the roll control position increasing to the right. Yaw control position increased from 2˚ left yaw to 17˚ right yaw. Heading was 173˚. Less than 1 second later the roll attitude went to 0˚.	*Sound similar to touching the ground* *TAWS Bank angle*
06:08:44	5 497	117	All landing gears were on the ground. Weight on wheels (WoW).	

ANNEXURE B


AERODROME CHART 26°14'31.12"S 028°09'04.88"E
ELEV 5483'
RADAR APP 134.40 (N)
123.70 (W)
124.50 (S & E)
TWR 118.70
RAND (JOHANNESBURG)
FAGM
ELEV, ALT & HGT IN FEET
DIST IN METERS
BRG ARE MAG
VAR 19°W (2009)
NOTE
1. Windshear on approach RWY 35.
2. High tension power lines on approach to RWY 17 marked with red/white spheres.
3. High trees on approach RWY 17.
26° 14' 00"S
26° 14' 30"S
26° 15' 00"S
DTHR 179 x 15m
THR 17
ELEV 5437'
PAPI 3.5°
+0.71% SLOPE
1197 x 15m ASPHALT
TOWER
PAPI 3°
THR 11
ELEV 5438'
+0.71% SLOPE
1579 x 15m ASPHALT
-0.71% SLOPE
DTHR 135 x 15m
THR 29
ELEV 5475'
PAPI 3°
-0.71% SLOPE
PAPI 3°
ELEV 5465'
THR 35
DTHR 116 x 15m
RAND
VOR/DME 117.7
RAV
26°14'43.42"S
028°09'16.26"E
5570
RWY LIGHTING
RWY | ALS | PAPI | RTHL | REDL | RENL
11 | NIL | 3° | GREEN | WHITE | RED
29 | NIL | 3° | GREEN | WHITE | RED
17 | NIL | 3.5° | GREEN | WHITE | RED
35 | NIL | 3° | GREEN | WHITE | RED
OTHER: OBST, TWY & AD BEACON
SCALE 1:20 000
0 180 360 720 Meters
028°08'30"E
028°09'E
028°09'30"E
PHYSICAL CHARACTERISTICS
RWY | DIRECTION (T) | THR COORDINATES | THR ELEVATION | TORA (m) | TODA (m) | ASDA (m) | LDA (m) | SWY (m) | CWY (m) | SLOPE | SURFACE | BEARING STRENGTH | CIRCUIT
11 | 089° | 26°14'33.55"S 028°08'25.99"E | 5438' | 1579 | 1579 | 1714 | 1714 | 135 | 0 | 0.007 U | ASPH | LCN 51 | R/H
29 | 269° | 26°14'32.87"S 028°09'22.86"E | 5475' | 1714 | 1714 | 1714 | 1579 | 0 | 0 | 0.007 D | ASPH | LCN 51 | L/H
17 | 157° | 26°14'12.66"S 028°08'54.55"E | 5437' | 1376 | 1376 | 1492 | 1313 | 116 | 0 | 0.007 U | ASPH | LCN 43 | R/H
35 | 337° | 26°14'48.44"S 028°09'11.51"E | 5465' | 1313 | 1313 | 1492 | 1376 | 179 | 0 | 0.007 D | ASPH | LCN 43 | L/H
CHANGE: RWY Physical Characteristics
EFF: 20 JUL 17
AD-01

ANNEXURE C

ALTITUDES AND HEIGHTS

QFE – Field pressure

Actual atmospheric pressure at the elevation of the airport.

Hp – Pressure altitude

Vertical distance from a standard level reference corresponding to 29.92 in.Hg / 1,013.2 mbar (1,013.2 hPa).

Height

Vertical distance from the lowest point of the airplane to the airport surface.

- Gross height: height reached using the gross climb gradient during a given time.
  Gross height is used to determine the level-off pressure altitude.
- Net height: height reached using the net climb gradient during a given time.
  Net height is used to determine a net flight path permitting any obstacle to be cleared by at least 35 ft (10.7 m) in order to meet the requirements.

