MINISTÈRE DU DÉVELOPPEMENT DURABLE
ET DES INFRASTRUCTURES
Département des transports

Administration des enquêtes techniques

FACTUAL REPORT

SERIOUS INCIDENT INVOLVING THE BOMBARDIER DHC-8-402, REGISTERED LX-LGG, OPERATED BY LUXAIR AND A REMOTELY PILOTED AIRCRAFT SYSTEM (RPAS) IN LUXEMBOURG ON 14 APRIL 2015

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ADMINISTRATION OF TECHNICAL INVESTIGATIONS

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FOREWORD

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 of the European Parliament and of the Council and Luxembourg amended law dated 30 April 2008 on technical investigations in relation to accidents and serious incidents which happened in the domains of civil aviation, maritime transport, railways and vehicle traffic on public roads, it is not the purpose of the aircraft accident investigation to apportion blame or liability.

The sole objective of the safety investigation and the Final Report is the prevention of accidents and incidents.

Consequently, the use of this report for purposes other than accident prevention may lead to wrong interpretations.

Note 1: All times in this report are in Coordinated Universal Time (UTC) unless stated otherwise.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

°C	Degree Celsius
AET	Administration des enquêtes techniques - Luxembourg safety investigation authority
AMSL	Altitude above mean sea level
ANA	Administration de la navigation aérienne – Air navigation administration
APP	Luxembourg approach
ASSURE	Alliance for system safety of UAS through research excellence
ATC	Air traffic control
ATS	Air traffic services
CAD	Computed aided design
CAVOK	Ceiling and visibility OK
CTR	Luxembourg control zone (vertical limits ground to 2500 ft AMSL)
DAC	Direction de l'aviation civile – Directorate of civil aviation
DAC-L	Direction de l'aviation civile du Luxembourg – Directorate of civil aviation of Luxemburg
EASA	European Aviation Safety Agency
EDDM	ICAO code for Munich Franz Josef Strauss Airport
EDFM	ICAO code for Mannheim City Airport
EGLC	ICAO code for London City Airport
ELLX	ICAO code for Luxembourg Airport
EU	European Union
FAA	Federal Aviation Administration
FE	Finite Element
ft	Foot
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rule
ILS	Instrument Landing System
KLAX	ICAO code for Los Angeles International Airport
KMIA	ICAO code for Miami International Airport
KT, kts	Knots (speed)
lbs	Pounds (mass)
LFAT	ICAO code for Le Touquet – Côte d'Opale Airport
MDDI	Ministère du Développement durable et des Infrastructures - Ministry of Sustainable Development and Infrastructure
NM	Nautical mile
NOTAM	Notice to airmen
NPA	Notice of Proposed Amendment
RPAS	Remotely piloted aircraft systems
RWY	Runway
SID	Standard Instrument Departure
TAF	Aerodrome Forecast
TWR	Luxembourg tower
UAS	Unmanned aircraft system
UK	United Kingdom
UTC	Coordinated universal time

1 SYNOPSIS

Date of the occurrence:
Tuesday 14 April 2015

Time of the occurrence:
15:55

Occurrence location:
Luxembourg Airport (ELLX), approximately 3NM from RWY24

- **Aircraft 1**

  Aircraft: Bombardier DHC-8-402

  Operator: Luxair S.A.

  Aircraft registration: LX-LGG

  Type of flight:
  Public transport of passengers
  Flight number: LG9734
  Call sign: LGL23U
  Departure: Munich – Destination: Luxembourg

- **Aircraft 2**

  RPAS: Not identified
  Operator: Not identified
  Owner: Not identified

2 FACTUAL INFORMATION

2.1 History of the flight

On 14 April 2015, the Bombardier DHC-8-402 registered LX-LGG and operated by Luxair S.A. was on an instrument flight rules (IFR) flight (number LG9734) from Munich Airport (EDDM) to Luxembourg Airport (ELLX).

On the final approach to runway 24, at a distance of approximately 3 NM from the runway threshold (area between Mensdorf and Roodt-sur-Syre) and at an altitude of 2300 ft, the aircraft experienced a near miss with a Remotely piloted aircraft system (RPAS).

The near miss occurred during daylight hours at approximately 15:55.

The crew continued the approach without performing an avoidance manoeuvre and landed the aircraft safely.

2.2 Communications and reporting

The RPAS was flying inside the Luxembourg Control Zone (CTR), which is a class D airspace from ground to an altitude of 2500 ft, controlled by Luxembourg tower (TWR). In this type of airspace, the presence of a RPAS is unexpected and generally prohibited, unless the Directorate of Civil Aviation (DAC) has granted a specific authorisation.

The LX-LGG crew immediately reported the occurrence to the TWR controller, who notified the following traffic about the likely presence of a RPAS in the approach path. The TWR also disseminated the information to the Luxembourg approach (APP) and to the police.

After the flight, the crew filed a safety report, describing the RPAS as ‘clearly seen, dark red colour, 1 m diameter, circular shape’ and reported that the estimated separation distance to the RPAS had been 20 m. The Indicated Airspeed (IAS) was about 130 kts.

