الهيئـــة الـعـامـــة للطيـــران الـمـدنـــي
GENERAL CIVIL AVIATION AUTHORITY

الإمارات العربية المتحدة
United Arab Emirates

Air Accident Investigation Sector

Accident

- Final Report -

AAIS Case Nº AIFN/0007/2019

Wake Turbulence Induced Loss of Control on Approach during Runway Lighting Calibration Flight

Operator:	Flight Calibration Services Limited
Make and Model:	Diamond DA62
Nationality and Registration:	The United Kingdom, G-MDME
Place of Occurrence:	3.5 nautical miles inbound to runway 30L Dubai International Airport
State of Occurrence:	The United Arab Emirates
Date of Occurrence:	16 May 2019

This Investigation was conducted by the Air Accident Investigation Sector of the United Arab Emirates pursuant to Civil Aviation Law No. 20 of 1991, in compliance with Air Accident and Incident Investigation Regulations, and in conformance with the provisions of Annex 13 to the Convention on International Civil Aviation.

This Investigation was conducted independently and without prejudice. The sole objective of the investigation is to prevent future aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

The Air Accident Investigation Sector issued this Final Report in accordance with national and international standards and best practice. Consultation with applicable stakeholders, and consideration of their comments, took place prior to the publication of this Report.

The Final Report is publicly available at:

http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx

The Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

P.O. Box 6558
Abu Dhabi
United Arab Emirates
E-mail: aai@gcaa.gov.ae
Website: www.gcaa.gov.ae

Accident Brief

AAIS Report Number:	AIFN/0007/2019
Operator:	Flight Calibration Services Limited
Aircraft Type and Registration:	Diamond DA62, G-MDME
MSN:	62.077
Number and Type of Engines:	Two, Austro Engine GmbH E4P-C
Date and Time:	16 May 2019, 1929 local time
Location:	3.5 nautical miles inbound to runway 30L Dubai International Airport, Dubai, the United Arab Emirates
Type of Flight:	Commercial
Persons Onboard:	Four
Fatalities:	Four

Investigation Process

The Accident involved a Diamond DA62 aircraft, registered as G-MDME, and was immediately notified by Dubai Air Traffic Control to the Air Accident Investigation Sector (AAIS) by phone call to the Duty Investigator Hotline Number +971 50 641 4667.

The AAIS formed an investigation team in line with ICAO Annex 13 obligations, the UAE being the State of Occurrence. An investigator-in-charge was appointed and several AAIS investigators were assigned to the investigation team.

After the initial on-site Investigation phase, the occurrence was classified as an Accident.

The AAIS notified the Air Accidents Investigation Branch (AAIB) of the United Kingdom, being the investigation authority of the State of Registry and of the Operator, the Federal Safety Investigation Authority of Austria, being the authority of the State of Manufacture of the aircraft and the engines, and the Transport Safety Board of Canada (TSB), being the authority of the State of Design. Accredited Representatives were designated and assisted by Advisers from Diamond Aircraft Industries GmbH and Austro Engine GmbH. In addition, the AAIB appointed an Adviser from the Operator to assist the Accredited Representative of the AAIB.

The Air Accident Investigation Committee of Thailand, being the investigation authority of the State of the Operator of the preceding Airbus A350 aircraft, and the Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile of France (BEA), being the investigation authority of the State of Manufacture and Design of the preceding aircraft appointed Accredited Representatives.

Notes:

1 Whenever the following words are mentioned in this Report with the first letter capitalized, it shall mean:

- (Accident). This investigated accident
- (Aircraft). The aircraft involved in this accident
- (Commander). The commander of the accident flight
- (Copilot). The copilot of the accident flight
- (Investigation). The investigation into this accident
- (Operator). Flight Calibration Services Limited
- (Report). This Final Report.

2 Unless otherwise mentioned, all times in this Report are local time (UTC plus 4 hours).

3 Photos and figures used in this Report are taken from different sources and are adjusted from the original for the sole purpose of improving clarity of the Report. Modifications to images are limited to cropping, magnification, or insertion of text boxes, arrows, or lines.

Abbreviations and Definitions

AAIS	Air Accident Investigation Sector
AMSL	Above mean sea level
ANS	Air navigation service
ATC	Air traffic control
CAA	The Civil Aviation Authority of the United Kingdom
CFRP	Carbon fiber reinforced plastic
dans	Dubai Air Navigation Services
EASA	European Union Aviation Safety Agency
ECU	Engine control unit
ELT	Emergency locator transmitter
FCSL	Flight Calibration Services Limited
ft	feet
GCAA	General Civil Aviation Authority of the United Arab Emirates
GFRP	Glass fiber reinforced plastic
hPa	Hectopascal
ICAO	The International Civil Aviation Organization
IFR	Instrument flight rules
kt	Knots
kW	Kilowatts
LIDAR	Light Detection and Ranging
MFD	Multi-function display
MTOW	Maximum take-off weight
nm	Nautical mile(s)
PFD	Primary flight display
PSR	Prompt safety recommendation
RPM	Revolutions per minute
SMS	Safety Management System
UAE	The United Arab Emirates
UTC	Universal time coordinated
UK	The United Kingdom
VFR	Visual flight rules
VHF	Very high frequency

Synopsis

On 16 May 2019, at 1533 local time of the United Arab Emirates, a Diamond DA62 Aircraft, registered as G-MDME, departed Sharjah International Airport (OMSJ) for a positioning flight to Dubai International Airport (OMDB), from where it was intended to operate an aerodrome lighting calibration flight. The crew comprised two pilots and a company Flight Inspector.

Prior to departure from OMDB the crew attended a meeting with Dubai air traffic control and airport representatives to discuss the calibration flight. During the meeting, the different flight profiles to be flown during the calibration mission were explained. The meeting included discussion on traffic information and how spacing from other aircraft on Final approach was to be assured.

The DA62 departed OMDB from runway 30R for the calibration flight at 1808 with the three crewmembers and an additional occupant, who was an observer employed by the aerodrome lighting provider, onboard. The observer had no defined duties related to the calibration flight.

The mission required the DA62 to fly several approaches to, and low passes over, runway 30L. At 1929, after uneventfully completing nine approaches, the DA62 commenced its tenth approach and joined the Final leg for runway 30L following a Thai Airways Airbus A350-900 aircraft which was on approach to the parallel runway 30R. The A350 was 3.7 nautical miles (nm) and 90 seconds ahead of the DA62 which was offset by 380 meters and approximately 200 feet below the altitude of the A350.

When the DA62 turned onto the Final leg, it levelled off at an altitude of 1,300 feet (ft) above mean sea level (AMSL) and an airspeed of 120 knots (kt). Shortly after, it rolled dynamically to the left, lost approximately 100 ft in altitude, and was recovered after nine seconds.

Seven seconds later, the DA62 abruptly rolled to the left until it became inverted and entered a steep dive. The DA62 impacted the ground approximately 3.5 nm inbound from the threshold of runway 30L. All four occupants sustained fatal injuries.

The Investigation determined that the cause of the Accident was a loss of control induced by an encounter with wake vortices generated by the preceding A350. It was identified that, while the flight crew operated under visual flight rules (VFR) and provided their own separation relative to preceding aircraft, the approaches during this mission were flown with spacings that were less than the separation minima provided by air traffic control to flights operating under instrument flight rules (IFR). The spacing was in excess of ICAO recommended separation minima for light aircraft operating under IFR following a heavier wake turbulence category aircraft. It was also identified that the wake turbulence advice provided by ATC during the first five approaches did not prompt the flight crew to increase the distance to preceding aircraft on approach to the parallel runway.

The Operator had declared their operation under the provisions of the European Union Aviation Safety Agency (EASA) Part-SPO *Specialised Operation* in 2017, and had previously operated under the Civil Aviation Authority of the United Kingdom (UK CAA) Aerial Work category between 2005 and 2017. The UK CAA were not required to carry out inspections of operators under the now obsolete “Aerial Work” category, and it could not be determined whether the UK CAA had carried out any oversight functions on the calibration operation prior to the Accident. The Investigation determined that the information collected through the online declaration was inadequate to assess the risk profile of the operation.

As a result of the investigation, the AAIS issued a number of safety recommendations to EASA and the UK CAA requesting them to review the oversight requirements and processes, and to equip commercially operated light aircraft with cockpit image and audio recording systems.

The AAIS made recommendations to the operator to conduct a comprehensive review to improve the safety management system and the effectiveness of its pilot training with particular attention on pilot decision-making.

Recommendations were issued to the General Civil Aviation Authority (GCAA) of the United Arab Emirates to ensure that UAE air navigation service providers review working processes for air traffic controllers, to ensure that the risk of wake turbulence encounters to calibration flights was mitigated.

The AAIS recommended that Dubai Airports review and enhance existing risk assessment and mitigation measures for calibration flights, and that the air navigation service provider review and enhance the air traffic services manual and other relevant instructions to consistently provide essential traffic information, and to review and enhance existing calibration flight procedures to effectively mitigate the risk of wake turbulence encounters.

The AAIS finally recommended that Transport Canada, as the state of certification and design, review the emergency locator transmitter system installation on the DA62 to improve the crashworthiness of the system, and consequently, the survivability of the occupants in the case of an accident.

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1. Factual Information

1.1 History of the Flight

On 16 May 2019, at 1533 local time of the United Arab Emirates, a Diamond DA62 Aircraft, registered as G-MDME, departed Sharjah International Airport (OMSJ) for a positioning flight to Dubai International Airport (OMDB) with two flight crewmembers and a company Flight Inspector for calibration systems onboard.

The DA62 was scheduled to carry out an aerodrome ground lighting calibration flight as part of the southern runway refurbishment project. The ground lighting check required the Aircraft to perform several approaches and low overflights of runway 30L.

Prior to departure from OMDB, the flight crew and the Flight Inspector conducted a meeting with representatives from air navigation services (ANS) and the airport to discuss the mission, and how the calibration flight would be conducted. Separation, spacing and traffic information requirements regarding other aircraft were discussed during this meeting.

After the meeting, at 1808, the DA62 departed OMDB from runway 30R with the two flight crewmembers, a Flight Inspector, and an additional observer onboard.

The DA62 completed nine uneventful approaches, performing different aerodrome lighting checks. At 1929, the DA62 entered the Final leg for runway 30L for a tenth approach behind an Airbus A350-900 which was flying the Final approach to the parallel runway 30R. The A350 was 3.7 nautical miles (nm) and 90 seconds ahead of the DA62 which was offset by 380 meters and approximately 200 feet below the altitude of the A350.

When the DA62 turned onto the approach, it levelled off at an altitude of 1,300 feet (ft) above mean sea level (AMSL) and an airspeed of 120 knots (kt). The airport runway approach camera captured the DA62 rolling dynamically to the left shortly after completing the turn. The DA62 lost approximately 100 ft in altitude, but was recovered after nine seconds (figure 1).

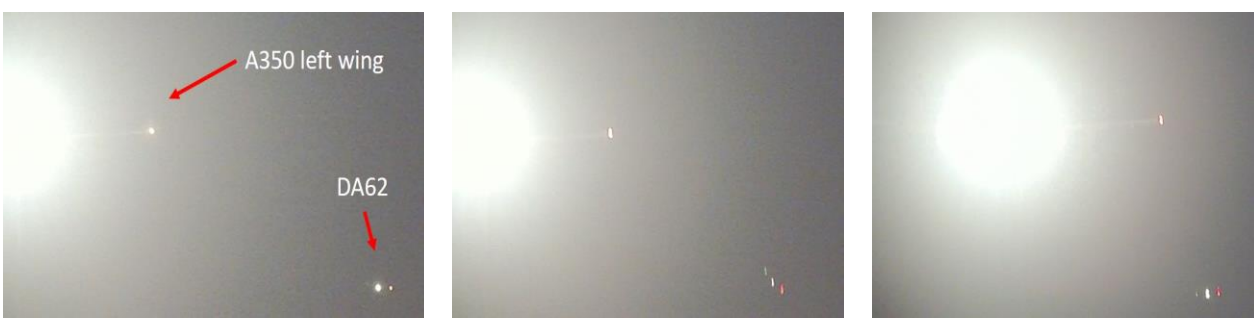

Figure 1. First upset and recovery as captured by the runway approach camera

Seven seconds later, the DA62 rolled abruptly to the left until it became inverted and then entered into a steep dive (figure 2). The DA62 impacted the ground approximately 3.5 nm inbound from the threshold of runway 30L. The impact was not visible to the runway approach camera.

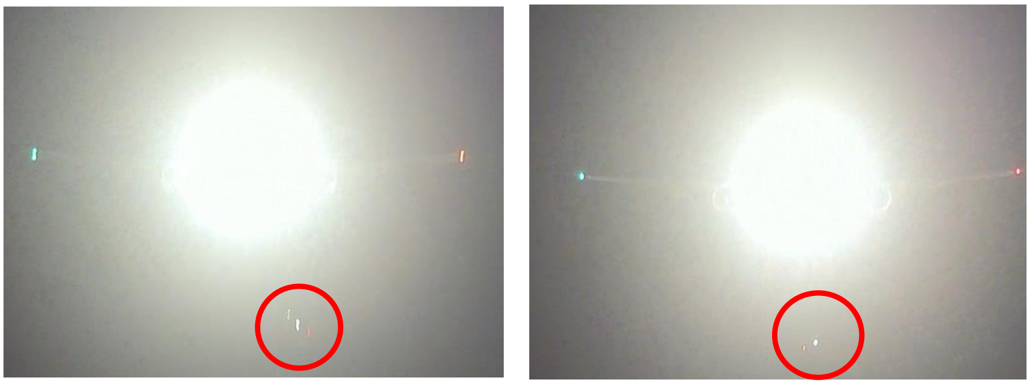

Figure 2. Second DA62 upset and roll into an inverted position following the A350

Evidence noted at the Accident site indicated that the DA62 impacted the ground while travelling at high speed in a direction opposite to the original direction of flight, on a heading of approximately 100 degrees. The elevation of the ground at the Accident site was approximately 130 ft above mean sea level.

1.2 Injuries to Persons

All four occupants of the Aircraft sustained fatal injuries.

1.3 Damage to Aircraft

The Aircraft was destroyed by impact forces and the subsequent fire.

1.4 Other Damage

Damage to the environment caused by the Aircraft impact, subsequent fires, spilled aircraft fluids, and fire-fighting activities, was evident at the Accident site.

1.5 Personnel Information

Table 1 illustrates the Commander and Copilot information current at the date of the Accident.

Table 1. Flight crew information

	Commander	Copilot
Age	52	26
Type of license	Commercial Pilot License (A)	Commercial Pilot License (A)
Valid until Medical expiry	9 September 2019	4 August 2019
Rating	Various single engine aircraft / PA31 / DA62 / rotorcraft	C172 / PA28 / PA31 / DA42 / DA62
Total flying time (hours)	3.441	757
Total on this type (hours)	645	440
Total on type last 90 days (hours)	86	141
Total on type last 28 days (hours)	33	13
Total last 24 hours (hours)	0	0

Last Multi-Engine Piston check (1 year validity)	19 July 2018	20 August 2018
Last line check	Not applicable	Not applicable
Medical class	1	1
Valid to	9 September 2019	4 August 2019
Medical limitation	VNL[1]	Nil

1.5.1 The Commander

The Commander obtained his private pilot license in 1983 at the age of 16. He joined the Royal Air Force of the United Kingdom in 1985 and retired in 2007 as an air traffic controller with the rank of Wing Commander. He obtained a commercial pilot license and commenced employment with the Operator as a part-time pilot and later accepted a full-time position.

In interviews conducted with other staff members from the Operator, the Commander was described as highly-regarded, very experienced, knowledgeable, and safety conscious. The Commander was being prepared to take over the role of chief pilot of the organization. The interviewees stated that he was known to challenge copilots at times, as a technique to improve their knowledge and skills.

The Commander's previous mission at OMDB, which was also his most recent flight with the Copilot, was in December 2018. The Commander had conducted calibration flights at OMDB on nine occasions since 2017, and had flown with the Copilot for 28 missions. The Commander and the Flight Inspector had flown together on 54 missions since 2017.

1.5.2 The Copilot

The Copilot joined the Operator in July 2018 with a total of 225 flying hours and he possessed a commercial pilot license issued by the UK CAA in January 2017.

The Copilot's flight logbook indicated that since he joined the Operator, he had conducted 94 positioning flights as pilot in command, and carried out calibration flights at OMDB five times, the most recent flight was in March 2019. He had previously flown with the Commander on 28 missions and with the Flight Inspector on 36 missions.

During interviews conducted with Operator pilots, the Copilot was described as "competent, safety conscious, but reserved and needing reassurance. He would speak up to express concerns, if he was familiar and comfortable with the other flight crewmember."

1.5.3 The Flight Inspector

The company Flight Inspector's previous aerodrome ground lighting calibration and inspection mission at OMDB was in March 2019. He had conducted calibration flights at OMDB 13 times since 2017, and had flown with the Copilot on 36 missions, and with the Commander on 54 occasions since 2017. His role was to conduct the inflight calibration assessment of the airport lighting from the passenger seat. The Flight Inspector was described as very competent and experienced.

[1] VNL: The pilot must have corrective spectacles available and carry a spare set of spectacles

1.6 Aircraft Information

1.6.1 Diamond DA62 type information

The DA62 was originally granted a type-certificate by the European Union Aviation Safety Agency (EASA) as a derivative of the DA42 and approved on type certificate EASA.A.005. The model was later certified on type certificate EASA.A.629. In November 2017, DA62 design responsibility was transferred from Diamond Aircraft Industries GmbH and EASA, to Diamond Aircraft Industries Inc. and Transport Canada. The Accident Aircraft, serial number 62.077, was produced by Diamond Aircraft Industries GmbH against EASA TC A.0005.

The DA62 was designed as a three-row, seven-seat, twin-engine aircraft. The fuselage, with a length of 9.17 meters (m), is manufactured as a semi-monocoque molded construction using carbon fiber reinforced plastic (CFRP). The DA62 has a 'T' tail manufactured of glass fiber reinforced plastic (GFRP) of semi-monocoque construction. The tricycle landing gear is retractable (figure 3). The wings, ailerons and flaps are made of GFRP/CFRP, and are principally of sandwich construction. The two CFRP manufactured main wing spars and both engine nacelles are part of the center wing. The length of the DA62 is 9.17 m, with a wing span of 14.57 m. The certified maximum take-off weight (MTOW) is 1,999 kg.

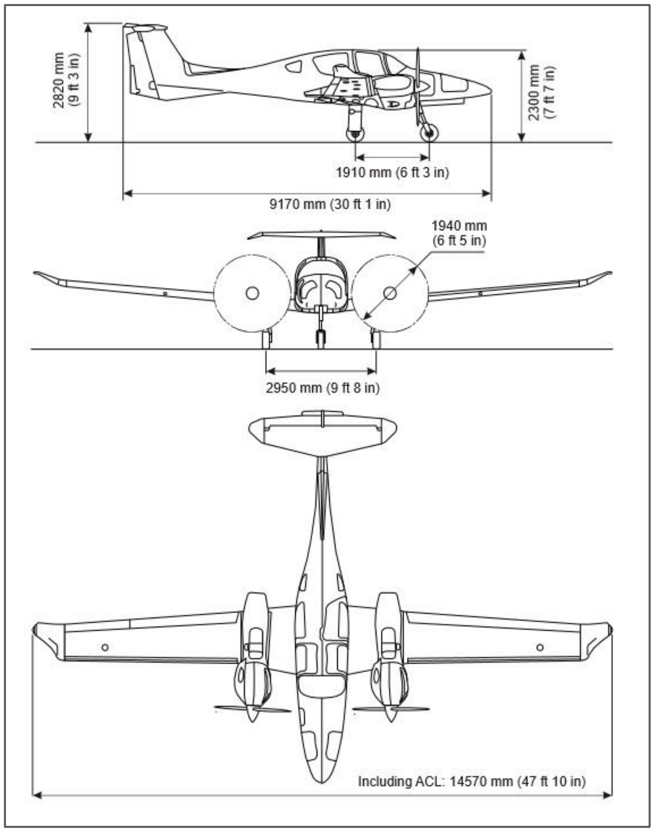

Figure 3. Diamond DA62 dimensions
[Source: Diamond Industries GmbH]

The DA62 design enables single-pilot operation and is fitted with a Garmin G1000 fully integrated avionics system, which comprises a flight, engine, communication, navigation, and surveillance instrumentation system. The system consists of a primary flight display (PFD), multi-function display (MFD), audio panel, air data computer, attitude and heading reference system, engine sensors and processing unit, and integrated avionics containing VHF communications, VHF navigation, and global positioning system.