Take-off safety height

Not less than 400 ft.

Minimum engagement height

The height below which the autopilot must be disengaged.

WIND

Wind components

Velocity and direction recorded at the height of 33 ft (10 m) above the runway surface.

- Headwind or tailwind: component parallel to the flight path.
- Crosswind: component perpendicular to the flight path.

Demonstrated crosswind

Satisfactory controllability during take-off and landing has been demonstrated with 90 degrees crosswind component up to 30 kt.

Operation in strong gusty crosswinds is not recommended.

ANNEXURE D

NARROW RUNWAY OPERATIONS

GENERAL

NARROW RUNWAY OPERATIONS MAIN ISSUES

Reduced runway width operations raise the following particular issues relevant to lateral control of the aircraft:

- At take-off:
  - Rejected take-off (RTO) following engine failure before V1,
  - Engine failure at/after V1,
  - Crosswind,
  - Runway conditions.
- At landing:
  - Weather and Wind,
  - Runway conditions,
  - Flare.

For both phases, the failures affecting lateral control and braking capacity must be considered.

REGULATORY BACKGROUND

There are currently no requirement about minimum runway width during the certification of an aircraft type, either in CFR 14 Part 25 or in CS 25.

As such, there is no runway width limitation in the AFM.

However:

- ICAO Annex 14 (Volume I, Chapter 3), for airport and runway design purposes, states a recommended minimum runway width, according to aircraft type, and function of the reference take-off field length (standard conditions, MTOW) and the most restrictive of wingspan or outer main gear wheel span.
  Accordingly, in this Annex 14, Falcon 900EX is referenced as belonging to category 3B, with an associated recommended minimum runway width of 98 ft (30 m).
- FAA AC 150/5300-13 (Chapter 1 §2 and Chapter 3 Table 3-3) recommended minimum width as a guideline for runway design, is established as a function of approach speed (A/C approach category) and wingspan (Airplane Design Group).
  Accordingly, in the table from AC150/5300-13, Falcon F900EX is referenced as belonging to Airplane Design Group II, with an associated recommended minimum runway width of 98 ft (30 m).

From an airworthiness perspective, FAR/CS 25 do not directly address runway width, but FAR 2.149(e) and CS 25.149 (e) specify some criteria for determination of VMCG:

- No credit for nose wheel steering,
- Maximum deviation from centerline during engine failure recovery is 30 ft (9,014 m),
- No crosswind.

There is, indeed, no direct regulatory connection between definition of VMCG and runway width, so the admissible 30 ft maximum deviation could significantly reduce the clearance between the outboard main landing gear and the runway edge during recovery after engine failure. Under a possible combination of adverse conditions or delayed PF reaction, the clearance could become inexistent.

RECOMMENDATIONS

NOTE

Current procedures as described in CODDE 2 remain applicable.
In any case, Captain's decision and common sense should prevail.

GENERAL

CAUTION

It is recommended:
- To consider as "Narrow Runway" any runway less than 30 m / 98 ft width,
- To cautiously consider crosswind, particularly in gusty wind, and make appropriate decision regarding operations under such conditions,
- That the PF be in the left hand seat (NWS tiller side),
- That the Nose Wheel Steering, braking, thrust reverser and Flight Control System be fully operational when operating to/from narrow runway,
- That Operator's MEL should cover dispatch conditions to/from narrow runway.

TAKE-OFF

It is recommended to use NWS up to VR.

Engine failure below V1: RTO phase:

- At low airspeed, combination of high thrust asymmetry and low rudder effectiveness may entail the deviation to be quite large. The live engine(s) must be retarded to Idle as quickly as possible to cancel thrust asymmetry and NWS must be used.
- Depending on A/C systems lost (particularly NWS) according to failed engine and/or rudder effectiveness at low airspeeds, differential braking may be needed.