The DA62 is certified for daytime flights according to visual flight rules. The DA62 is also certified for night flying according to night visual flight rules and flights according to instrument flight rules, with appropriate equipment.

1.6.2 Aircraft data

The Accident Aircraft was configured to accommodate two pilots and three other occupants. The third two-seat row was removed to facilitate stowage of the portable runway calibration equipment.

The Aircraft had been modified by the installation of two auxiliary fuel tanks as per modification MÄM 62-001, which increased the MTOW to 2,300 kg.

An optional air conditioning system to accommodate hot environment operations was fitted to the Aircraft.

Table 2 illustrates the general Aircraft data at the time of the Accident.

Table 2. Aircraft data		
Manufacturer		Diamond Aircraft GmbH
Model		DA62
Manufacture serial number		62.077
Date of manufacture		10 November 2017
Nationality and registration		The United Kingdom, G-MDME
Name of the owner		Flight Calibration Services Limited
Name of the Operator		Flight Calibration Services Limited
Certificate of Airworthiness		
	Number: Issue date:	069621/001 14 December 2017
Certificate of Registration		
	Number: Issue date:	G-MDME/R1 21 November 2017
Date of delivery		21 November 2017
Total time since new		720 hours
Total cycles since new		337 cycles
Last major inspection and date		Not applicable due to the age of the Aircraft
Time since last 100-Hour inspection		1 hours 27 minutes
Cycles since last inspection		1 cycle
ICAO Wake Turbulence Category		Light

1.6.3 Engines

The Aircraft was fitted with two Austro Engine GmbH E4P-C, liquid-cooled, inline four-cylinder, four-stroke engines. Each engine produces a maximum of 132 kW (177 hp) at 2,300 revolutions per minute (RPM), and a maximum continuous 126 kW (169 hp).

Each engine was fitted with an electronic engine control unit (ECU) which controls manifold pressure, injected fuel quantity and propeller speed according to the desired engine power set by the corresponding power lever. Both power levers were located on the center console.

A propeller governor, controlled by the ECU, was flanged onto the front of each engine. The propeller-to-engine speed reduction ratio was 1:1.69.

The indications for engine parameters were integrated within the Garmin G1000 multi-purpose display.

1.6.4 Propellers

The three-bladed propellers were manufactured by MT-Propeller. They were hydraulically regulated with a constant speed feathering function. Each propeller was fabricated from wooden composite material coated by reinforced plastic and with a stainless steel cladded edge.

The propeller pitch control system consisted of a governor valve. The pitch was set by the ECU via an electro-mechanical actuator on the governor. To change the blade pitch angle gearbox oil is pumped into the propeller hub. Increasing the oil pressure leads to a decrease in pitch and a higher RPM. Decreasing the pressure leads to a higher pitch and lower RPM.

Table 3 illustrates engine and propeller data at the time of the Accident[2].

Table 3. Engine and propeller data

Engine manufacturer: Austro Engine GmbH			Propeller manufacturer: MT Propeller	
	No. 1 engine	**No. 2 engine**	**No. 1 propeller**	**No. 2 propeller**
Model	E4P-C	E4P-C	MTV-6-R-C-F/CF 194-80	MTV-6-R-C-F/CF 194-80
Serial number	E4P-C-00140	E4P-C-00130	170723	170722
Date installed	10 November 2017	10 November 2017	10 November 2017	10 November 2017
Total time since new	720 hours	720 hours	720 hours	720 hours
Total cycles since new	337 cycles	337 cycles	337 cycles	337 cycles
Time since last inspection	1 hour 27 minutes	1 hour 27 minutes	1 hour 27 minutes	1 hour 27 minutes
Cycles since last inspection	1 cycle	1 cycle	1 cycle	1 cycle

1.6.5 Garmin G1000 Integrated Avionics System

The G1000 Integrated Avionics System was a fully integrated flight, engine, communication, navigation and surveillance instrumentation system. The system consisted of one primary flight display (PFD) and one multi-function display (MFD), an audio panel, an air data computer, an attitude and heading reference system, engine sensors and processing unit, and integrated avionics containing VHF communications, VHF navigation, and global positioning system.

The primary function of the PFD is to provide attitude, heading, air data, navigation, and alerting information to the pilot. The primary function of the MFD is to provide engine information, mapping, terrain information, autopilot operation, and information for flight planning.

In standard configuration, with the commander in control of the aircraft seated in the left hand seat, the PFD is selected on the left cockpit monitor, and the MFD on the right. The MFD

[2] Time of the Accident includes the positioning flight from Sharjah International Airport to Dubai International Airport (6 minutes) and 1 hour 21 minutes of the Accident flight

then displays engine data, maps, terrain, flight planning, progress information, and air traffic and topography displays.

If the copilot takes control of the aircraft from the right hand seat, the PFD can be switched to be displayed on both cockpit monitors in the PFD backup mode. In this mode, the traffic map is displayed only as a small map on both monitors.

1.6.5.1 Advisory traffic avoidance system

The Garmin G1000 fitted to the DA62 included an optional ‘hazard avoidance system’ provided by the Avidyne TAS600 system. It displayed a traffic map page and was configured to provide an advisory traffic avoidance system.

The features of the traffic avoidance system were limited to providing traffic advisories, as the system had no provision to provide resolution advisories[3]. When the system was in operating mode, it interrogated the transponders of other aircraft in the vicinity. The system used this information to derive the distance, relative bearing, and if reported, the altitude and vertical trend for each aircraft within its surveillance range.

The traffic avoidance system then calculated a closure rate to each ‘intruder’ aircraft. If the closure rate met the threat criteria for a traffic advisory, the system provided visual indications and voice alerts. A traffic advisory was displayed as a solid amber circle. A yellow highlighted TRAFFIC indication appeared to the right of the airspeed on the PFD, flashed for five seconds, and remained displayed until no more traffic advisories were detected (figure 4).

1.6.5.2 Traffic map

The traffic map showed surrounding traffic in relation to the aircraft’s current position and altitude. It was the principal map for viewing traffic information and had adjustable traffic display range rings. The distance indication appeared on each range ring and displayed a selected range of 1 nm, 2 nm, 6 nm, 12 nm and 24 nm (figure 4). The traffic map on the MFP can be selected to overlay other maps, such as the terrain map, a topographic map or an airways map.

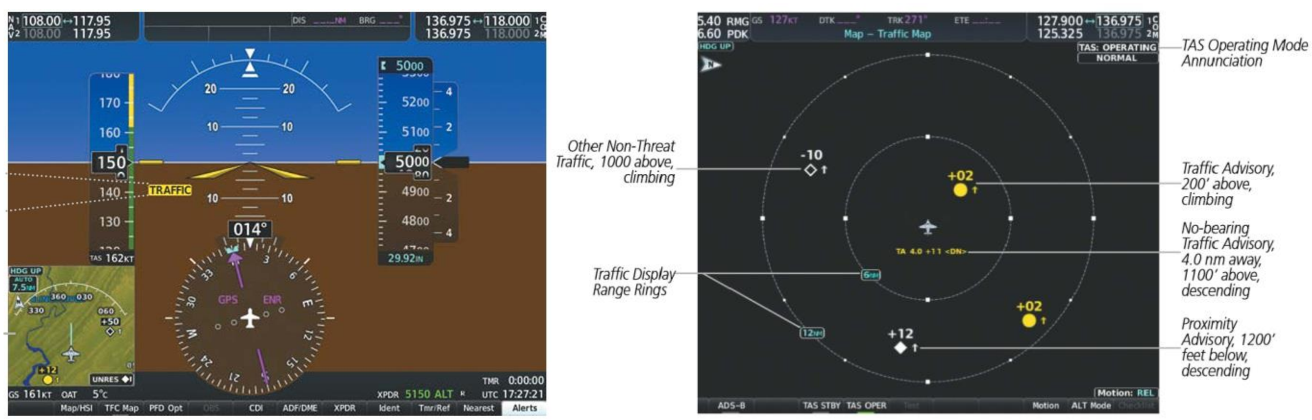

Figure 4. Traffic information maps on PFD and MFD [Source: Diamond Industries GmbH]

[3] A traffic advisory requires the pilot to visually search for traffic and to maintain visual separation. A resolution advisory provides the pilot with instructions to avoid traffic. The pilot was expected to follow resolution advisories immediately.

1.6.6 Aircraft fuel

The total fuel capacity of the DA62 was 337 liters, divided into a three-chamber fuel tank in each wing with a capacity of 197 liters, and auxiliary fuel tanks[4] installed in the aft section of the engine nacelles with a capacity of 140 liters. Of the total fuel capacity, 327 liters was usable fuel.[5]

The fuel content in the main fuel tanks was displayed on the MFD. The auxiliary fuel tank system was designed without a fuel quantity indication system. When the fuel transfer pump emptied each auxiliary tank, an “empty” caution message was displayed on the MFD.

The DA62 departed OMSJ, after uplifting 126 liters of Jet-A1 fuel. The refueling officer stated that on request of the Commander, all four fuel tanks were completely filled for departure. The Commander recorded on the technical logbook the uplift of 126 liters and a departure fuel of 326 liters. The Commander recorded an endurance of 5 hours 45 minutes in the filed flight plan.

1.6.7 Weight and balance

The Commander filed the flight plan in OMSJ for a flight with three persons onboard. He knew the uplifted fuel, aircraft weight and approximate passenger and baggage weights. The Investigation reviewed airport CCTV footage and chose an average weight for each crew member of 85 kg, including 7 kg for each flight bag. While the Operator’s *Operations Manual* did not distinguish between the person’s location and the location of the hand baggage, the investigation calculated different scenarios of hand baggage locations. The total aircraft weight with three persons, three crew bags and the calibration equipment of 23 kg, were estimated as 2,250 kg, which was below the maximum take-off weight for departure from OMSJ. The center of gravity could not be determined because it was not known where the flight bags were stowed.

A calculation of the total aircraft weight including the additional observer and considering the estimated fuel burn for the positioning flight from OMSJ, showed that the aircraft weight was approximately 54 kg above the maximum take-off weight when it departed OMDB. Due to the unknown location of the flight bags, the center of gravity could not be determined for this flight. Taking into account the fuel burn during the 90 minutes of flight-time until the Accident occurred, the aircraft weight had reduced to being less than the maximum take-off weight. However, the fuel consumption, reducing the fuel weight from the main fuel tanks, did not change the Aircraft’s center of gravity.

The Operator’s procedures required the Commander to determine the mass and the positon of the center of gravity by using a ‘company spreadsheet computer’, flight planning software, or the manual load sheet. The Commander had to ensure that the manual load sheet was either carried in a flameproof bag on the aircraft, or be provided to a ground station before departure.

The Investigation located the Aircraft technical logbook at the Accident site and noted that the *Mass and Balance* reference pages, dated 1 November 2015, were two revisions behind the latest revision of the *Diamond DA62 Airplane Flight Manual*, dated 14 November 2017. However, the content of these pages did not differ from the latest revision.

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[4] Auxiliary Fuel Tank Modification MÄM 62-001

[5] Reference: EASA DA62 Type Certificate Data Sheet EASA.IM.A.629, Issue 5

1.6.8 Acceptable deferred defects record

The Investigation located the *Acceptable Deferred Defects Record* in the Aircraft technical logbook. It revealed that on 26 March 2018, an entry was made to record that both auxiliary fuel tank gauges were unserviceable. The Operator confirmed that the defect was reported in March 2018 and that the auxiliary fuel indications were checked at every maintenance input during the 100-Hour inspections. The Operator advised that the fault had not reoccurred or been reported by any other flight crew. Therefore, the defect had been kept open to ensure that the reported defect remained under observation.

Since this defect was recorded, eight 100-/200-Hour inspections were carried out. Each inspection was certified with the statement “No other AD’s SB’s SI’s SL’s or defects at this time.”

The Investigation noted that the auxiliary fuel tank modification as per MÄM 62-001 does not include a cockpit fuel content indication. The pilot’s options for determining the fuel content in these tanks for weight and balance calculations was by selecting the tanks either empty or full. The modification provides for an ‘empty caution message’, displayed when each of the auxiliary fuel tank is empty and the fuel transfer pump is selected to “on”.

1.7 Meteorological Information

The prevailing meteorological conditions at the time of the Accident were ‘ceiling and visibility ok’ (CAVOK). The barometric pressure was 1005 hPa. Low-level winds were recorded at 1,000 ft with a speed of 6 kt from 020 degrees, and a speed of 11 kt from 010 degrees at 1,500 ft. Sunset on 16 May 2019 in Dubai was at 1857.

The METAR for 1500 UTC (1900 local time) and 1530 UTC (1930 local time) at Dubai International Airport read:

METAR OMDB 161500Z 03006KT 350V050 CAVOK 34/14 Q1004 NOSIG

METAR OMDB 161530Z 02005KT CAVOK 34/14 Q1005 NOSIG

1.8 Aids to Navigation

The DA62 was operated under VFR but was equipped with a Garmin G1000 Integrated Avionics System, which included a navigation and surveillance instrumentation system displayed on the MFD.

Runway 30L was equipped with an instrument landing system (ILS), which allowed the flight crew to observe their flight path on approach.

Ground-based navigation aids, onboard navigation aids, or aerodrome visual ground aids and their serviceability were not a factor in this Accident.

1.9 Communications

During the pre-flight meeting with the airport and ANS representatives, a VHF frequency was dedicated for the calibration flight. On this frequency, ATC issued air traffic information to the flight crew. These communications were recorded and were made available to the Investigation.

Inter-pilot communication was made via the intercom system, which was not recorded.

Additionally, a separate VHF frequency was established to facilitate communication between the Flight Inspector and ground staff from the aerodrome ground lighting system provider. Communications on this frequency were not recorded.

1.10 Aerodrome Information

OMDB is the primary airport serving Dubai, the United Arab Emirates. It is located 4.6 km east of Dubai city and has two staggered parallel runways, 12R/30L and 12L/30R. The runways are 4,447 m and 4,351 m long, respectively. The distance between the two runway centerlines is approximately 385 m.

The threshold of runway 30R is approximately one nautical mile displaced away from the threshold of runway 30L, resulting in an approximately 330 ft higher approach profile than the approach to runway 30L (figure 5). Due to the close distance between the runways, ATC considers the approaches as the same approach track and applies segregated approaches onto the staggered runways.

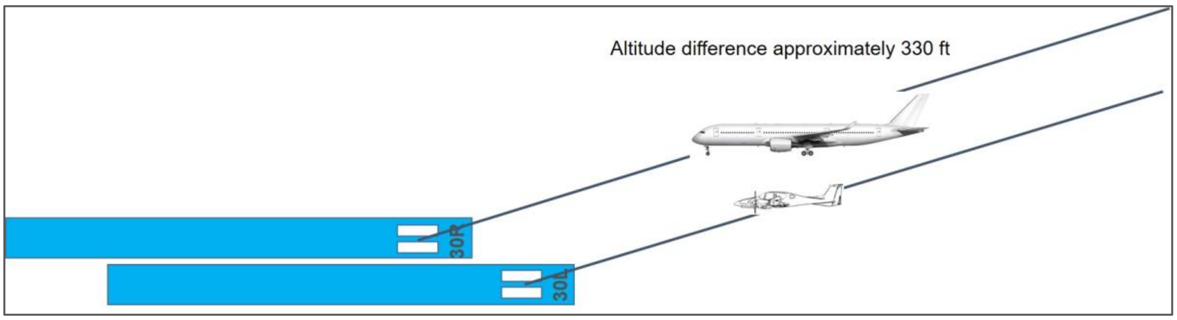

Figure 5. Approach profile to parallel runways 30L and 30R with displaced threshold

As part of OMDB's Southern Runway Rehabilitation Project, the aerodrome ground lighting system for runways 12R and 30L had been upgraded. The commissioning process required aerodrome ground lighting calibration checks to verify compliance with lighting accuracy requirements.

During the calibration flights for runway 30L, the parallel runway 30R remained operational for arrivals and departures of other air traffic.

1.11 Flight Recorders

The Aircraft was not fitted with a cockpit voice recorder or flight data recorder. Due to its weight category, this equipment was not a requirement of the civil aviation regulations of the United Kingdom.

Due to the lack of onboard recorders, the Investigation relied on witness accounts, recordings from airport cameras, and witness marks at the Accident site, to determine the Aircraft flightpath after the loss of control.

The Investigation recovered the two engine ECUs and the Garmin G1000 unit with the intention of possible data retrieval from their non-volatile memories, but the severity of the damage sustained by these components prevented any data retrieval.

The Aircraft was fitted with a Mode S transponder, but did not transmit enhanced surveillance data[6] to a ground station due to the system's limited capability.

1.12 Wreckage and Impact Information

The Aircraft impacted the ground in a nature reserve with an elevation of 130 ft, approximately 3.5 nm inbound from the threshold of runway 30L. The nature reserve had an average elevation of 130 ft and comprised sandy undulating terrain with scattered shrubs and trees. The majority of the trees ranged between 4 to 10 m in height with trunk diameters varying between 85 to 200 mm.

Ground scars and damage to a nearby tree indicated that the Aircraft impacted the terrain at high speed, 24 degrees nose down, 30 degrees right wing down, and on a heading of approximately 100 degrees.

The first impact marks consisted of two large ground scars, each about 0.6 m deep. The distance between the two scars was compatible with the distance between the two engines. Evidence of fire was identified, which spread from these ground scars onwards. Unburnt aircraft wreckage pieces, mainly from the lower fuselage and tail section, were found between the two ground scars.

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[6] Mode S enhanced surveillance was a variant of the Mode S transponder protocol that includes downlink aircraft parameters returned by the airborne Mode S transponder. Roll angle or vertical rate are part of the downlink aircraft parameters

A small tree, located beyond the first impact point, exhibited marks of contact with the left wing. The left wing wiring conduit was found attached to the tree and provided an estimated wing impact location (figure 6).

Figure 6. The initial impact point ground scars

The main wreckage was located approximately 20 m from the initial impact. A trail of burnt and unburnt aircraft pieces extended up to 160 m from the first impact.

The Aircraft was totally destroyed by impact forces and the post-impact fire. The GFRP and CFRP fuselage and wing structures were consumed by fire. The engines, landing gear, fuel tanks, nose bay avionics rack, and some other unidentified pieces were found in the main wreckage (figure 7).

The left wing center fuel tank had sustained an impact dent near to the leading edge, which matched the trunk diameter of the small tree located beyond the initial impact.

The cockpit instrument panel came to rest in an inverted position approximately 25 m beyond the main wreckage. Both propeller governors were found approximately 37 m beyond the main wreckage. The Aircraft seats were located approximately 50 to 68 m beyond this point.