NOTE

A/C particular condition for potential large deviation during RTO:
- Light gross weight,
- Aft CG,
- 20° FLAPS + SLATS,
- Unfavorable conditions: crosswind from the failed engine side.

CAUTION

At VR do not delay reaction: immediately rotate the A/C.

Engine failure after V1:

- Immediately and aggressively counter the departing moment in yaw.

LANDING

CAUTION

Crew should always exercise conservative judgment when considering approach and landing, and particularly in adverse weather condition or degraded aircraft status.

Successful landing on a narrow runway essentially depends on a stabilized approach and accurate tracking of runway extended centerline on the final approach segment. Any late attempt to compensate for an incorrect runway alignment may result in severe hazards.

If overall landing conditions are considered as unsatisfactory: GO AROUND!

Lateral engine inoperative landing is not recommended: diversion to a suitable runway is to be privileged.

- There could be a tendency to flare out late due to visual aspect of the runway. This could lead to hard and/or bounced touchdown.
- During the deceleration roll, be particularly vigilant regarding lateral control of the A/C.

For all operations to/from narrow runways, a dedicated training on a simulator with a representative and validated typical environment should prove effective.

CAUTION

STRICTLY HOLD THE CENTERLINE.

BE VIGILANT.

ANNEXURE E

3.1.8 Secondary runway

Recommendation.— *The length of a secondary runway should be determined similarly to primary runways except that it needs only to be adequate for those aeroplanes which require to use that secondary runway in addition to the other runway or runways in order to obtain a usability factor of at least 95 per cent.*

3.1.9 Runways with stopways or clearways

Recommendation.— *Where a runway is associated with a stopway or clearway, an actual runway length less than that resulting from application of 3.1.7 or 3.1.8, as appropriate, may be considered satisfactory, but in such a case any combination of runway, stopway and clearway provided should permit compliance with the operational requirements for take-off and landing of the aeroplanes the runway is intended to serve.*

Note.— Guidance on use of stopways and clearways is given in Attachment A, Section 2.

Width of runways

3.1.10 **Recommendation.—** *The width of a runway should be not less than the appropriate dimension specified in the following tabulation:*

	Outer Main Gear Wheel Span (OMGWS)			
Code number	Up to but not including 4.5 m	4.5 m up to but not including 6 m	6 m up to but not including 9 m	9 m up to but not including 15 m
1[a]	*18 m*	*18 m*	*23 m*	–
2[a]	*23 m*	*23 m*	*30 m*	–
3	*30 m*	*30 m*	*30 m*	*45 m*
4	–	–	*45 m*	*45 m*

a. The width of a precision approach runway should be not less than 30 m where the code number is 1 or 2.

Note 1.— The combinations of code numbers and OMGWS for which widths are specified have been developed for typical aeroplane characteristics.

Note 2.— Factors affecting runway width are given in the Aerodrome Design Manual *(Doc 9157), Part 1.*

Note 3.— See 3.2 concerning the provision of runway shoulders, in particular for Code F aeroplanes with four (or more) engines.