The examination of the wreckage and a close surveillance of the area surrounding the Accident site did not show any indication of an inflight break-up or separation of aircraft parts.

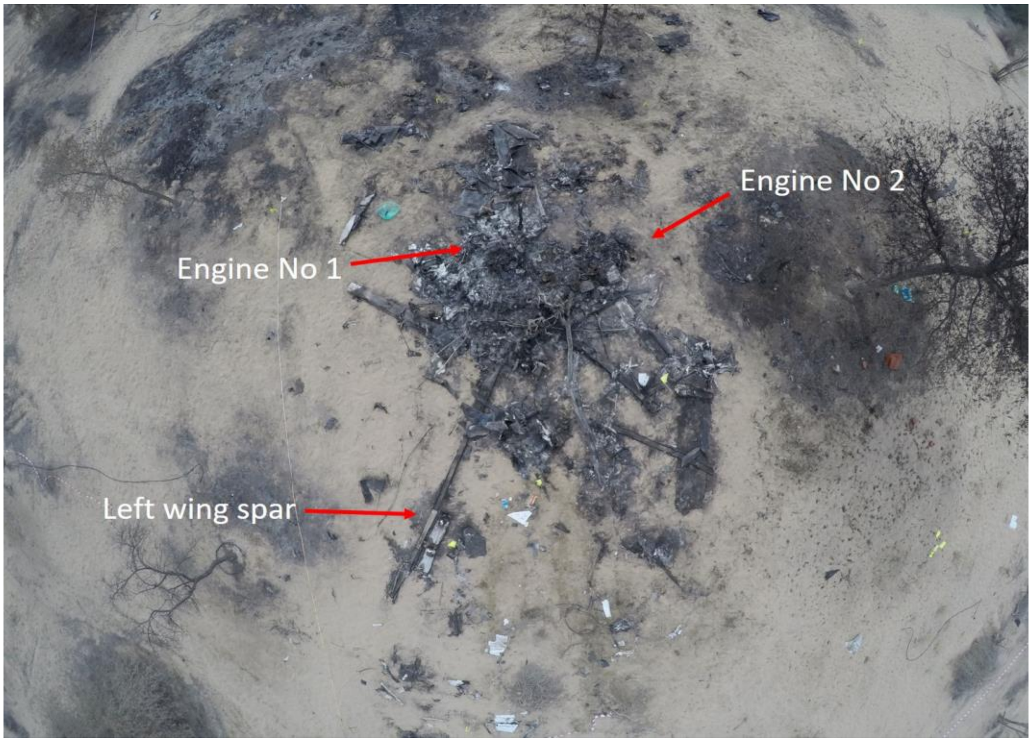

Figure 7. The main wreckage at the second impact point

1.13 Medical and Pathological Information

The post-Accident toxicology tests did not reveal evidence of any psychoactive substance that could have degraded the flight crew's performance.

1.14 Fire

A nearby closed-circuit television (CCTV) camera captured a fireball emanating from the site to a height of approximately 30 m.

At the Accident site, the first evidence of fire was found where the No. 2 engine initially impacted the ground. Smaller fires ignited vegetation and spread at different points throughout the Accident site. The main wreckage was consumed by fire.

1.15 Survival Aspects

The Accident was not survivable.

1.15.1 Emergency locator transmitter

The Aircraft was fitted with a 406 MHz Kannad 406 AF emergency locator transmitter (ELT), which was installed in the aft fuselage beneath the aft baggage compartment. The ELT antenna was mounted on the upper surface of the fuselage, above the ELT installation (figure 8a).

The Investigation found that the ELT had been destroyed by the impact forces, and that the antenna and electrical cables were severed from the unit (figure 8b).

No ELT signal was received by the UAE National Search and Rescue Center.

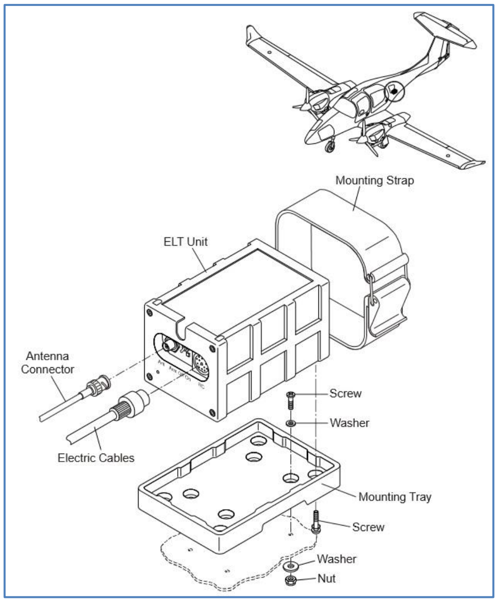

Figure 8a. ELT installation
[Source: Diamond Industries GmbH]

Figure 8b. ELT as found at the Accident site

1.16 Tests and Research

1.16.1 Diamond DA62 upset recovery

After the Aircraft recovered from the first upset at an altitude of 1,300 ft AMSL, it dynamically rolled to the left into an inverted state. The approach camera recorded the sudden roll movement without noticeable altitude loss. The roll rate was estimated as more than 90 degrees per second. Once the Aircraft was inverted, it entered into a steep dive.

After discussions with flight test pilots, the Aircraft manufacturer advised that, if a pilot with experience in upset recovery maneuvers attempted to recover from inverted flight in still air, a minimum altitude above ground level of 1,800 ft to 2,000 ft would be required.

According to the manufacturer, the influence of wake vortices on the Aircraft flight stability and control at the recorded altitude made a recovery unlikely.

1.17 Organizational and Management Information

1.17.1 The Operator

Flight Calibration Services Limited (FCSL) is a flight inspection organization established in the United Kingdom in 2005. At the time of the Accident FCSL held approval issued by the UK CAA under *Air Navigation Order 2016.* The approval authorized FCSL to provide flight inspections of air navigation service equipment within the United Kingdom. Since 2017, FCSL has operated under EASA *Air Operations Regulation (EU) No 9652012,* Part-SPO *Specialised Operations.*

FCSL also provides flight inspection services for airports outside the United Kingdom, including in the Middle East.

FCSL owned and operated six flight inspection aircraft, comprising one Piper Chieftain PA31 and five Diamond DA62s. Two of the aircraft were permanently based at FCSL's maintenance facility at Sharjah International Airport, the United Arab Emirates.

1.17.2 Flight crewmember responsibilities

In a normal multi-crew environment, the roles of the two flight crewmembers are commonly described as pilot flying and pilot monitoring. As the DA62 was designed to enable single-pilot operation, the cockpit layout, as well as the aircraft flight manual and checklists omit the role and responsibilities of the copilot for a multi-crew operation.

FCSL generally operates the DA62 with two pilots for positioning flights and for operation of flight missions. However, the FCSL *Operations Manual* does not provide flight operations procedures specific to a multi-crew environment.

The manual describes the general responsibilities of the flight crewmembers as follows:

> "1.4 Responsibilities of the Aircraft Commander
>
> The Company will nominate one of the pilots to be the aircraft commander for each flight or series of flights. The Authority of the Commander is absolute in respects of the safety and conduct of the flights that he is tasked to command."

Paragraph 1.4.2.11 reads:

> "The commander shall take all reasonable steps to ensure that the aeroplane mass and balance is within the calculated limits for the operating conditions & confirm that the aeroplane's performance will enable it to complete safely the propose flight;"

Section 1.5 Responsibilities of Crew Members other than the Commander, reads:

> "It is the specific responsibility of the First Officer:
>
> …
>
> (b) to confirm the safe navigation of the aircraft, maintaining a continuous and independent check upon both the geographical position of the aircraft and its safe terrain clearance;
>
> (c) to volunteer such advice, information, and assistance to the Commander, as may contribute favourably towards the safe and efficient conduct of the flight;
>
> …"

1.17.3 The Operator's weight and balance documentation OM-Part A, Section 8

The Operator's *Operations Manual* describes the procedure for the 'mass' and balance calculation and documentation.

Paragraph 8.1.8.6 The Mass of Crewmembers and Crew Baggage reads:

> "The Commander shall use the following mass values to determine the dry operating mass:
>
> Actual masses including any crew baggage; or
>
> Standard masses, including hand baggage, of 85 kg (187 lbs) for crew; or
>
> Other standard masses acceptable to the Authority."

Paragraph 8.1.8.7 The Mass of Passengers & Their Hand Baggage reads:

> "The Commander shall compute the mass of passengers and checked baggage using either:
>
> The actual weighed mass of each person and the actual weighed mass of baggage, or;
>
> The standard mass values specific in Table T8-17 below, or;

Where the number of passenger seats available is less than 10, the passenger mass may be established by use of a verbal statement by, or on behalf of, each passenger and adding to it 8 kg to account for hand baggage and clothing."

"If determining the mass of passengers using standard mass values, the standard mass values in Table T8-17 below must be used."

T8-17 MASS VALUES FOR PASSENGERS, 19 SEATS OR LESS			
TYPE OF PASSENGER	TOTAL NUMBER OF PASSENGER SEATS		
	1 - 5	6 - 9	10 - 19
MALE	104 kg (229lbs)	96 kg (211lbs)	92 kg (202lbs)
FEMALE	86 kg (189lbs)	78 kg (171lbs)	74 kg (163lbs)
CHILDREN 2-12 YEARS	35 kg (77lbs)	35 kg (77lbs)	35 kg (77lbs)

Figure 9. OM-A Section 8 Table T8-17 Mass Values for passengers [Source: FCSL Operations Manual]

The Operator utilized table T8-17 for the determination of passenger weights, which was not developed for the Operator's aircraft types and operation (figure 9). The table did not distinguish the locations of the passenger weights and the included hand baggage weight, as was relevant for the weight and balance calculation.

OM-A Section 8, Paragraph 8.1.8.11 reads:

"The mass and position of the CG of the loaded aeroplane shall be determined by the Commander either,

- By using the Company Spreadsheet Computer
- Flight Planning Software, or
- Use of a manual Load Sheet (Part B, Section 6, Appendix B)."

And:

"The Commander shall ensure that, if the load sheet is not carried in the cockpit flameproof bag a copy must be left on the ground."

OM-A states further:

"The Commander shall ensure that, if the load sheet is not carried in the cockpit flameproof bag a copy must be left on the ground. For multi sector flights the Commander shall ensure that a load sheet for each sector is prepared"

The Investigation did not find a load sheet in the technical logbook or a flameproof bag at the Accident site. In interviews with FCSL pilots, it was identified that a manual load sheet was not used. The Investigation was unable to locate any load sheet left with the ground handling agents in OMSJ or OMDB.

Last minute changes are described in OM-A as:

"If any last minute change occurs after the completion of the mass and balance documentation, this must be brought to the attention of the commander and the last minute change must be entered on the mass and balance documentation."

1.17.4 Operations Manual OM-Part A - wake turbulence

The Operator's *OM-A* provides pilots with precautions for wake turbulence. The highlighted section in table T8-31 refers to the Accident flight.

Paragraph 8.3.9.2 - *Specific precautions to be followed*, reads:

"Although air traffic controllers will normally warn departing or arriving aeroplane[s] of the need to observe particular intervals when following aeroplane[s] of a higher wake turbulence category, commanders should apply the following separations:"

T8-31 WAKE TURBULENCE SEPARATION		
CONDITIONS:	SUCCESSIVE AIRCRAFT ON FINAL APPROACH	
LEADING AIRCRAFT	FOLLOWING AIRCRAFT	MINIMUM DISTANCE (MILES)
HEAVY (A380-800)	A380-800	Not required
	HEAVY	6
	MEDIUM	7
	SMALL	7
	LIGHT	8
HEAVY	HEAVY	4
	MEDIUM	5
	SMALL	6
	LIGHT	8
MEDIUM	MEDIUM (SEE NOTE)	3
	SMALL	4
	LIGHT	6
SMALL	MEDIUM OR SMALL	3
	LIGHT	4
NOTE: Where the leading medium aeroplane is a B757 the minimum distance shall be increased to 4 miles.		

Figure 10. OM-A Section 8 Table T8-31 Operator's Wake Turbulence Separation [Source: FCSL Operations Manual]

1.17.5 Aerodrome ground lighting inspections

The Operator's flight inspection procedures described the details of aerodrome ground lighting inspections and calibration for approach lighting and runway lights, including supplementary approach lights, runway edge lights, runway threshold lights, runway end lights, PAPI[7] lights, aerodrome beacon, and obstacle lights.

The purpose of inspection and calibration flights is to confirm that all lights are illuminated, and that a uniform luminous intensity pattern is provided for aircraft takeoff and landing. These checks usually require a series of normal approaches on the glide slope and low altitude approaches.

The mission plan identified 19 checks, which required nine different approach profiles. These profiles required altitudes of 1,000 ft, 1,500 ft, 1,800 ft, 2,000 ft and 3,500 ft; and commenced at 6 nm, 9 nm, 12 nm, 17 nm and 25 nm from the runway threshold inbound to runway 30L.

[7] PAPI: Precision Approach Path Indicator

1.17.6 The Operator's procedures for flight inspections

According to interviews with FCSL flight crewmembers, the workload during aerodrome ground light calibration flights was usually divided between the flight crewmembers. The commander controls the aircraft whereas the copilot is responsible for:

- Communication with ATC and aerodrome lighting engineers on two different frequencies
- Video recording of the runway lighting using a hand-held tablet
- Visually scanning the airspace.

The commander may communicate with ATC in cases where the copilot is in communication with the runway lighting engineers on the other frequency.

Each approach was considered to be part of one continuous calibration flight segment, therefore no aircraft configuration changes are made and no checklists are called until the final approach for landing.

The commander was usually the pilot in control of the aircraft. However, at the commander's discretion the controls may be handed over to a copilot that the commander deemed sufficiently experienced. For this, the PFD may be duplicated on the copilot's MFD.

1.17.7 Operator flight crew training and pilot proficiency monitoring

The Operator generally employed pilots with a commercial pilot license from the general aviation sector or graduates from flying schools. While pilots underwent induction training on the Operator's procedures, a regular recurrent training program had not been established.

Pilot proficiency was monitored biannually, usually during calibration flights. No formal process or proficiency criteria for pilots was established by the Operator. Results and concerns were verbally reported to the chief pilot. Annual pilot license skill tests were externally performed by UK CAA authorized examiners.

According to the Operator's policy, the flight crew of calibration flights consisted of a commander, a copilot, and a flight inspector. The Operator did not have in place a crew resource management or equivalent training program to train and enhance the interaction of these crewmembers.

1.17.8 Operator safety management system

The Operator had established a safety management system (SMS) which was described in the FCSL *SMS Safety Management Manual* dated February 2017. The manual described that the company directors held overall responsibility for implementation of the SMS and final accountability for all safety issues.

Section 3.4 − *Aviation Safety Policy and Objective*, stated:

> "The Company recognizes that aviation is a potentially high risk industry requiring a positive approach to the management of safety. We are committed to the introduction of a formal SMS to enable the identification [of] hazards, the analysis of risks and implementation of appropriate defences."

According to the *Safety Management Manual*, the safety officer was to report to the flight inspection manager. The safety officer responsibilities included facilitating the risk management process with its hazard identification, risk assessment, risk mitigation, and the monitoring of corrective actions implementation. A hazard, incident and occurrence reporting system called 'flight inspection observation note' (FION), was utilized to collect reports from staff. FION was part of the risk management process.

During his interview, the Chief Executive Officer (CEO) stated that he lacks expertise on the safety management process and therefore was not actively involved. Instead, he "delegated his safety responsibilities and accountabilities to a manager", who was acting as a safety officer and as a flight inspection manager.

In the interview, it was noted that the CEO believed that he did not have any requirement to attend SMS training and that he was not accountable for the SMS, as he had delegated his SMS accountabilities and responsibilities.

The *SMS Manual* contained processes designed to provide staff with the relevant level of SMS training. Section 5.2.7.2 − *Training needs*, described the level of training as follows:

"Corporate safety training for all staff

a) Management safety responsibility
b) Operational personnel
c) Aviation safety specialists."

Section 5.2.7.4 − *Safety Training for Management*, stated that the management team will attend an external safety management course.

ICAO *Standards and Recommended Practices* identified that, depending on the size, structure and complexity of the organization, the accountable executive may be the CEO, or the chairperson of the board of directors. The identified executive with safety accountabilities, irrespective of other functions, has the ultimate responsibility and accountability for the implementation and maintenance of the SMS. These accountabilities and responsibilities cannot be delegated to other persons.[8]

The CEO was a member of the company board of directors since 2005. He was appointed as CEO in January 2019, when the position was established. In his position as member of the board of directors or as the CEO, he did not involve himself in the regulatory requirements of the operation or the safety management processes. He considered his "primary role as a financial director of the organization."

1.17.9 EASA *Air Operations Regulation (EU) No 965/2012,* Part-SPO

Regulation No. 965/2012 Part-SPO *Specialised Operations*, applies to any aircraft operating specialized activities within the European Union, except for commercial air transport.

These activities may include commercial agriculture, construction, photography, surveying, observation, patrol, and aerial advertisement. Operators under this Part are not required to obtain an air operator certificate (AOC).

Part-SPO was adopted by the United Kingdom on 21 April 2017 and required an online declaration in which the organization and the operation are described. Prior to the Part-SPO adoption date, operators with non-complex aircraft were categorized as 'Aerial Work' operators.

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8 ICAO Doc 9859 − *Safety Management Manual*, Chapter 5. − *Safety Management Systems (SMS)*

The information provided by the applicant through the online declaration assists the national civil aviation authorities in developing the required oversight program based on the nature and complexity of the organization and operation. A review of the online form revealed that the form fields were focused on administration details without particulars on regulatory requirements for flight operations.

The online form concludes with a declaration by the accountable manager that:

- the management system documentations, including the operations manual, will comply with the applicable Part-SPO requirements
- all flights will be carried out in accordance with the procedures and instructions specified in the operations manual
- all flight crewmembers, are trained in accordance with the applicable requirements.

According to the UK CAA, the declaration is followed by an initial desktop operator priority assessment, where additional information may be requested. The UK CAA policy, the Part-SPO oversight schedule commences during the first four years from the date of an operator's declaration. Prioritizing an oversight activity of a Part-SPO operator depends on the complexity of operation. FCSL was listed in the low-priority category, since the UK CAA considered that FCSL operated "non-complex motor powered aircraft[9]."

The UK CAA were not required to carry out inspections of operators under the now obsolete Aerial Work category. In accordance with EASA Part-ARO.GEN.305[10], the UK CAA was only required to carry out an oversight inspection within the first four years. The UK CAA could not verify that, between 2005 and the Accident in 2019, an oversight function had been carried out on the Operator under either Aerial Work or Part-SPO.

1.17.10 The UK CAA − Compliance audit

As a result of the Accident, an inspector from the General Aviation Unit in the UK CAA carried out an oversight audit of the Operator on 30 July 2019. The scope of the audit included the Operator's management system, safety management system, occurrence reporting, the *operations manual* (dated 1 July 2019), training records, the standard operating procedures, and aircraft instruments, data and equipment.

The audit report stated that: "Generally, there were good procedures in place and the company is active in developing new equipment for flight calibration." The audit did not identify any non-compliances with Part-SPO. However, a total of 18 Level Two[11] findings were raised and discussed. Two of these findings were identified as "Partially compliant."