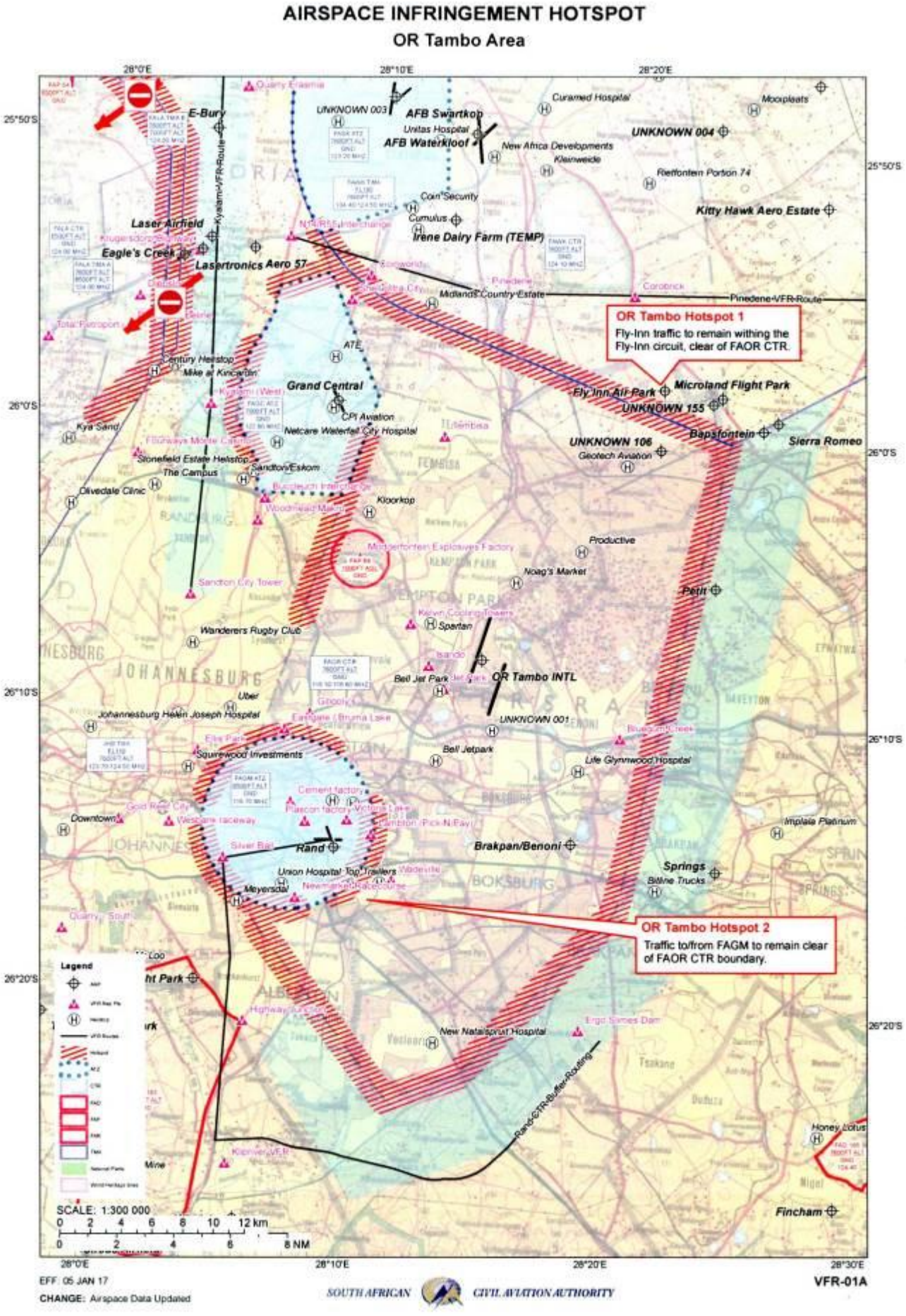
Minimum distance between parallel runways

3.1.11 **Recommendation.—** *Where parallel non-instrument runways are intended for simultaneous use, the minimum distance between their centre lines should be:*