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[9] The term 'complex motor-powered aircraft' is defined in Regulation (EU) 2018/1139 as an aeroplane with a maximum certificated take-off mass exceeding 5700 kg, or certificated for a maximum passenger seating configuration of more than nineteen, or certificated for operation with a minimum crew of at least two pilots, or equipped with (a) turbojet engine(s) or more than one turboprop engine

[10] EASA Part-ARO.GEN.305 refers to the national civil aviation authority oversight program covering the oversight activities required by EASA Part-ARO.GEN.300

[11] The CAA UK defines Level One findings as non-conformances that were identified at the time of the audit and are considered to be of a serious nature. Confirmation of satisfactory rectification must be received prior to any further flying activity.

The audit identified that the Operator had filed six Part-SPO declarations for changes in the organization, starting from the date when the EASA Part-SPO became effective in 2017. It was found that throughout these declarations, information on the fleet and the type of operation had not been updated. Sixteen findings related to the operations manual referring to incorrect regulatory references, incorrect description of the type of operations, missing or incorrect procedures, lack of crewmember role description, and neglect of records retention requirements.

The audit identified that "The operator had conducted a number of risk assessments but could not produce a completed Hazard Log at the time of the audit. Prior to each Part-SPO flight, hazards are identified and recorded by the operating crew. The identification of aviation safety hazards entailed by the activities of the operator, their evaluation and the management of associated risks including taking actions to mitigate the risk and verify their effectiveness should be summarized in a Hazard Log."

As a result, the UK CAA required the Operator to submit a completed hazard log summarizing the identified hazards and mitigations, by 4 November 2019.

Another Level Two finding was pertinent to the *minimum equipment list (MEL).* The finding stated that: "The operator was unable to provide a copy of the approval for the Minimum Equipment List at the time of the audit for either aircraft type (DA62 or PA31). Please make an application to npa@caa.co.uk with the MEL, the associated MMEL and the MEL compliance Statement. There is a one-off payment. Please refer to the CAA website for more details. Please send a copy of the MEL approval for each aircraft type." The Operator was required to complete the necessary action by 4 November 2019.

A Level Two finding was documented regarding the operational procedures for wake turbulence encounters. It read "The Operations Manual (OM-A-8.3.9) contains procedures for Wake Turbulence. The categorisation of aircraft has changed (RECAT-EU). Please update this section with reference to RECAT-EU and the correct categorisations." The Operator was requested to make the necessary changes by 4 November 2019.

The audit report provided by the UK CAA to the Investigation did not provide information about pilot training, pilot performance monitoring, weight and balance procedures, roles and responsibilities of key safety personnel, or information that had relevance to the Accident scenario. The UK CAA advised that the audit report provided to the Investigation only showed the non-conformances or observations, and that the Operator was found compliant in the areas of pilot training and monitoring, weight and balance procedures, and personnel requirements.

Many of the Level Two findings referred to regulations which were current before the Part-SPO (2017) and may have been present during the operation under Aerial Work since 2005, and when the Operator filed their initial Part-SPO declaration in 2017.

Level Two findings are non-conformances that were identified at the time of the audit and are considered to be in need of remedial action. Satisfactory rectification is to be confirmed within the relevant timescales.

Observations are noted for the auditee's information purposes. Corrective action is not obligatory, but acknowledgement and the identification of any intended action is expected. A rejected observation must be justified.

1.17.11 Air navigation service provider

Dubai Air Navigation Services (dans) is certified by the General Civil Aviation Authority of the United Arab Emirates (GCAA) as the air navigation services provider at OMDB, responsible for providing aerodrome control services within the Dubai control zone from the surface to 1,500 feet.

OMDB is a controlled aerodrome at which air traffic control service is provided to aerodrome air traffic. The airspace classification of the Dubai control zone is Class D, where flights under instrument flight rules (IFR) and flights under visual flight rules (VFR) are permitted and all flights are provided with air traffic control service. IFR flights are separated from other IFR flights and receive air traffic information in respect of VFR flights. Similarly, VFR flights receive air traffic information in respect of all other flights.

Because of the complexity of the operation and to cater for occasional special requirements from the flight crew regarding flight profiles, dans had established a small group of designated air traffic controllers responsible for coordinating and controlling flight calibration missions.

1.18 Additional Information

1.18.1 Radar monitor observations

The DA62 was operating under VFR and the crew applied their own separation to air traffic arriving to runway 30R, in accordance with ICAO *Standards and Recommended Practices*. Due to runway 30L being in close proximity of the operational parallel runway 30R, ATC had previously identified a likelihood of intensified wake turbulence encounters, and consequently increased the wake turbulence separation minima for lighter IFR traffic operating on runway 30L behind heavier aircraft types on runway 30R. The increased separation minima were established at 3 nm in excess of the recommended ICAO standard wake turbulence separation minima. In addition, the spacing between arrivals on runway 30R had been increased to accommodate gaps for the calibration flights.

The Investigation observed the radar recordings from the positioning flight to OMDB and all of the approaches flown during the calibration flight. The observations identified that for the ten approaches during which the flight crew applied their own separation under VFR, the distance between the DA62 and preceding air traffic on the operational parallel runway was repeatedly less than the increased wake turbulence separation minima provided by ATC to IFR flights (table 4).

Table 4. G-MDME approach information

Approach #	Time (local time)	Preceding aircraft on runway 30R	Wake turbulence category	Spacing to the preceding aircraft in distance and time	ICAO wake turbulence separation minima	Separation provided by ATC	Spacing between 30R air traffic
OMSJ - OMDB	1548	A320	M	2.7 nm / 1:12 min 500 ft above	5 nm	N/A	19 nm
1	1819	B738	M	3.2 nm / 1:15 min 700 ft below	5 nm	8 nm	Nil
2	1829	B777	H	5.5 nm* / 2:36 min	6 nm	9 nm	16 nm

				700 ft below			
3	1842	A388	J	5.4 nm / 2:15 min 800 ft below	8 nm	11 nm	15 nm
4	1851	A320	M	6 nm* / 3:35 min 600 ft below	5 nm	8 nm	16 nm
5	1856	B777	H	6 nm* / 2:26 min 800 ft below	6 nm	9 nm	15 nm
6	1902	B777	H	6 nm* / 2:42 min 800 ft below	6 nm	9 nm	17 nm
7	1909	A388	J	5 nm / 1:50 min 900 ft below	8 nm	11 nm	25 nm
8	1916	Nil[12]	N/A	N/A	N/A	N/A	12 nm
9	1921	B777	H	5.3 nm* / 1:59 min 400 ft below	6 nm	9 nm	20 nm
10	1929	A359	H	3.7 nm / 1:30 min 200 ft below	6 nm	9 nm	15 nm

*The preceding aircraft had already landed when the DA62 was established on approach to runway 30L

The observation also identified that, except for the positioning flight, where the DA62 remained 500 ft above the flightpath of the preceding aircraft landing on runway 30R, the DA62 captured the approach path on all but one other approach at a lower altitude in relation to the preceding air traffic landing on runway 30R. The altitude difference varied between 200 and 900 ft below the preceding aircraft altitude.

12 On this approach the DA62 did not follow other air traffic

On the approach during which the Accident occurred, a preceding A350 was on Final to runway 30R. The DA62 followed the A350 at a distance of 3.7 nm, approximately 5.5 nm inbound to runway 30L, and entered the approach at an altitude of 1,300 to 1,400 ft AMSL. The A350 had passed through this location on the parallel approach path at an altitude of 1,500 to 1,600 ft AMSL, 90 seconds earlier (figure 11).

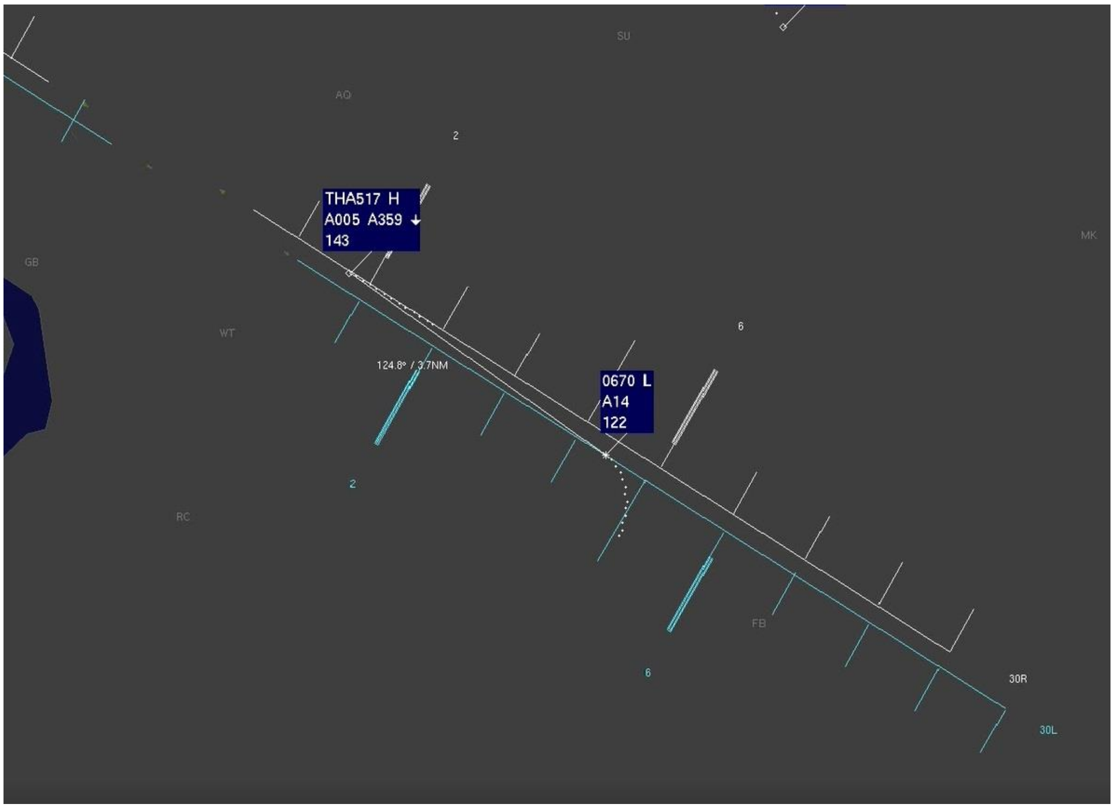

Figure 11. Aircraft approach to runway 30L following Airbus A350-900

According to ANS records, a handover of ATC duty responsibilities took place during the calibration flight, sometime after the first five approaches had been flown. The first air traffic controller had consistently issued the DA62 with air traffic information that included a caution of possible wake turbulence in relation to air traffic flying the approach to runway 30R. The second air traffic controller also issued air traffic information but omitted to issue any cautions of possible wake turbulence from other air traffic on approach to runway 30R.

Radar playbacks indicated that the Commander was the flight crewmember answering ATC calls on five of the ten approaches, including during the final two approaches.

The recorded flight maneuvers flown during each approach were reviewed with the Operator's key personnel who were familiar with the Commander's flying routine. It was concluded that, considering both flight crewmembers' experience, the Commander was, most probably, the pilot in control of the DA62 during the entire calibration mission.

1.18.2 Correspondence and pre-calibration flight meeting

The ANS provider commenced communication with the Commander by email sent on 8 May 2019. It was in that email that ANS provided the 3 nm additional separation to the recommended ICAO standard wake turbulence separation minima to the Commander.

The email read:

> "Due to the calibrations being on the south runway, with north runway operations in place, when being handled by the radar approach unit you will be afforded the following separation on approach to 30L which is greater than normal as the approach path is lower than the parallel approach:"

The email included a table which displayed the additional spacing to preceding aircraft with different wake turbulence categories.

The email continued with:

> " When on tower frequency, sighting traffic and applying own pilot separation can we expect you to positon for similar spacing to the above table. As traffic levels are currently lower at OMDB than normal, we can accommodate increased spacing, we just want to know what to expect, so to be able to plan for arrivals following you accordingly."

The Commander accepted the separations provided by responding to the email, stating that he had performed calibration flights at OMDB "on a number of occasions", and on many of the circuits he "Can tighten things significantly."

The Commander added in the email:

> "In general terms, our experience tells us that we are content to be tighter than the IFR wake minima behind aircraft positioning for the other runway. We have the ability to identify callsigns of other aircraft using ADS-B[13] which helps when coordinating the sequence with ATC."

The Investigation could not confirm the use of the Aircraft transponder for the purpose of identifying call signs of other air traffic. In interviews with the Operator's personnel, it was established that the Commander regularly used a personal hand-held device for navigation purposes.

Meetings with the flight crew were held one day prior to, and shortly before the calibration flight commencement. During these meetings, the flight crew and the Flight Inspector discussed with ANS and airport operational staff the details of the calibration flight. The operational parallel runway 30R, aircraft separation, spacing, and traffic information requirements regarding other aircraft were among the topics discussed during this meeting. As the calibration flight was planned to be under VFR, it was decided that the flight crew would apply their own separation from aircraft approaching the operational parallel runway 30R as per standard Class D operating procedures.

According to ANS, the Commander had expressed his understanding of wake turbulence implications during the meeting and his only expressed concern was the hazard of wake vortices generated by any preceding Airbus A380.

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[13] Automatic Dependent Surveillance – Broadcast is a system that relies on aircraft or airport vehicles broadcasting their identity, position and other information, and can be captured for surveillance purposes on the ground or onboard other aircraft in order to facilitate airborne traffic situational awareness, spacing, separation and self-separation. [Source: Skybrary]

1.18.3 Flight plan and number of occupants

The flight plan for the calibration flight was filed prior to departure at 0937, while the DA62 was at OMSJ. As per the flight plan, the estimated flight duration was two hours, with three people onboard (appendix A).

Prior to departure from OMDB, the Commander informed ATC that the number of persons onboard was four. This was confirmed by CCTV footage from the OMDB apron.

The Operator advised that it was not unusual that an observer was allowed to be onboard during calibration flights, but according to the *Operations Manual*, it was the responsibility of the Commander to re-calculate the weight and balance, and to provide a change message or to re-file the flight plan.

1.18.4 Technical logbook information

The Investigation noted that the Aircraft's technical logbook page recorded the calculated take-off and landing distances required in feet. The take-off runway and landing distances available were also recorded in feet. These distances in the *Airplane Flight Manual* tables are provided in meters.

The take-off and landing distances recorded in the technical logbook page by the Commander could not be correlated with the information provided in the *Airplane Flight Manual Take-Off Distance – Normal Procedure*, or *Landing Distance – Flaps LDG*.

In addition, the Investigation noted that the reference pages to the *Airplane Flight Manual* in the technical logbook were at revision 2, dated 1 November 2015, and had not been revised to the latest *Airplane Flight Manual* revision 4, dated 14 November 2017.

1.18.5 The preceding aircraft

The aircraft preceding the DA62 was an Airbus A350-900 with a weight of 176.8 tons and a wingspan of 65 m. It performed an uneventful precision approach and landed on runway 30R at 1929:26.

According to data retrieved from the quick access recorder and made available to the Investigation, the A350 crew applied the 'decelerate approach' technique. This technique required the establishment of the approach on the glideslope and localizer down to an altitude of 250 ft. The A350 decelerated from 190 kt at 2,500 ft to an approach speed of 138 kt at 750 ft. The slat/flap configuration was selected at '3' when the aircraft was at 1,800 ft. The autopilot was disengaged at 580 ft.

The quick access recorder recorded a right cross wind component of up to 9 kt, at an altitude of 2,200 ft, which decreased to 6 kt at altitudes between 1,100 and 500 ft.

1.18.6 Wake vortex and wake turbulence − General

Turbulence in the wake of an aircraft is generally caused by wing tip vortices, which are a consequence of the differential pressure between the lower and upper wing surfaces. That differential pressure causes the air to move outwards on the lower wing producing counter-clockwise cylindrical vortices on the right wing and clockwise rotations on the left wing, viewed in the direction of flight (figure 12).

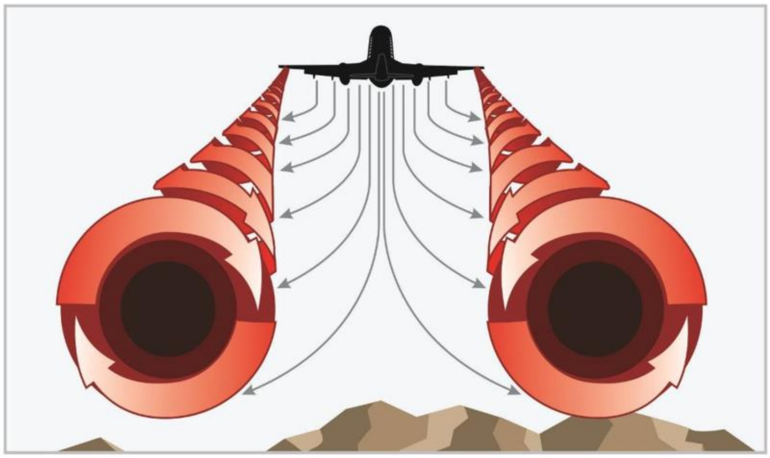

Figure 12. Wake vortex turbulence [Source: FAA]

The strength of the vortex is dependent mainly on the aircraft weight, speed, wing design, and the configuration of the wing. Generally, the strength of a vortex increases with the increase in aircraft weight or its decrease in speed. The wingspan and shape affects the vortex characteristics through the decay rate.

Advisory Circular AC-90-23G − Aircraft Wake Turbulence, issued by the Federal Aviation Administration (FAA) of the United States, describes the following:

> "In flight experiments, aircraft have been intentionally flown directly through trailing vortex cores of larger aircraft. It shows that the capability of an aircraft to counteract the roll imposed by the wake vortex primarily depends on the wingspan and counter control responsiveness of the encountering aircraft."

The *Advisory Circular* also adds:

> "It is more difficult for aircraft with short wingspans (relative to the vortex-generating aircraft) to counter the imposed roll induced by vortex flow. Pilots of short-span aircraft, even of the high performance type, must be especially alert to vortex encounters."

Figure 13 illustrates the effect of wake vortices on a small aircraft following a large aircraft and the expected counter control. For the small aircraft to roll to the left it must have entered the center of the right wing's anticlockwise vortex, or its left wing penetrated the inboard side of the left wing's clockwise vortex, or its right wing penetrated the outboard side of the left wing's clockwise vortex.

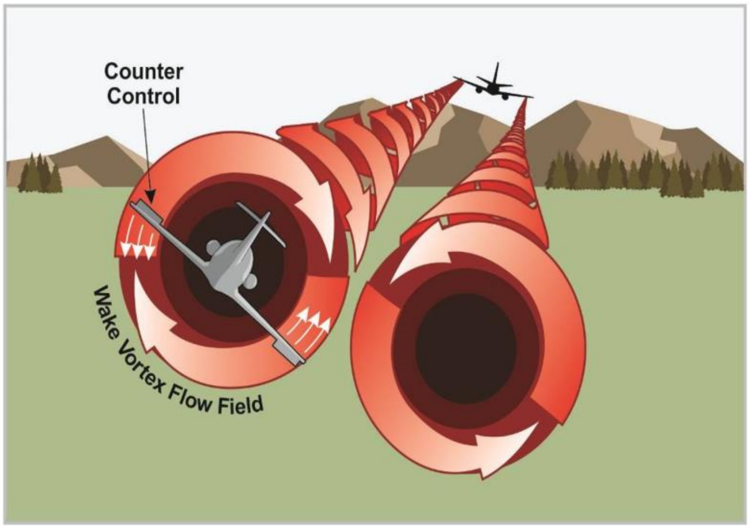

Figure 13. Wake vortices and small aircraft [Source: FAA]

Vortices typically descend slowly and move outwards when in contact with the ground (figure 14). They may persist for up to three minutes and are more likely to persist at lower wind speeds. In particular, in cross-wind conditions, similar to the conditions at the time of the Accident, both vortices may remain at a similar parallel distance when they drift across the flight path, as illustrated in figure 24 of section 1.19.5 Airbus wake turbulence estimation.

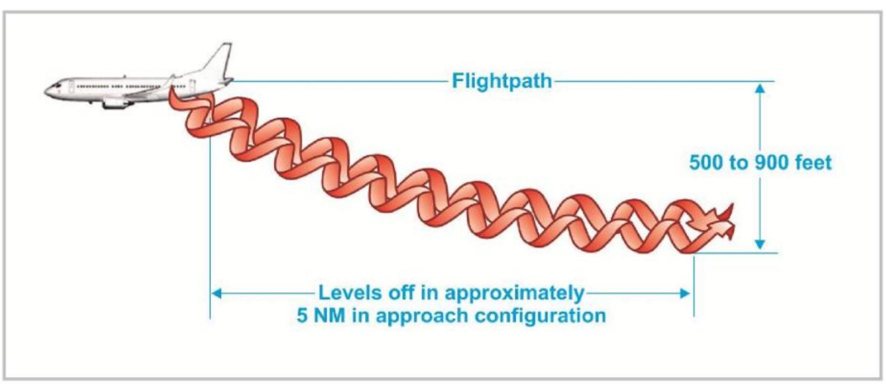

Figure 14. Decent of vortices from large aircraft [Source: FAA]

The risk of encountering wake vortices becomes more probable and severe in the vicinity of airports where aircraft are on approach to or departure from the same runway. The vortices may cause sudden roll movements beyond the flight crew's capability to counteract, leading to a loss of control.

The FAA *Advisory Circular* advises that: "Pilots should fly at or above the preceding aircraft's flightpath, altering course as necessary, to avoid the area behind and below the generating aircraft."

1.18.7 *Safety Alert 2017-10 – Wake Turbulence Awareness*, issued by the GCAA

The GCAA issued *Safety Alert 2017-10* in 2017 addressed to air traffic controllers, flight crew and operators. It highlighted the possibility of wake turbulence events in all phases of flight, including when shortening the distance below the wake turbulence separation minima during approach and departure. The *Safety Alert* highlights the advice from the International Civil Aviation Organization (ICAO) that: "… The application of the wake turbulence minimum is not an assurance against a wake turbulence encounter; its application only minimizes the hazard."

The *Safety Alert* provides guidance and recommendations such as:

"– Wake turbulence separation standards do not guarantee avoidance of encounters, they only attempt to minimize the risk

– Wake turbulence is somewhat predictable and can be generalized as the vortices descending at 700 ft/min and extending for up to 25 nm behind the aircraft

– Lateral offsets can reduce the risk in some circumstances

– ATC should monitor flight profiles, and consider giving wake vortex warning in the event that an aircraft will fly in the airspace below the trajectory of either a heavy aircraft, or an aircraft of a heavier weight category than the experiencing aircraft

– Controllers should factor wake vortex behavior into their situational awareness, and provide a caution to pilots of any increased risk of a wake turbulence encounter."

1.18.8 dans − Wake turbulence separation procedure

The dans Manual of Air Traffic Services (DMATS), section 3.5 − *Wake Turbulence and Wake Turbulence Separation*, described the wake turbulence separation requirements and stated: "Wake turbulence separation shall be applied to all aircraft being provided with an air traffic control service in the approach and departure phase of flight. See Table 5 below."

The referenced table (figure 15) depicts the following:

Wake Turbulence Separation		
Leading Aircraft	**Following Aircraft**	**Wake Turbulence Separation Minima Distance (NM)**
Super	Super	#Nil
Super	Heavy	6
Super	Medium	7
Super	Light	8
Heavy	Heavy	4
Heavy	Medium	5
Heavy	Light	6
Medium	Light	5

Figure 15. DMATS Wake turbulence separation table [Source: dans]

The *Manual* described that the wake turbulence separation minima set out in this table shall be applied when either:

> "– Both aircraft are using the same RWY, or parallel RWYs separated by less than 760 meters;
>
> …
>
> – An aircraft is crossing behind another aircraft at the same altitude, or less than 1000 ft below."

In regards to requests from pilots for a visual approach and the provision of essential air traffic information, section 3.7 of the *Manual* − *Visual Approaches*, reads:

> "To ensure all requirements are met when issuing a visual approach on final approach the following phraseology shall be used: "[Callsign], traffic is (aircraft type and wake turbulence category, and if applicable, relative position and distance), report in sight to accept visual approach behind." When pilot has reported and accepts visual approach: "[Callsign], (caution wake turbulence, if applicable), cleared visual approach runway (designator), maintain own separation."

1.18.9 ICAO *Document 4444 – Air Traffic Management*

ICAO *Document 4444* specifies the procedures for air navigation services — air traffic management (PANS-ATM) to be applied to various air traffic.

In relation to VFR and IFR flight separation during departure and approach the *Document* states:

> "5.8.1.1 The ATC unit concerned shall not be required to apply wake turbulence separation:
>
> a) for arriving VFR flights landing on the same runway as a preceding landing HEAVY or MEDIUM aircraft; and
>
> b) between arriving IFR flights executing visual approach when the aircraft has reported the preceding aircraft in sight and has been instructed to follow and maintain own separation from that aircraft.
>
> 5.8.1.2 The ATC unit shall, in respect of the flights specified in 5.8.1.1 a) and b), as well as when otherwise deemed necessary, issue a caution of possible wake turbulence. The pilot-in-command of the aircraft concerned shall be responsible for ensuring that the spacing from a preceding aircraft of a heavier wake turbulence category is acceptable. If it is determined that additional spacing is required, the flight crew shall inform the ATC unit accordingly, stating their requirements.
>
> 5.8.2.1.1 The following minima shall be applied to aircraft landing behind a HEAVY or a MEDIUM aircraft:
>
> a) MEDIUM aircraft behind HEAVY aircraft — 2 minutes;
>
> b) LIGHT aircraft behind a HEAVY or MEDIUM aircraft — 3 minutes."

"8.7.3.4 The following distance-based wake turbulence separation minima [for IFR flights] shall be applied to aircraft being provided with an ATS surveillance service in the approach and departure phases of flight in the circumstances given in 8.7.3.4.1.

Aircraft category		
Preceding aircraft	*Succeeding aircraft*	*Distance-based wake turbulence separation minima*
HEAVY	HEAVY	7.4 km (4.0 NM)
	MEDIUM	9.3 km (5.0 NM)
	LIGHT	11.1 km (6.0 NM)
MEDIUM	LIGHT	9.3 km (5.0 NM)

8.7.3.4.1. The minima set out in 8.7.3.4 shall be applied when:

a) an aircraft is operating directly behind another aircraft at the same altitude or less than 300 m (1000 ft) below; or

b) both aircraft are using the same runway, or parallel runways separated by less than 760 m (2500 ft); or

c) an aircraft is crossing behind another aircraft, at the same altitude or less than 300 m (1000 ft) below."

1.18.10 Proposed wake turbulence separation per *RECAT-EU*[14] study

The European organization for the safety of air navigation (Eurocontrol), in consultation with stakeholders, developed a re-categorization scheme of ICAO wake turbulence separation minima on approach and departure, called *RECAT-EU*.

The *RECAT-EU* study, published in 2015, compared the wake generation and wake resistance between aircraft based on their mass. The *RECAT-EU* added sub-categories to the original ICAO categorization. The "Heavy" and "Medium" categories are sub-categorised into a scheme of "Upper Heavy" and "Lower Heavy" and "Upper Medium" and "Lower Medium", based on the aircraft characteristics.

According to Eurocontrol, the introduction of these sub-categories, allows for a reduction of separation minima for some air traffic pairs of aircraft, which will increase air traffic capacity in approaches and departures, while maintaining an acceptable level of safety. The changes are also intended to reduce the risk of wake turbulence accidents for smaller aircraft by increasing separation minima and/or listing them under a different category.

EASA conducted a technical review and confirmed that the *RECAT-EU* wake turbulence scheme can be used by air navigation service providers as a basis to revise current schemes.

14 *RECAT-EU European Wake Turbulence Categorization and Separation Minima on Approach and Departure*, Edition: 1.1 dated: 15 July 2015

According to the EASA study, the A350 is categorized as an "Upper Heavy" and the DA62 as a "Light" aircraft. Accordingly, the wake turbulence separation minima, for the DA62 following as IFR traffic, would be 7 nm, as highlighted in figure 16.

RECAT-EU scheme		"SUPER HEAVY"	"UPPER HEAVY"	"LOWER HEAVY"	"UPPER MEDIUM"	"LOWER MEDIUM"	"LIGHT"
Leader / Follower		"A"	"B"	"C"	"D"	"E"	"F"
"SUPER HEAVY"	"A"	**3 NM**	**4 NM**	**5 NM**	**5 NM**	**6 NM**	**8 NM**
"UPPER HEAVY"	"B"		**3 NM**	**4 NM**	**4 NM**	**5 NM**	**7 NM**
"LOWER HEAVY"	"C"		**(*)**	**3 NM**	**3 NM**	**4 NM**	**6 NM**
"UPPER MEDIUM"	"D"						**5 NM**
"LOWER MEDIUM"	"E"						**4 NM**
"LIGHT"	"F"						**3 NM**

Figure 16. RECAT EU Separation minima between wake turbulence categories

1.18.11 Diamond aircraft ELT failures

The Investigation researched Diamond aircraft emergency locator transmitter (ELT) failures to identify any trend. Because of the limited accidents involving Diamond aircraft, the research was not conclusive.

The investigation report by the Australian Transport Safety Bureau of a Diamond DA40 inflight loss of control accident was closer reviewed. The DA40 had entered into a spin during a training flight on 26 September 2018. The impact caused the fuselage to break-up and the rear fuselage separated from the forward fuselage, causing damage to the ELT installation.

The Investigation contacted the Australian Transport Safety Bureau for further details and was advised that as a result of the damage to the ELT installation, the ELT did not transmit a signal.[15]

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15 Australian Transport Safety Bureau (ATSB) Report AO-2017-096

1.18.12 UK CAA − *No-objection letter*

As part of the acceptance process for foreign operators to practice commercial aviation activities in the United Arab Emirates, the GCAA requires a *no-objection letter* from the State of Registry.

The UK CAA issued a *no-objection letter* for the Operator, which was attached to the application submitted to the GCAA for calibration services at Dubai International Airport. The *letter* stated:

> "The UK Civil Aviation Authority (CAA) has no objection to the proposal by Flight Calibration Services Limited to carry out Aerial Work in the United Arab Emirates (UAE) provided that Flight Calibration Services Limited remain in full compliance with applicable regulations and are appropriately insured for the work being done."

1.18.13 Aircraft airborne recording systems

Based on its weight and engine categories, the DA62 was not required by EASA certification requirements to be equipped with flight recorders. However, EASA conducted four systematic studies of safety investigation reports for the purpose of assessing the potential safety benefits of airborne recording systems.

The scope of the fourth study focused on the safety benefits of gaining factual information from airborne image recording systems. The results of these studies are described in appendix E of EASA document NPA 2017-03. The study concluded that these recorders bring a moderate benefit for light private aircraft categories, and focus should be addressed to light commercial aircraft, which includes the Operator's type of operation.

The EASA definition of a commercial operation definition states:

> "Any operation of an aircraft, in return for remuneration or other valuable consideration, which is available to the public or, when not made available to the public, which is performed under a contract between an operator and a customer, where the latter has no control over the operator."

1.19 Useful or Effective Investigation Techniques

1.19.1 Light detection and ranging (LIDAR) recordings

The ANS provider has installed three light detection and ranging (LIDAR)[16] systems around Dubai International Airport. The systems are utilized to measure the strength and behavior of wake vortices generated by approaching and departing aircraft. The data provided by the LIDAR stations are recorded in metric units. Therefore, the Report provided distances and heights relevant to recorded LIDAR data in this section in meters and feet.

1.19.2 LIDAR station DXB2

One LIDAR station, DXB2, was located approximately 3.3 nm southeast of Dubai International Airport. It records wake vortex data in five-second intervals perpendicularly to the

[16] The LIDAR laser light beam reflects off airborne particles to calculate the wind speed and direction by applying the Doppler Effect.

approach paths to runways 30R and 30L. The station was located approximately 38 m (124 ft) above mean sea level.

Each LIDAR station was programmed to measure wind parameters at the end of every hour. The last reading before the Accident was at 1859, when, at a height above ground of 400 m (1,312 ft), DXB2 recorded 5 m/s (9.7 kt) wind speed, from 30 degrees, 2 m/s downwards. Recorded wind readings at 1959, the first reading after the Accident, were almost equal to the readings recorded one hour earlier.

At the time of the Accident, DXB2 did not record any other abnormal wind conditions or wind speeds in the scanned range.

The DXB2 scan range (green line) and the position of the approach paths to runways 30L (red line) and 30R (blue line) are shown in figure 18. The runway 30L approach intercepts the scan area at a distance of 718 m from DXB2, 336 m (1,100 ft) above ground. The runway 30R approach intercepts the scan area at a distance of 336 m, 434 m (1,424 ft) above ground as illustrated in figure 18.

The Accident site was near the approach path to runway 30L, at a distance of approximately 500 m from the DXB2 scan area. This distance represented a time difference of eight seconds for the DA62 travelling at 120 kt.

The A350 was recorded by DXB2 at approximately 1927:24 at an altitude of 1,500 ft AMSL on the approach path to runway 30R, perpendicular to the location of the abrupt roll and steep dive of the DA62 at approximately 1928:54 at 1,300 ft AMSL, as shown in figure 17.

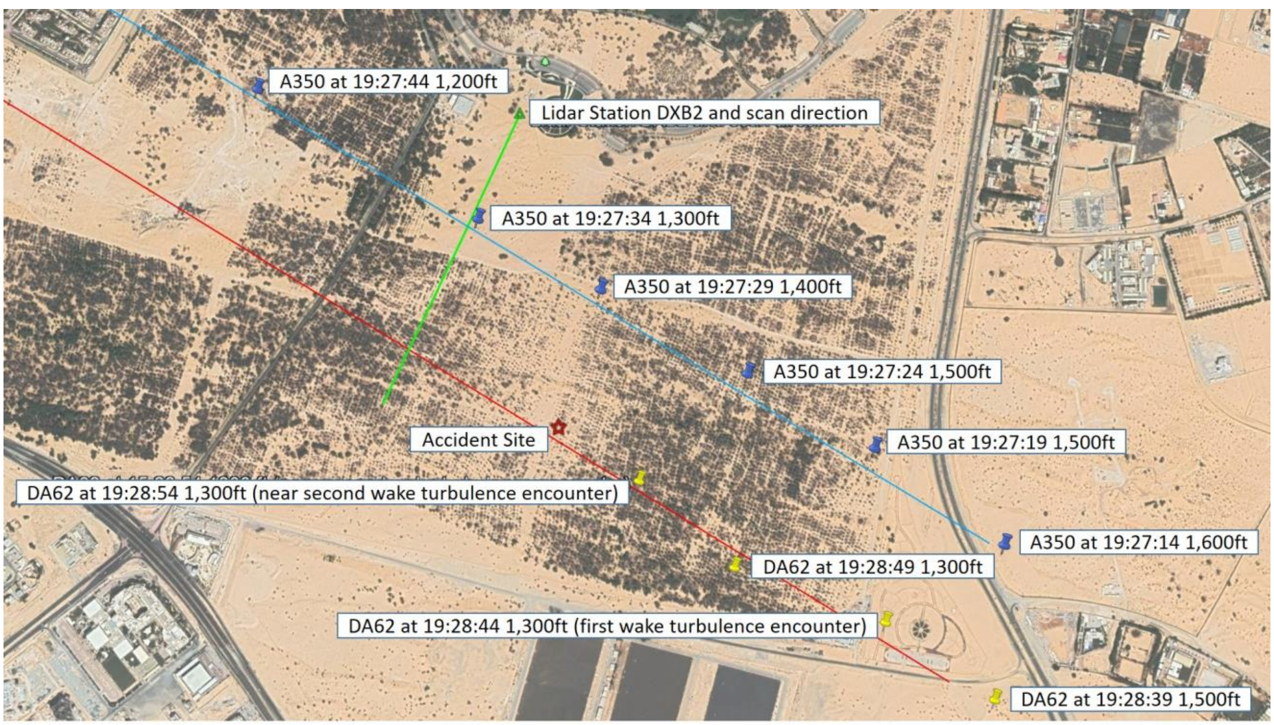

Figure 17. LIDAR station DXB2 scan range and aircraft locations

1.19.3 The A350 LIDAR data

Figure 18 illustrates the LIDAR scan area in relation to the approach paths to runways 30L and 30R. It also illustrates the behavior of wake vortices generated by the left and right wings of the A350. The figure illustrates the drift rates of the vortices towards the runway 30L approach path and the vortices locations at the time of the second sudden roll upset of the DA62.

The Investigation determined that the core of the left wing vortex had passed through the approach path of the DA62 at a height of approximately 289 m (948 ft). The right wing vortex followed at a height of 287 m (942 ft).

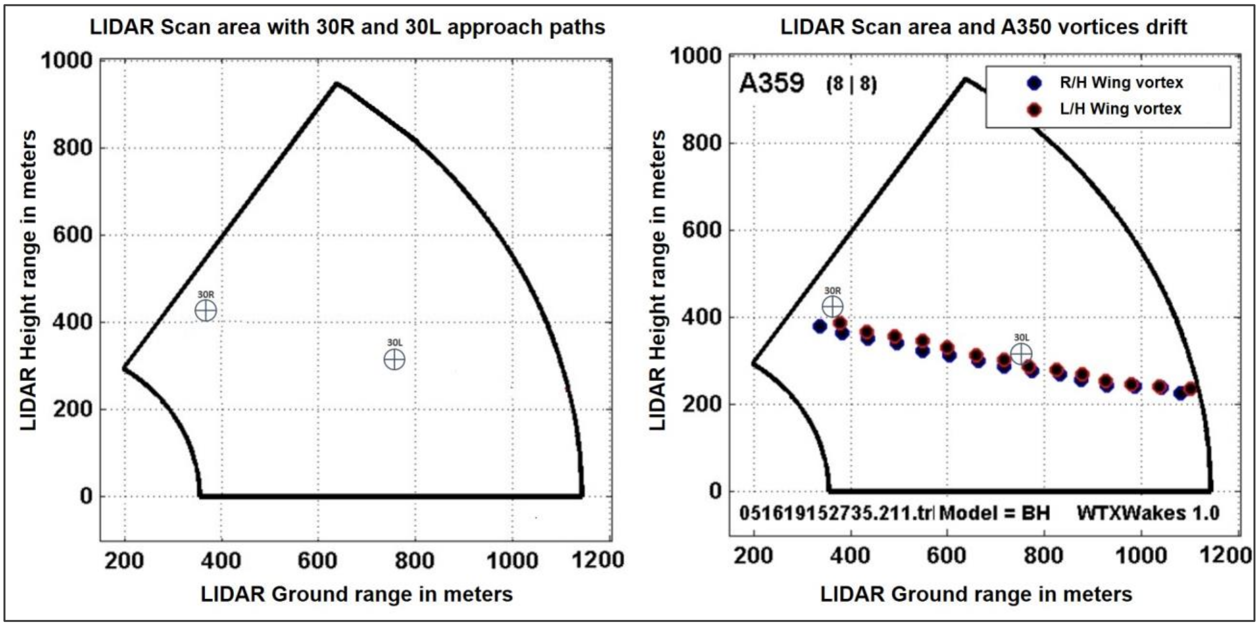

Figure 18. LIDAR ground range and A350 generated vortices [Source: dans]

Figure 19 identifies that the vortices remained at a similar parallel distance of approximately 50 m apart for 150 seconds.