— *210 m where the higher code number is 3 or 4;*

Aircraft Make	*Model*	*Code*	*Aeroplane reference field length (m)*	*Wing span (m)*	*Outer main gear wheel span (m)*
Bombardier Aero.	CRJ 100	3B	1 470	21.2	4.0
	CRJ 100ER	3B	1 720	21.2	4.0
	CRJ 200	3B	1 440	21.2	4.0
	CRJ 200ER	3B	1 700	21.2	4.0
Dassault Aviation	Falcon 20	3B	1 463	16.3	3.7
	Falcon 200	3B	1 700	16.3	3.5
	F50/F50EX	3B	1 586	18.9	4.5
	Falcon 900	3B	1 504	19.3	4.6
	Falcon 900EX	3B	1 590	19.3	4.6
	F2000	3B	1 658	19.3	5.0
Embraer	EMB-135 LR	3B	1 745	20.0	4.1
Fokker	F28-1000	3B	1 646	23.6	5.8
	F28-2000	3B	1 646	23.6	5.8
I.A.I.	SPX	3B	1 644	16.6	—
	Galaxy	3B	1 798	17.7	—
Gulfstream Aero.	G IV-SP	3B	1 661	23.7	4.8
Nord	262	3B	1 260	21.9	3.4
Antonov	AN24	3C	1 600	29.2	8.8
Boeing	B717-200	3C	1 670	28.4	5.4
	B737-600	3C	1 690	34.3	7.0
	B737-700	3C	1 598	34.3	7.0
Convair	240	3C	1 301	28.0	8.4
	440	3C	1 564	32.1	8.6
	580	3C	1 341	32.1	8.6
	600	3C	1 378	28.0	8.4
	640	3C	1 570	32.1	8.6
Douglas	DC3	3C	1 204	28.8	5.8
	DC4	3C	1 542	35.8	8.5
	DC6A/6B	3C	1 375	35.8	8.5
	DC9-20	3C	1 551	28.5	6.0
Embraer	EMB-120 ER	3C	1 481	19.8	6.6
Fokker	F27-500	3C	1 670	29.0	7.9
	F27-600	3C	1 670	29.0	7.9
	F28-3000	3C	1 640	25.1	5.8

ANNEXURE F


AIRSPACE INFRINGEMENT HOTSPOT
OR Tambo Area
OR Tambo Hotspot 1
Fly-Inn traffic to remain withing the Fly-Inn circuit, clear of FAOR CTR.
OR Tambo Hotspot 2
Traffic to/from FAGM to remain clear of FAOR CTR boundary.
Legend
SCALE: 1:300 000
0 2 4 6 8 10 12 km
0 2 4 6 8 NM
EFF: 05 JAN 17
CHANGE: Airspace Data Updated
SOUTH AFRICAN CIVIL AVIATION AUTHORITY
VFR-01A
28°0'E
28°10'E
28°20'E
28°30'E
25°50'S
26°0'S
26°10'S
26°20'S
E-Bury
Kyalami-VFR-Route
Laser Airfield
Eagle's Creek Jy
Lasertronics Aero 57
Century Helistop
Mike al Kincardin
Grand Central
CPI Aviation
Netcare Waterfall City Hospital
Kya Sand
Stonefield Estate Helistop
The Campus
Sandton/Eskom
Olivedale Clinic
Sandton City Tower
Wanderers Rugby Club
Johannesburg Helen Joseph Hospital
Uber
Squirewood Investments
Downtown
Rand
Meyerstal
Union Hospital Top Trailers
Brakpan/Benoni
Springs
Bidvine Trucks
Life Glynnwood Hospital
Implats Platinum
Bell Jetpark
OR Tambo INTL
UNKNOWN 001
Spartan
Noag's Market
Productive
Petit
Bapsfontein
Sierra Romeo
UNKNOWN 106
Geotech Aviation
UNKNOWN 155
Microland Flight Park
Fly Inn Air Park
Midland Country Estate
Pinedene-VFR-Route
Irene Dairy Farm (TEMP)
Cumulus
Kitty Hawk Aero Estate
Rietfontein Portion 74
UNKNOWN 004
New Africa Developments
Klainwelde
AFB Swartkop
AFB Waterkloof
Unitas Hospital
UNKNOWN 003
Curamed Hospital
Mooipleats
Klopkop
Productive
New Natalspruit Hospital
Honey Lotus
Fincham
Rand-CTR-Buffer-Routing