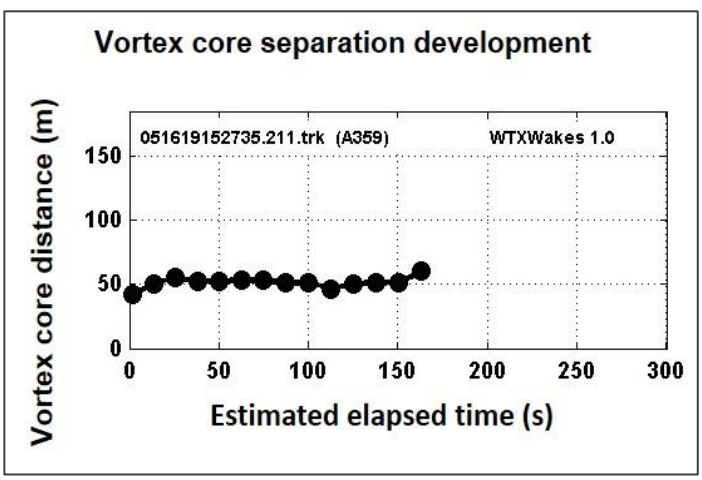

Figure 19. A350 wake vortices drift [Source: dans]

Figure 20 illustrates the wake vortices and the vertical and horizontal drift. The left and right wing vortices drifted to the left with a speed of 4.6 m/s and 4.4 m/s respectively, and reached the runway 30L approach path after approximately 74 and 87 seconds.

The left wing vortex descended at a rate of 1.08 m/s and moved into the approach path to runway 30L with a speed of 4.56 m/s. The right wing vortex reached a sink rate of 1.16 m/s and a drift speed of 4.44 m/s to the left.

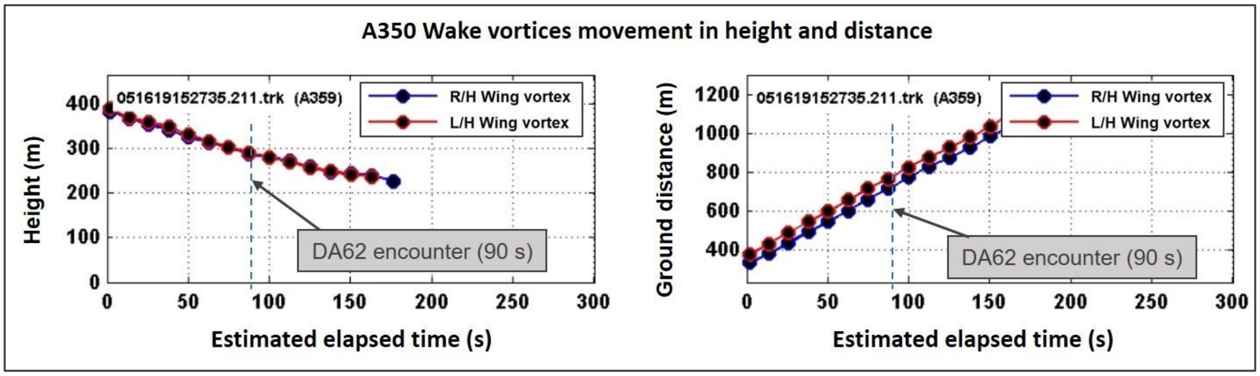

Figure 20. A350 wake vortices drift [Source: dans]

Figure 21 represents the wake vortex circulation strength and progress. It illustrates that both vortices were generated with the same vortex circulation strength. However, the strength of the left vortex increased to a maximum of 108% after approximately 13 seconds, while the right vortex strength increased to a maximum of 110% after approximately 26 seconds.

Both vortices degraded to 81% after 90 seconds when the DA62 followed at an altitude of 1,300 ft AMSL on the runway 30L approach path.

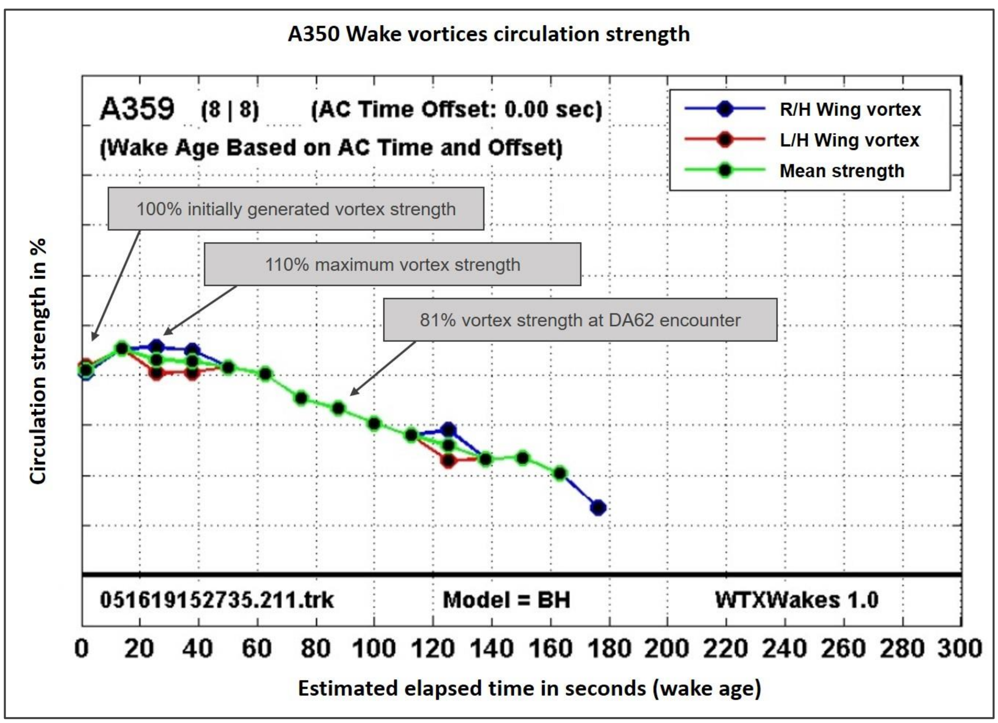

Figure 21. A350 Generated vortices and at time of DA62 encounter [Source: dans]

1.19.4 Boeing B777 LIDAR data

The LIDAR data were reviewed for an approach that was carried out before the Accident approach. The DA62 was following a B777 and was 120 seconds behind. The LIDAR data indicated that the time separation was sufficient for the DA62 to follow without a wake turbulence encounter.

The B777 left and right wing wake vortices had descended to 202 m and 195 m at a distance of 937 m and 886 m respectively, from LIDAR station DXB2. With these distances, the DA62 would have been above the B777 vortices when it followed on the approach path to runway 30L (figure 223).

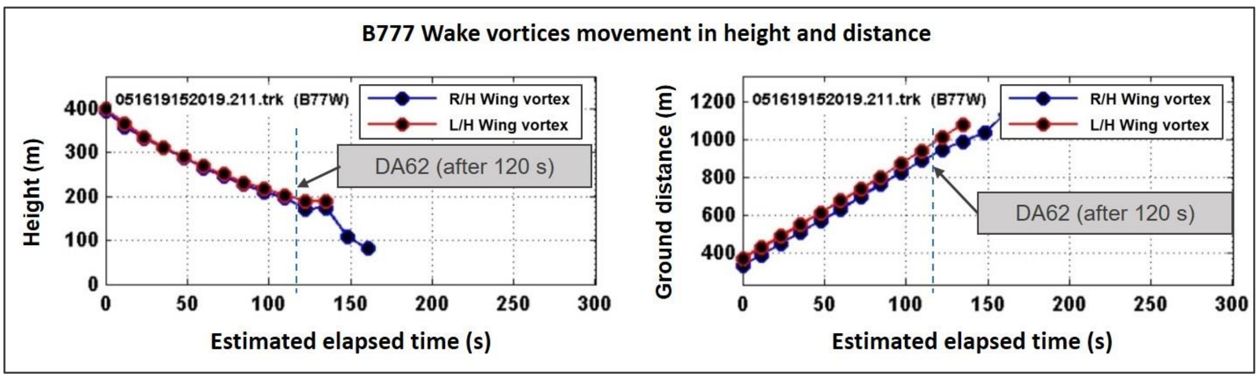

Figure 22. B777 generated vortices and drift at time of DA62 following [Source: dans]

1.19.5 Airbus wake turbulence estimation

The Investigation provided Airbus with relevant and available data from the LIDAR station, quick access recorder data from the preceding A350, radar recordings, and recorded footage from the airport approach cameras, for the purpose of estimating the wake turbulence generated by the A350 at the time and place of the DA62 loss of control.

The estimation considered the position of the A350 in relation to the DA62, the A350 wake vortex characteristics in the landing configuration, and the wake vortex displacement towards the runway 30L approach path, based on the onboard wind computation from the A350 navigation system.

The Airbus report confirmed that “the estimated characteristic of wake vortex generated by [the preceding] A350 are consistent with a rate of decent enabling wake vortex to descent [descend] to the vicinity of the RWY 30L 3° glideslope height taking into account the parallel approaches configuration, the 4D trajectories (time, latitude, longitude, altitude) of both aircraft”, and the on-board wind computation from A350 navigation system. (Figure 23)

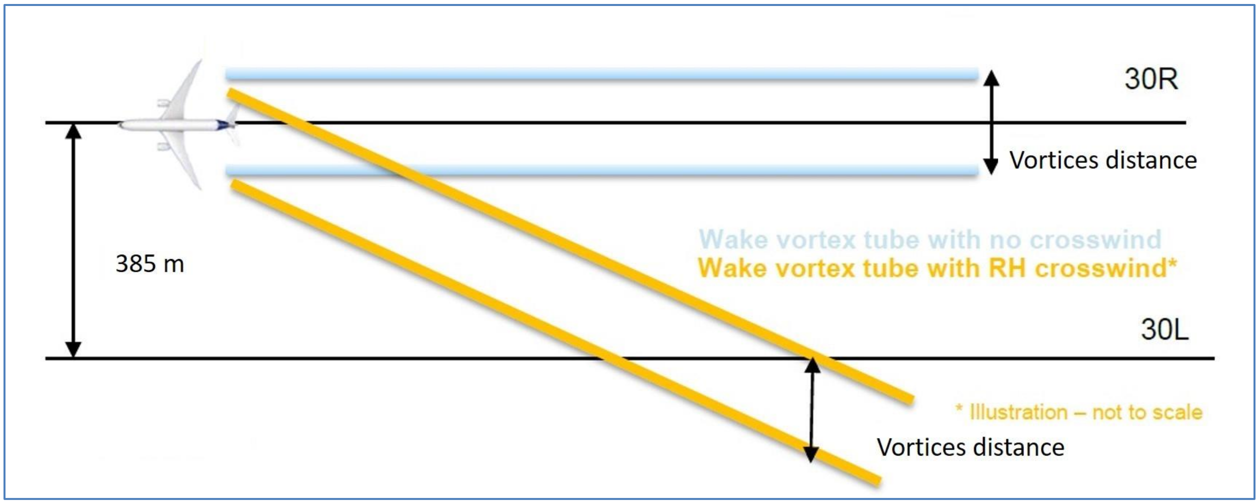

Figure 23. Representation of A350 generated vortices and drift [Source: Airbus Industries]

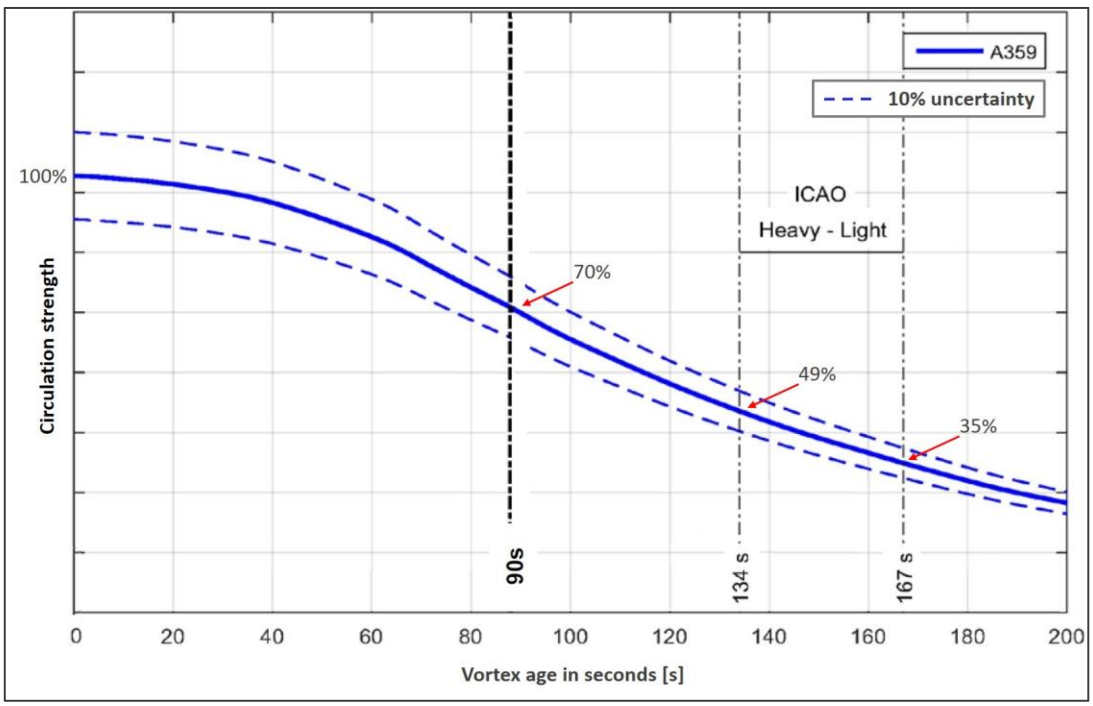

Figure 24. Heavy to Light aircraft separation as recommended by ICAO
[Source: Airbus Industries]

The Airbus report concluded that "The estimated wake vortex turbulence circulation [strength], at the time of 2^{nd} encounter … is around 30% lower than the maximal circulation obtained at the time of wake generation by the preceding heavy aircraft…"

The Airbus report added that "Applying ICAO separation distance between Heavy and Light aircraft, the wake vortex circulation encountered in similar condition (weather and angle interception angle of encounter) would have been 30 to 50% lower than the one encountered during the event, depending on the approach speed profile."

According to the Airbus report, and as illustrated in figure 24, the DA62 encountered a vortex circulation strength of approximately 70% of the maximal vortex strength generated by the preceding A350. Had the ICAO recommended separation be applied, the encountered wake vortex circulation strengths had been between 35 and 49% of the maximal generated strength. A 10% uncertainty range of the circulation decay is displayed by blue dashed lines.

2. Analysis

2.1 General

The Investigation reviewed all available evidence for the purpose of identifying the cause of the Accident. The DA62 was not required to be fitted with onboard recorders; therefore, witness accounts, radar recording, the LIDAR station recording, footage captured by the airport approach cameras and evidence collected at the Accident site were analyzed by the Investigation. The evidence identified the first Aircraft upset and the second abrupt roll and steep dive. It provided the Investigation with a detailed timeline of events.

2.2 Pilot in Control of the Aircraft

The Investigation analyzed a number of factors to identify which pilot was in control of the Aircraft, because this was considered relevant to critical decisions made in relation to maintaining their own separation from other air traffic.

The Operator advised that according to their policy, the workload during the mission and the cockpit layout would generally require that the commander in the left hand seat be the pilot in control of the aircraft, while the copilot communicated with ATC from the right hand seat. However, the policy allows the commander to assign flying tasks to the copilot.

During the Accident flight, the Commander was communicating with ATC during most of the approaches. This may have occurred at times when the Copilot was arranging aspects of the flight inspection task on the ground frequency.

The Copilot was less experienced and a review of his flight logbook indicated that he had been the pilot in command on positioning flights, but had not been in command on any previous calibration flights.

The flight at dusk with air traffic operating to the parallel runway presented an operational challenge and a high workload. Having an observer from the ground lighting organization onboard may have added to expectations for a precise operation.

The Investigation consulted with FCSL staff familiar with the flight crew and viewed radar playbacks of the approach patterns in an attempt to determine the most likely person in control of the Aircraft.

Considering these factors, the Investigation determines that it is most likely that the Commander was in control of the Aircraft during the ten approaches, including during the approach when the Aircraft encountered wake turbulence.

2.3 Loss of Control

The Investigation considered various scenarios that had the potential to cause an inflight loss of control as recorded by the runway approach camera.

There was no indication that the Aircraft had encountered a flight control defect or a structural failure prior to impact. The flight crew did not communicate any emergency during the loss of control or at any other time, indicating that this was a sudden unexpected event which required their full attention in an attempt to regain control of the Aircraft.

The Aircraft had sufficient fuel onboard, as recorded on the fuel docket, and there was no indication that the engines had stopped producing power.

While the weight and balance calculation indicated that the Aircraft weight during takeoff from OMDB was above the maximum take-off weight with reference to section 2.8 Weight and Balance Calculations, the Aircraft weight at the time of the Accident had been reduced by fuel consumption to a weight below the maximum permissible aircraft weight. While the Investigation could not determine the exact center of gravity during takeoff, or at the time of the Accident, there was no indication that the flight crew experienced any problems in controlling the Aircraft prior to the initial upset.

Both crewmembers passed their medical examinations in July and August 2018. Interviews with ground staff described both pilots as fit and healthy on the day of the Accident. This was also confirmed by observations from CCTV recordings of the crew's arrival at the airport prior to departure. A loss of control due to physical or psychological crew incapacitation was unlikely.

The Investigation focused on the data retrieved from the radar recording, footage captured by the runway approach camera, and the LIDAR station located nearest to the approach paths to runways 30L/30R, for the purpose of identifying the cause of the loss of control.

The data from the LIDAR station was analyzed and provided the Investigation with critical information confirming that due to the prevailing wind conditions, at the time when the DA62 lost control, wake vortices from the preceding Airbus A350 had drifted from the higher approach path of runway 30R, crossing the approach path of runway 30L.

Therefore, the Investigation determined that the DA62 entered the wake vortices generated by the preceding A350's right wing during the first upset which caused a dynamic roll to the left. When the DA62 was recovered from this encounter and returned to the approach path, it encountered the wake vortex generated by the left wing.

Following the first wake turbulence upset and recovery the flight crew lost control of the Aircraft during the second wake turbulence encounter which caused the Aircraft to roll abruptly to the left until it became inverted and entered a steep dive.

The Commander, who was most probably the pilot in control of the Aircraft, recovered from the first vortex encounter, before encountering the second sudden and rapid roll movement. Within two seconds of the second vortex encounter the Aircraft was inverted at an altitude of approximately 1,170 ft above ground, over an area of unlit parkland at dusk, which made observation of any visual external altitude reference difficult.

The impact evidence suggests that the Commander was attempting to fly the Aircraft out of the inverted attitude in a direction opposite to the direction of flight by pulling on the control stick. According to the manufacturer, with this flight control input, in ideal conditions, an altitude of 1,800 to 2,000 ft above ground level would have been required to recover.

Given the insufficient altitude, the Investigation determined that recovery of the Aircraft and a safe continuation of the flight was not possible.

The Operator did not provide the flight crew with upset recovery training. The Investigation could not determine whether this would have provided the Commander with skills to react differently and recover the Aircraft.

2.4 Communication Prior to the Calibration Flight

dans had been in communication with the Commander prior to the mission to discuss the details of the calibration flight and to provide assurance that there was no time constraint on the calibration flight. In an email to the Commander, dans included a table listing the standard

ICAO standard wake turbulence air traffic separations, extended by 3 nm for each category. This extended separation from preceding air traffic to runway 30R, ensured that the calibration flight was not affected by other air traffic. These safety initiatives were introduced because the ANS provider understood the implications of the lower approach path to runway 30L due to the displaced runway 30R threshold.

The Commander was sufficiently aware of the specific runway arrangement at Dubai International Airport, where he had performed calibration flights on a number of occasions. In his email, he advised that on many of the circuits, he “can tighten things significantly”.

His statement that he was “content to be tighter than the IFR wake minima behind aircraft positioning for the other runway” indicated that he had underestimated the risks associated with wake vortices. This attitude was exhibited by the Commander during the meeting prior to the calibration flight on the day of the Accident, where his only concern was about A380 generated wake vortices.

2.5 The Diamond DA62 Separation Identification System

The DA62 was equipped with a Garmin G1000, which provides a traffic map with selectable scale circles displayed on the MFD. The traffic map displays the position of other air traffic in relation to the Aircraft position. The instrument did not have provision to provide flight information for the preceding air traffic. However, the Commander stated in his email to ANS that “We have the ability to identify callsigns of other aircraft using ADS-B which helps when coordinating the sequence with ATC.” This indicated that he may have utilized personal portable equipment to identify aircraft information including flight numbers. The Investigation could not determine what information would have been provided nor how reliable the information was.

In order to identify the preceding aircraft type for the determination of appropriate separation, the Commander had to correlate the information provided by ATC with the information displayed on the traffic map.

The Investigation determines that the information provided by ATC and the Aircraft systems were sufficient to enable the flight crew to determine the Aircraft position in relation to the airport, both approach paths, and the distance to other air traffic, and consequently to establish a safe vertical and horizontal separation.

2.6 Trans-cockpit Authority Gradient

The Commander was described by other pilots as a competent and experienced pilot, who presented a “challenging leadership style” in an attempt to enhance other pilot’s knowledge and skills. The Copilot was described as “reserved and, at times, needing assurances in his decisions.”

The personal attributes of both pilots describe a steep trans-cockpit authority gradient[17], where the Commander was in charge and the Copilot would have found it difficult to challenge the Commander’s decisions.

[17] ICAO Circular 234-AN/142: Trans-cockpit authority gradient was the authority relationship between commander and copilot. For example, in the case of a domineering commander and an unassertive copilot, the gradient will be steep. If two commanders are rostered together, the gradient may be shallow

Even if the Copilot had been concerned during the first number of approaches, where the Aircraft was too close and too low in relation to other air traffic, it was unlikely that the Copilot would have shown the necessary assertiveness to challenge the Commander in this situation.

2.7 ATC Air Traffic Information

The air traffic controller providing the control service during the first five approaches issued air traffic information and essential local air traffic information to all air traffic, including issuing cautionary warnings of possible wake turbulence from heavier air traffic on approach to runway 30R. After the hand-over the second controller continued to issue air traffic information and essential local air traffic information to all air traffic. However, cautionary warnings of possible wake turbulence encounters were no longer provided.

Examination of the radar recording revealed that the DA62 entered the Final approach to runway 30R during the VFR positioning flight from OMSJ to OMDB some 500 ft above the preceding air traffic, in accordance with the recommended safe self-separation procedures.

The calibration flight required flying specific flight profiles and locating the DA62 at physical locations, which positioned it at the beginning of every approach to runway 30L at a lower altitude in relation to preceding air traffic on the parallel approach to runway 30R. While this was a procedural requirement, the achieved horizontal separation to preceding air traffic was the flight crew’s decision under VFR. It was observed that during the approaches, this spacing was less than the industry recommended wake turbulence separation minima for IFR flights. The selected Aircraft altitude remained between 200 and 900 ft below the other air traffic on the parallel approach. Horizontal self-separation was as short as 5 nm behind an A380, where an IFR separation of 8 nm is recommended by ICAO, and where 11 nm separation was provided by ATC.

The Investigation determined that the provision of wake turbulence advice during the first five approaches and its absence during the last five approaches did not influence the Commander’s judgement and decisions regarding self-separation from preceding air traffic. The Commander continued reducing self-separation, even from A380s, which were his only expressed concern during the meeting prior to the calibration flight.

The Commander had been provided with sufficient distance from preceding air traffic to establish a safe approach and was not provided with any time constraints by ANS that may have caused time pressure to complete the flight earlier.

The Commander spent his military career as an air traffic controller, where wake turbulence knowledge was essential. Other company pilots described him as safety conscious and they sometimes consulted him on flight operational issues. The Investigation carefully considered possible causes for the Commander’s misjudgment which led him to generally reduce the separation from other air traffic, but could not determine his reasoning.

The ability to assess a situation accurately depends on a number of factors, including knowledge based on learning, training received, flying experience, and expectations based on exposure to a variety of situations. The Commander had a long history as a pilot of light aircraft, where wake vortex encounters are one of the main hazards.

While decisions are generally made with the best intentions and based on present information and past experience, it is possible that the Commander did not develop a mental picture of the surrounding air traffic, or simply underestimated the hazard. He may have compared the flight with other uneventful missions at single-runway airports. When no wake vortices were encountered during the first nine approaches, he may have been convinced that his assessment of the wake vortex hazard was accurate.

2.8 Weight and Balance Calculations

The Investigation could not verify the exact weight of the occupants or their flight bags. However, footage from the airport CCTV and personal items found at the Accident site were used to determine an average weight of 78 kg per crewmember, flight inspector, and the observer. Seven kilograms were added to the weight of each of the four occupants to represent the weight of the flight bags. CCTV footage from the apron could not clearly identify the stowage location of the flight bags on the Aircraft, which prevented the Investigation from accurately calculating the weight and balance.

The Commander filed a flight plan prior to departure from OMSJ. Although he recorded a two-hour mission, he decided to upload the maximum amount of fuel in the main and auxiliary tanks. This resulted in a total Aircraft weight that was within the limitation of the maximum take-off weight, and a center of gravity that was within the permissible center of gravity range.

When the observer boarded the calibration flight as a fourth occupant in OMDB, the total Aircraft weight reached approximately 2,336 kg, which exceeded the maximum take-off weight of 2,300 kg. Due to the unknown location of the flight bags, the center of gravity of the Aircraft could not be determined.

The fuel consumption after takeoff from OMDB brought the total Aircraft weight to within the permissible limit at the time of the Accident.

The Aircraft ramp weight of 2,100 kg, as recorded by the Commander in the Aircraft technical logbook page at OMSJ, could not be verified by the Investigation. Even with three occupants, the Aircraft's ramp weight was approximately 2,250 kg. Therefore, the Investigation determines that the recorded ramp weight was an estimate rather than the result of an accurate weight and balance calculation by the Commander.

The Investigation could not determine why the Commander underestimated the ramp weight and why he did not identify that the maximum take-off weight was exceeded when the fourth person was allowed to board. It is therefore recommended that the Operator change their weight and balance procedures to formally request a weight and balance report from commanders prior to every flight, to ensure that a record exists to verify aircraft operation within the permissible weight and balance range.

2.9 The Failure of the Emergency Locator Transmitter

In 2017, a loss of control resulted in an aircraft accident involving a Diamond DA42, in which the emergency locator transmitter system was sufficiently damaged to inhibit the transmission of a signal. In this investigated Accident and in the 2017 DA42 accident, the aircraft impacted the ground but the ELTs did not activate to transmit a signal to the emergency and rescue authorities.

Any delay in identifying an aircraft accident and its location can significantly reduce the chances for survival of injured occupants.

It can be reasonably expected that any aircraft impact with terrain may severely damage the aft fuselage of an aircraft. This will most probably damage the current ELT system and prevent it from activating, as occurred in this Accident.

The Investigation recommends that the ELT installation on Diamond DA62 aircraft be reviewed in order to improve the crashworthiness of the system during an accident.

2.10 The Operator's Safety Management System

The Operator established a safety management system as described in the FCSL *SMS Manual*. According to this manual, the company directors have the final accountability for all safety issues. In the interview with the CEO, it was established that he delegated his SMS accountability and responsibility to operational managers.

The CEO referred to his role as a "financial director" who had no role in the SMS, and he excluded himself from all SMS functions. The director responsible for flight operations was acting as Safety Manager and had been designated as the accountable manager for the SMS. During the review of the SMS manual and the interview with the CEO, the Investigation noticed that the described procedures and the day-to-day management of the Operator's SMS did not align.

The Operator's *Aviation Safety Policy and Objective* formally recognizes that aviation is a potentially high-risk industry requiring a positive approach to the management of safety. It pledges its commitment to the introduction of a formal SMS to enable the identification of hazards, the analysis of risks and implementation of appropriate defenses. While the SMS manual stated that the organization would work closely with the Civil Aviation Authority of the United Kingdom (UK CAA) to seek guidance and advice, no such interaction has been recorded. The Investigation found that the Operator had documented procedures in place that portray a higher standard than was present and required for the type of service provided.

The Investigation found that some SMS functions, such as reporting of occurrences or a verbal risk assessment, were present within FCSL. However, the management's attitude towards the SMS, the delegation of safety accountabilities and responsibilities, non-conformances with SMS procedures, did not ensure the effective management of safety.

The Investigation found that this complex operation with non-complex aircraft, and with a pilot population consisting primarily of general aviation pilots and flying school graduates, was relying on guidance and oversight from the UK CAA, to establish and maintain a safe operating environment. It appears that since commencement of the operation in 2005, the lack of such guidance had not been identified. It is therefore recommended that the UK CAA conduct a baseline assessment of the operational risks, and conduct a thorough compliance and safety audit of the Operator's SMS and operational procedures.

2.11 EASA Part-SPO *Specialized Operation* and Declaration Information

In order for national civil aviation authorities to assess operational risks and to monitor ongoing safety performance of any commercial operation, it is necessary to have an effective system in place. This process commonly begins with a baseline compliance assessment and continues with ongoing oversight audits. To make an informed decision, this baseline assessment requires sufficient information about the type of operation, the organizational structure and supporting manuals and procedures.

EASA's regulations are not intended to approve commercial specialized operations under EASA Part-SPO *Specialized Operation*. However, the information requested by an online declaration process is primarily collecting administrative information and is not adequate to determine probable operational risks. National civil aviation authorities adopting EASA's requirements may therefore not be sufficiently equipped to conduct informed safety assessments of commercial specialized operations.

The Investigation finds that, while it is the responsibility of each national civil aviation authority in the European Union to ensure that a process is in place to sufficiently understand operational risk, it is the responsibility of EASA to provide sufficient guidelines to enable this process. It is therefore recommended that EASA review their processes to register commercial specialized operators under EASA Part-SPO *Specialized Operation*.

2.12 UK CAA Oversight Program for under EASA Part-SPO

The Civil Aviation Authority of the UK adopted EASA's requirement for information provided by operators' declarations for the specialized operations category, EASA Part-SPO. This limits the UK CAA's ability to effectively manage risks associated with commercial specialized operations.

Operators in the UK under this category can legally provide commercial services, within the UK or internationally, once the declaration fee is paid. An accountable manager officially declares that the management system documentation including the operations manual reflect the applicable Part-SPO requirements, that all flights will be carried out in accordance with the procedures and instructions specified in the operations manual, and that all flight crew members, are trained in accordance with the applicable requirements.

The UK CAA inspector responsible for an operator's declaration may request additional information, if required. However, the UK CAA advised that on-site audits of an operator under Part-SPO may not be conducted for up to four years from the date of declaration. It was the UK CAA's experience that during this period of time, some operators may no longer have been providing aviation services, thus having provided commercial services without oversight.

The Investigation is concerned that the process adopted by the UK CAA, reflected a self-regulating approach for a sector in the commercial aviation service industry, which was not adequately developed. This approach lacks the regulatory and safety oversight that is expected by the public and organizations requesting these services within the UK or internationally.

When the Operator extended their aviation activities beyond UK borders, the General Civil Aviation Authority of the UAE requested a no-objection statement from the UK CAA, as they relied on the UK CAA's understanding and regulatory oversight of the Operator.

The Investigation finds that it is the responsibility of each national civil aviation authority to ensure that a process is in place to sufficiently understand risks associated with a registered operation, and therefore recommends that the UK CAA review their processes to register and continuously monitor commercial operations under EASA Part-SPO *Specialised Operations* in the UK.

2.13 UK CAA Post-Accident Audit

As a result of the Accident, the UK CAA conducted a one-person, one-day oversight audit of the Operator on 30 July 2019. The Air Accident Investigation Sector of the United Arab Emirates issued a Preliminary Investigation Report on 20 June 2019, which provided basic factual information as was evident at the time. The 'History of Flight' section of the Preliminary Report provided information regarding the identified self-separation issues between the DA62 and the preceding Airbus A350. However, the scope of the audit was not relevant to the known factual information contained in the Preliminary Report. Instead, the audit report stated that "Generally, there were good procedures in place and the company is active in developing new equipment for flight calibration."

The audit identified a total of 18 Level Two findings, including 16 findings of issues related to the content of the *Operations Manual*. A review of these issues identified that they were most likely already present when the Operator filed the initial declaration for EASA Part-SPO in 2017 and during six declarations which were re-filed since then.

The Investigation is concerned about the UK CAA approach to accepting commercial UK aviation service providers, and their conduct of regulatory oversight of operations under EASA Part-SPO *Specialised Operations*. The July 2019 audit appears to have been the CAA's first oversight activity since the Operator started operation in 2005. Although a fatal Accident occurred, minimal resources were deployed for an audit scope that resembled a baseline audit. The auditor's acceptance of missing procedures, missing forms, and incomplete hazard logs reflected an inappropriate reaction by the UK CAA to the fatal Accident and the inherent risks of the operation.

2.14 Airborne Recording Systems

Due to its weight category, the Aircraft was not fitted with an audio or flight data recorder. The severity of the Accident and the damage to aircraft components prevented the recovery of any data from recorded Aircraft system media. This provided the Investigation with the challenge of collecting evidence from other sources to identify the most probable cause of the loss of control.

An airborne image and audio recording system would have provided the Investigation with certainty about which pilot was in control of the Aircraft. Recorded images and audio could have been used to identify the trans-cockpit gradient, provided information on the flight crew's state of mind during the mission, showed the actual workload during normal approaches and during the wake vortex encounter, recorded any distractions and the flight crew's reactions to the wake vortex encounters, recorded conformance with company procedures, and would have recorded any other factors that may have contributed to the Accident.

A safety recommendation addressed to the General Civil Aviation Authority of the United Arab Emirates in 2016 recommended the installation of a video recording system for commercial hot air balloon operations. These recordings have been instrumental in the identification of balloon accident causes in the United Arab Emirates, where the accidents often occurred at remote locations.

It is recommended that the General Civil Aviation Authority of the United Arab Emirates (GCAA) require airborne image and audio recording systems for specialized commercial operations.

2.15 Flight Plan and Number of Persons Onboard

Prior to departure for the calibration flight, the Commander informed ATC that the number of persons onboard was four. There was no reason for ATC to verify that this information was consistent with the filed flight plan. It was the responsibility of the Commander to provide a change message or to re-file the flight plan should flight information change.

As a result of this omission, the search and rescue responders were provided with inconsistent information from the flight plan regarding the number of occupants of the Aircraft.

The Investigation could not determine why the Commander did not provide the updated information to ATC when the additional person boarded the Aircraft prior to departure from OMDB.

3. Conclusions

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 organization or individual.

- **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 occurring, or mitigated the severity of the consequences of the Accident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 Findings relevant to the Aircraft

(a) The Aircraft was certified, equipped, and maintained in accordance with the existing requirements of the *Civil Aviation Regulations* of the European Union Aviation Safety Agency (EASA) and the Civil Aviation Authority of the United Kingdom (UK CAA).

(b) The Aircraft was manufactured in November 2017 and had accumulated a total of 720 hours and 337 flights.

(c) The Aircraft underwent maintenance prior to the positioning flight from OMSJ to OMDB.

(d) A deferred defect related to unserviceable auxiliary fuel tank gauges was recorded in the *Acceptable Deferred Defects Record*.

(e) The onboard reference pages to the *Airplane Flight Manual* had not been revised and were out of date.

(f) An onboard flight data recording system was not required to be fitted to the Aircraft.

3.2.2 Findings relevant to the flight crew and flight operation

(a) The flight crewmembers were licensed and qualified for the flight in accordance with the existing requirements of the *Civil Aviation Regulations* of the UK CAA.

(b) The flight crewmembers were well-rested prior to the flight.

(c) The Commander was most likely the pilot in control of the Aircraft.

(d) The Commander did not file a new flight plan, but informed ATC verbally about the number of persons onboard prior to taxiing at OMDB.

(e) The Aircraft took off from OMDB with a higher than permissible maximum take-off weight.

(f) The Aircraft's center of gravity during takeoff could not be determined.

(g) On the positioning flight from OMSJ, the flight crew elected to remain above the approach path of the preceding air traffic.

(h) According to international standards, separation from other traffic during VFR flights is provided by the commander.

(i) On the approaches during the VFR calibration flight, the self-separation to other air traffic was less than the ICAO recommended IFR wake turbulence separation, and less than the increased separation provided by ATC.

3.2.3 Findings relevant to the Operator

(a) The Operator's flight inspection service was approved by the UK CAA for the purpose of inspecting air traffic service equipment within the United Kingdom.

(b) As a provider of a UK CAA-approved flight inspection service, the Operator used approved flight inspection equipment, software, operating instructions, and aircraft types.

(c) The Operator filed an online declaration with the UK CAA for commercial calibration flights in 2017, in accordance with EASA Part-SPO.

(d) According to the Operator's information, the company had been a UK CAA-approved flight inspection organization since 2005.

(e) It could not be confirmed by the Investigation that the UK CAA had audited the Operator's flight operation activities and procedures prior to the Accident.

(f) An audit of the Operator following the Accident identified 18 Level Two findings, not relevant to the circumstances of the Accident.

3.2.4 Other findings

(a) The online declaration application facilitated by the UK CAA, based on EASA Part-SPO, did not provide sufficient information for the UK CAA to establish a relevant risk profile for the Operator's activities.

(b) Wake vortices from the A350, recorded by the LIDAR station DXB2, had drifted into the approach path of runway 30L at the time of the DA62's loss of control.

3.3 Causes

The Air Accident Investigation Sector of the United Arab Emirates determines that the Accident was due to an in-flight loss of control during the approach to runway 30L caused by an encounter with wake vortices generated by a preceding Airbus A350-900 aircraft, which was approximately 3.7 nm and 90 seconds ahead on the approach to runway 30R.

3.4 Contributing Factors to the Accident

The Investigation identified that the Commander's decision to reduce the self-separation from preceding air traffic during approaches to runway 30R, and wind conditions in which the wake vortices from the approach path to runway 30R drifted across into the approach path to runway 30L, were contributing factors to the Accident.

The Operator lacked an effective safety management system, which prevented the identification of operational hazards during calibration flights, in particular calibration flights carried out at airports during times when more than one runway is in operation.

The UK CAA did not exercise effective oversight of the Operator. This prevented an informed baseline assessment of operational risk, and resulted in the Operator providing commercial aviation services without adequate regulatory involvement.

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 section 3 of this Report; the AAIS expects that all safety issues identified by the Investigation are addressed by the receiving States and organizations.

4.2 Prompt Safety Recommendation to the General Civil Aviation Authority of the United Arab Emirates (GCAA)

As a result of the initial investigation, and based on the likelihood that a wake turbulence encounter due to close proximity between the DA62 and the preceding A350 aircraft contributed to the accident, the Investigation issued a prompt safety recommendation PSR 01/2019 to the General Civil Aviation Authority on 23 May 2019 which states that:

> "The General Civil Aviation Authority issue a safety alert to all air navigation service providers in the United Arab Emirates and to all operators of light aircraft, to enhance awareness among pilots and air traffic controllers of their separation procedures, particularly under visual flight rules."

Safety Alert 2019-03 - *Non-Routine Operations for ANSPs and Aircraft Operators*, was issued on 4 November 2019 to satisfy this recommendation.

4.3 Safety Actions Taken

4.3.1 Safety actions taken by dans and Dubai Airports

As a result of the Accident and the initial findings, dans and Dubai Airports continued the calibration flights in May 2019 in a sterile airport environment, where only other VFR aircraft in a lower or the same wake turbulence category, were permitted to operate.

Meetings with stakeholders were recorded and acknowledged by all participants.

A 4-minute separation was applied to departing and arriving IFR aircraft, with information provided on the aircraft wake turbulence category and a caution of possible wake turbulence.

Flight Calibration Services Limited (FCSL) was required to provide a safety assessment and concept of operations to dans, which included all calibration activities.

4.3.2 Safety actions taken by Flight Calibration Services Limited

As a result of the Accident, FCSL contacted all company pilots to raise their awareness of minimum self-separation criteria as detailed in a Eurocontrol document titled *European Wake Turbulence Categorizations and Separation Minima on Approach and Departure*.

A training course on wake turbulence effects during takeoff and landing, and practical upset recovery training was developed.

4.3.3 Safety actions taken by the Civil Aviation Authority of the United Kingdom (UK CAA)

As a result of the UK CAA's own audit of its oversight work, the UK CAA has reviewed the working processes to assess operational risks of newly declared SPO operators and are in the process of changing how it verifies the operators' continued compliance with the applicable requirements in accordance with EASA Air Operations Regulation ARO.GEN.300 Oversight (a)(2).

The UK CAA reviewed and are in the process of changing the online declaration form to include more information in order for the inspector to better assess the complexity and operational risks posed by the operator.

General Aviation Part-SPO operators and processes were reviewed to include an added assessment of complexity and an audit during the first 12 months from the date of declaration for new operators. Those operators who have already declared and are not already known to the UK CAA in terms of other oversight functions, will be subject to an on-site audit over the next 12 months.

FSCL's operation was re-assessed as 'high complexity' and will require an audit by the UK CAA every 12 months. The UK CAA received responses from FSCL to the audit findings. Sixteen of the eighteen findings were viewed as sufficiently rectified and closed. The next on-site audit was scheduled for July 2020.

4.4 Final Report Safety Recommendations

The Investigation identified that FCSL conducted flight calibration services since 2005 under the Aerial Work category, and under EASA Part-SPO *Specialised Operations* since 2017. According to EASA Regulations, the UK CAA was not required to issue an approval for operations under this category. The UK CAA accepted an online declaration. However, the UK CAA was responsible for the oversight of commercial aviation operators in the United Kingdom, to ensure that management commitment to safety supported a safe operation.

The information provided in the online declaration was not adequate to determine probable operational risks in the FCSL operation. Furthermore, it could not be established if FCSL had been subjected to a UK CAA audit of their flight operation between 2005 and the time of the Accident. The post-Accident audit revealed 18 Level Two findings. However, no findings related to the FCSL's understanding of, and attitude towards, the safety management system (SMS) were documented.

The provision of air traffic information and essential local air traffic information to all air traffic, including the provision of cautionary warnings of possible wake turbulence is a critical aspect in supporting flight crew to maintain their situational awareness. This is particularly important during times of high workload and may remind flight crewmembers to identify any overlooked wake turbulence hazards.

As an interim initiative, dans and Dubai Airports completed the calibration flights in a sterile airport environment, introduced a 4-minute separation between the calibration aircraft and heavier departing and arriving IFR aircraft, and requested a safety assessment from FCSL. Some of these initiatives should be considered as permanent policy to ensure that future calibration flights are conducted in a safe environment.

The Aircraft was not required to be fitted with an onboard recording system, which could have provided the Investigation with critical initial information about the circumstances of the Accident flight. An airborne image and audio recording system would have provided a high degree of certainty in key aspects of the Investigation into this Accident.

The loss of the emergency locator transmitter system due to impact damage prevented the transmission of a signal to the emergency and rescue authorities. While this Accident was not survivable, the opportunity should not be lost to identify any deficiencies in the crashworthiness of the emergency locator transmitter system, because any future delay in identifying an aircraft accident and transmitting its location, can significantly reduce the chances for survival of injured occupants.

Therefore, the Air Accident Investigation Sector of the United Arab Emirates recommends that:

4.4.1 The European Union Aviation Safety Authority (EASA)

SR47/2020

Review the requirements to register commercial operations under EASA Part-SPO *Specialised Operations*, to ensure that national civil aviation authorities, adopting these requirements, are provided with essential applicant information to enable an effective initial assessment of potential operational risks.

SR48/2020

Introduce regulation requiring airborne image and audio recording systems in commercially operated light aircraft.

4.4.2 Flight Calibration Services Limited (FCSL)

SR49/2020

Conduct a comprehensive review of the safety management system (SMS), and improve the system accordingly to assure:

(a) a provision of feedback on the SMS effectiveness is contained within the system capabilities,

(b) that specific roles are designated to specific personnel to manage the SMS with clear responsibilities and accountabilities, and

(c) that the SMS is fully supported by the FCSL accountable manager and the management team.

SR50/2020

Conduct a comprehensive review of the effectiveness of FCSL's pilot training with the aim of improving pilot competency in crew resource management and human factors with particular attention to pilot decision-making.

4.4.3 The Civil Aviation Authority of the United Kingdom (UK CAA)

SR51/2020

Improve the working processes to assess operational risks of newly declared EASA Part-SPO operators, and to verify continued compliance with the applicable requirements in accordance with EASA Air OPS ARO.GEN.300 Oversight (a)(2).

SR52/2020

Conduct a baseline assessment of the operational risks, and a thorough compliance and safety audit of FCSL's safety management system, flight operations, pilot training, weight and balance procedures, and documented procedures for calibration flights.

4.4.4 Dubai Air Navigation Services (dans)

SR53/2020

Review and enhance the air traffic services manual and other relevant instructions that require air traffic controllers to consistently provide essential traffic information, including wake turbulence advice, to arriving and departing air traffic.

SR54/2020

Review and enhance existing procedures for calibration flights to mitigate risk of wake turbulence encounters.

4.4.5 Dubai Airports

SR55/2020

Review and enhance existing risk assessment and mitigation measures for calibration flights. The review should consider the possibility of inhibiting air traffic operations during calibration flights as a mitigation action.

4.4.6 The General Civil Aviation Authority of the United Arab Emirates (GCAA)

SR56/2020

Ensure that air navigation service providers in the United Arab Emirates review working processes for air traffic controllers to consistently provide air traffic information, including wake turbulence advice, to arriving and departing air traffic.

SR57/2020

Ensure that air navigation service providers in the United Arab Emirates review working processes for calibration flights at airports to ensure that the risk of wake turbulence encounters is mitigated.

4.4.7 Transport Canada

SR58/2020

Conduct a safety study of the crashworthiness of the emergency locator transmitter (ELT) system installation on the Diamond DA62, and apply the necessary improvements identified to ensure that the system functions as intended by the aircraft design standards.

This Investigation Report is issued by:

The Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

Email: aai@gcaa.gov.ae

5. Appendices

5.1 Appendix A: Flight Plan

FLIGHT PLAN

PRIORITY: <<≡ FF →
ADDRESSEE(S): <<≡

FILING TIME → ORIGINATOR <<≡

SPECIFIC IDENTIFICATION OF ADDRESSEE(S) AND/OR ORIGINATOR

3 MESSAGE TYPE: <<≡(FPL
7 AIRCRAFT IDENTIFICATION: - V O R 0 8
8 FLIGHT RULES: - V
TYPE OF FLIGHT: G <<≡

9 NUMBER: - 1
TYPE OF AIRCRAFT: D A 6 2
WAKE TURBULENCE CAT: / L
10 EQUIPMENT: - SDFGRWY/B1D1L <<≡

13 DEPARTURE AERODROME: - O M D B
TIME: 1 4 0 0 <<≡

15 CRUISING SPEED: - N 0 1 6 0
LEVEL: V F R
ROUTE: → DCT

)<<≡

16 DESTINATION AERODROME: - O M D B
TOTAL EET (HR MIN): 0 2 0 0
ALTN AERODROME: →
2ND ALTN AERODROME: → <<≡

18 OTHER INFORMATION

-PBN/A1B2C2D2L1S1S2 DOF/190516 OPR/FLIGHT CALIBRATION SERVICES RMK/CREW CONTACT [redacted] FILED BY [redacted] PER/B
REG/GMDME STAYINFO1/IDBW0100 STAYINFO2/IDBE0100
)<<≡

SUPPLEMENTARY INFORMATION (NOT TO BE TRANSMITTED IN FPL MESSAGES)

19 ENDURANCE
HH MIN: -E/ 0 5 4 5
PERSONS ON BOARD: →P/ 0 0 3
EMERGENCY RADIO: →R/ UHF X, VHF X, ELT

SURVIVAL EQUIPMENT: → X
POLAR: / X
DESERT: X
MARITIME: X
JUNGLE: X
JACKETS: →
LIGHT: / X
FLUORES: X
UHF: X
VHF: X

DINGHIES: → X
NUMBER: →
CAPACITY: →
COVER: X →
COLOUR: <<≡

AIRCRAFT COLOUR AND MARKINGS
A/ WHITE WITH ORANGE NOSE

REMARKS
→ N/ Crew Contact Number [redacted] <<≡

PILOT IN COMMAND
C / [redacted] <<≡

FILED BY

SPACE RESERVED FOR ADDITIONAL REQUIREMENTS

(FPL-VOR08-VG
-DA62/L-SDFGRWY/B1D1L
-OMDB1400
-N0160VFR DCT
-OMDB0200
-PBN/A1B2C2D2L1S1S2 DOF/190516 OPR/FLIGHT CALIBRATION SERVICES RMK/CREW CONTACT [redacted] FILED BY [redacted] PER/B
REG/GMDME STAYINFO1/IDBW0100 STAYINFO2/IDBE0100
-E/0545 P/003 R/E A/WHITE WITH ORANGE NOSE N/CREW CONTACT NUMBER [redacted])

PAGE 1 OF 1 GENERATED: 05:37 UTC 16 MAY 2019 FLIGHT DOC REF#: 2255429 WWW.ROCKETROUTE.COM
THE PILOT IN COMMAND MUST VERIFY CORRECTNESS OF THIS INFORMATION. ROCKETROUTE ACCEPTS NO RESPONSIBILITY FOR ACCURACY OR COMPLETENESS

5.2 Appendix B: EASA OPS Declaration

Civil Aviation Authority

EASA-Ops Declaration

Tracking Code:

APPLICANT DETAILS

Applicant Details

Applicant Type *

COMPANY DETAILS

The Applicant is the person responsible for payment of CAA charges. This application will be considered in respect of and, if appropriate, granted to, the Company Name as registered under the Company Number provided on this form.

Registered Address

Registered Company Name *

Registered Company Number *

Country of Company Registration

Country Code of Company Registration

Trading Name

Country

Country Code

5.2 Appendix B: EASA OPS Declaration - Page 2

Address Line 1 *

Address Line 2

Address Line 3

Address Line 4

Address Line 5

County *

Postcode *

Trading Address

Do you have a Trading address? *

◯ Yes ◯ No

Contact Details

Telephone * | Mobile Telephone | Fax

Email *

Website

Authorised Representative of Company

This application is to be submitted by either a Director or Company Secretary or a person authorised by the Board to act on behalf of the Company.

Name

Title *

Forename * | Surname *

5.2 Appendix B: EASA OPS Declaration - Page 3

Position *

Telephone *

Email *

Primary Contact

Please give details for the Primary Contact *

Correspondence Address

The following address shall be used for correspondence. Please amend if a different address is to be used for correspondence.

Country

Country Code

Address Line 1 *

Address Line 2

Address Line 3

Address Line 4

Address Line 5

County *

Postcode *

Change Correspondence Address *

◯Yes ◯No

5.2 Appendix B: EASA OPS Declaration - Page 4

APPLICATION

Application

Please select one of the following options, depending on whether you wish to make a new declaration, vary an existing declaration or notify the UK CAA that you are ceasing operations, or have disposed of an aircraft for which a previous declaration was made. *

OPERATOR

Operator

Please state the full Operator Name (Organisation) *

Does the Operator hold a Specific Approval for Dangerous Goods? *

◯Yes ◯No

Place at which the Operator is established or residing

Country

Country Code

Address Line 1 *

Address Line 2

Address Line 3

Address Line 4

Address Line 5

County *

5.2 Appendix B: EASA OPS Declaration - Page 5

Postcode *

Is the Place from which the Operations are to be conducted the same as the place at which the Operator is established or residing? *

◯ Yes ◯ No

Accountable Manager

Please select the Accountable Manager *

Forename *

Surname *

Telephone *

Email *

AIRCRAFT OPERATION

Aircraft Operation

Aircraft 1

Please enter the Aircraft Registration Mark *

Aircraft Make

Aircraft Model

Series

Please select the Type of Operation for this aircraft.

◯ Part-NCC ◯ Part-SPO ◯ Both

Date of declaration *

5.2 Appendix B: EASA OPS Declaration - Page 6

Please enter the Aircraft Registration Mark *

Aircraft Make

Aircraft Model

Series

Please select the Type of Operation for this aircraft.

◯Part-NCC ◯Part-SPO ◯Both

Date of declaration *

Address of the Aircraft Main Base

Country

Country Code

Address Line 1 *

Address Line 2

Address Line 3

Address Line 4

Address Line 5

County *

5.2 Appendix B: EASA OPS Declaration - Page 7

Postcode *

Specific Approvals

Please select the Specific Approvals held for the Aircraft. *

☐ Performance Based Navigation
☐ Minimum Navigation Performance Specification
☐ Reduced Vertical Separation Minima
☐ Low Visibility Operations
☐ None

Specialised Operations

State Specialised Operations authorisations held *

☐ Helicopter external loads operations
☐ Helicopter survey operations
☐ Human external cargo operations
☐ Parachute operations and skydiving
☐ Agricultural flights
☐ Aerial photography flights
☐ Glider towing
☐ Aerial advertising flights
☐ Calibration flights
☐ Construction work flights, including stringing power line operations, clearing saw operations
☐ Oil spill work
☐ Avalanche mining operations
☐ Survey operations, including aerial mapping operations, pollution control activity
☐ News media flights, television and movie flights
☐ Special events flights, including such as flying display, competition flights
☐ Animal herding and rescue flights and veterinary dropping flights
☐ Maritime funeral operations
☐ Scientific research flights (other than those under Annex II of Regulation 216/2008)
☐ Cloud seeding
☐ Aerobatic Flights
☐ Sensational Flights
☐ Other

Do you use an Alternative Means of Compliance to any of the implementing rules?

○ Yes ○ No

5.2 Appendix B: EASA OPS Declaration - Page 8

Is the aircraft registered in an EASA or non-EASA Member State? *

◯ EASA ◯ non-EASA

Continuing Airworthiness Management Organisation (CAMO)

Name of Continuing Airworthiness Management Organisation (CAMO) *

Approval Reference of CAMO *

Address of CAMO

Country

Country Code

Address Line 1 *

Address Line 2

Address Line 3

Address Line 4

Address Line 5

County *

Postcode *

☐ I declare that this aircraft holds a valid Certificate of Airworthiness and complies with Regulation (EU) No. 1321/2014 *

CHARGES

5.2 Appendix B: EASA OPS Declaration - Page 9

Charges

☐ I confirm that I have read and understand the CAA Scheme of Charges (General Aviation) *

The charge(s) required as calculated in accordance with the CAA Operating Licence Scheme of Charges (published in CAA Official Record Series 5) (www.caa.co.uk/ors5) is: *

Please note, this application will not be processed until the applicable charges have been received. By clicking on 'Yes' you are consenting to all the information contained in your application being copied to your nominated payer.

Are charges to be paid by someone other than the applicant? *

◯ Yes ◯ No

PAYMENT DETAILS

Payment Type

By what method would you like to pay the initial fee? *

If you want the CAA to quote an Applicant Reference/Purchase Order Number on your invoices please provide the reference here.

Applicant Reference/Purchase Order Number

DECLARATIONS

Declarations

False Representation Statement

i. It is an offence to make, with intent to deceive, any false representation for the purpose of procuring the grant, Issue, renewal or variation of any certificate, licence, approval, permission or other document.

Charges on Application

ii. I agree to pay the charges payable on application in accordance with the Scheme of Charges. Please note that the CAA will not process this application until payment is received.

Further Charges

iii. I agree to pay any additional charges which may become payable in respect of this application under the Scheme of Charges.

IMPORTANT

iv. Additional Charges: Where the cost of the CAA investigations exceeds the application charge payable, the applicant shall pay additional charges to recover those excess costs incurred by the CAA in accordance with the Scheme of Charges.

v. Overseas Visits: If a Member or employee of the CAA is required to travel overseas in respect of this application you are advised to read the CAA Scheme of Charges to which this application relates and the section entitled 'Additional charge where functions are performed abroad'. All expenses incurred in pursuance of this application by virtue of travelling overseas will be payable by the applicant on demand.

5.2 Appendix B: EASA OPS Declaration - Page 10

vi. Withdrawal/Cancellation of Application: In the event that this application is withdrawn by the applicant, a cancellation charge may be levied. The cancellation charge reflects the work carried out by the CAA on behalf of the applicant up to the point of cancellation. Please see the CAA Refunds Policy at www.caa.co.uk/refunds for more information. Where sufficient funds remain from the original application charge, this charge will be deducted from any refund made in respect of the application following cancellation.

vii. I hereby declare that to the best of my knowledge the particulars entered on this application are accurate. I agree to pay the charges payable on application in accordance with the Scheme of Charges, and I agree to pay any additional charges which may become payable in respect of this application under the Scheme of Charges.

☐ Check this box to confirm your understanding and acceptance of i-vii above. *

☐ I, the Accountable Manager, declare on behalf of the Operator that the Management System documentation including the Operations Manual reflect the applicable requirements set out in Part-ORO, Part-NCC, Part-SPO and Part-SPA. *

☐ I, the Accountable Manager, declare on behalf of the Operator that all flights will be carried out in accordance with the procedures and instructions specified in the Operations Manual. *

☐ I, the Accountable Manager, declare on behalf of the Operator that all flight and cabin crew members as applicable, are trained in accordance with the applicable requirements. *

I am a member of an industry standard.

◯ Yes ◯ No

☐ I, the Accountable Manager, declare on behalf of the Operator that any change in the operation that affects the information disclosed in this declaration will be notified to the competent authority. *

☐ I, the Accountable Manager, declare on behalf of the Operator that the information disclosed in this declaration is correct. *

SUBMISSION INSTRUCTIONS

Submission

Your form has been successfully submitted. Please keep a copy of this acknowledgement for your records.

Date and Time:

Application Submission Number:

To save or print a copy of the completed form and acknowledgement go to the "File" menu and select "Save as" or "Print".

Please send cheques/banker's draft (with the Application Submission Number written clearly on the reverse) and any documents to be posted to:

Civil Aviation Authority,
Ground Floor East,
Aviation House,
Gatwick Airport South,
West Sussex,
RH6 0YR

Please send documents to be posted to:

Civil Aviation Authority,
Ground Floor East,
Aviation House,
Gatwick Airport South,
West Sussex,
RH6 0YR