Later that day, the TWR filled out an ‘Air traffic services (ATS) occurrence reporting form’ and sent it through the normal occurrence reporting channel to the DAC at 17:18.

The police could not localize the drone or identify the operator.

2.3 Additional information

On 17 April 2015, a meeting was held at Luxair Safety Department with representatives from the Administration des enquêtes techniques (AET), the Direction de l'aviation civile (DAC), the Administration de la navigation aérienne (ANA) and Luxair S.A. The captain of the occurrence flight was present too. The following topics were discussed:

- The presence of an unidentified RPAS in a controlled airspace and in the vicinity of an airport.
- The lack of national and EU regulation to frame the private and commercial operations of Remotely piloted aircraft system (RPAS).
- The captain's statement that the flight crew was not prepared to respond to this type of near miss and did not attempt an avoidance manoeuvre.
- The captain's intention to file a police complaint, considering the event as "endangerment of the lives of others".
- The decision of the AET to open a safety investigation.
- A communication campaign by the Ministry of Sustainable Development and Infrastructure (MDDI) to inform the public about the hazards linked to the operations of RPAS.

Note: On 5 June 2015, the minister of the MDDI presented, in cooperation with the DAC and the ANA, the best practices as regards using RPAS in Luxembourg. At this occasion, a "code of good conduct" and a press file were published on the website of the government[1].

2.4 Meteorological information

The aviation weather forecast by ANA on the occurrence day was as follows:

Aerodrome Forecast (TAF) of 14 April 2015 at 14:00:
20009KT CAVOK (Ceiling and visibility OK)

The visibility at the time of the occurrence was good.

2.5 Near misses between aircraft and drones since the date of the occurrence

Near misses with drones notified by operators based in Luxembourg or near misses which occurred in Luxembourg are summarised in the Table 1 below.

[1] Link to the government web page:
https://dac.gouvernement.lu/fr/actualites.gouvernement%2Bfr%2Bactualites%2Btoutes_actualites%2Barticles%2B2015%2B06-juin%2B05-drones-aeromodeles.html

Location	UTC date	Aircraft model	Occurrence Report
EGLC[2]	19/04/2015	BOMBARDIER DHC-8-402	On approach to RWY 09, the flight crew had a near miss with a drone flying at the same altitude of 2000ft. It was of black and white colour with some letters on it. Both crewmembers agreed on the fact that the second letter was an X. It passed on the copilot's side and might have been flying stationary. The crew immediately reported the presence of a drone to Thames Radar. On the ground, the crew informed the tower. Before disembarkation, the captain asked the passengers if someone had seen a drone and could provide more information.
ELLX	21/08/2015	PIPER PA28	When approaching the VFR exit point Carly at 2000ft, a remote controlled aircraft doing a loop left of the aircraft's track (same altitude) was spotted by the flight crew. ATC was informed.
KMIA	29/11/2015	BOEING 747	On approach to RWY 09 in VMC, a small drone, glider or balloon approached the aircraft head on and passed approximately 150m to the left and 100ft below. The aircraft was at 4400ft descending on the RNAV glide path. It was too late for an avoidance manoeuvre. ATC and police were informed.
EGLC	06/12/2015	BOMBARDIER DHC-8-402	At approximately 1.5 Nm on final RWY 27, in VMC, and at an altitude of 1000ft, both pilots saw a big red/black drone at same altitude, between 50m and 100m away from them. The event was reported immediately to ATC. The next aircraft in the approach sequence reported the same occurrence. During the turnaround, a police officer came to the airplane to get more details.
EGLC	30/12/2015	BOMBARDIER DHC-8-402	During the right hand base turn, at 6NM on final approach for RW09, the flight crew spotted a drone at the same altitude. The drone's position was at 3 o'clock within 500m. ATC informed. Occurrence reported to police on ground.
ELLX	13/09/2016	FOKKER F28	The pilot observed a drone at 4000ft, very close to his flight path on right base leg RWY06. He contacted APP to report the occurrence and then provided further description of the drone to TWR after landing.
KLAX	12/05/2017	BOEING 747	On the ILS for RWY 25L at point FULER at 6300ft, both pilots spotted a drone approaching head on in very close proximity to the aircraft. ATC was informed immediately.
East of Esch-sur-Alzette (L)	23/05/2017	ROBINSON R44	East of Esch-sur-Alzette (L), outside the CTR, at an altitude of 2000ft, the helicopter crossed a drone at the same altitude in the opposite direction, at a distance of less than 200 meters. Information was transmitted to ATC on ELLX TWR frequency 118.1.
KLAX	27/08/2017	BOEING 747	During the ILS approach to RWY 25L the flight crew had a near miss with a large drone. While descending through 12000ft between the fixes CRCUS and KRAIN, a bright red drone was briefly visible below the aircraft's nose. The flight crew estimated a distance of 100ft. Crew informed ATC.
EGLC	06/09/2017	BOMBARDIER DHC-8-402	The aircraft was on departure, midway between LCW01 and LCN02 on the EKNIV1A SID, when the third pilot, seated in the observer position, saw a DJI Mavic type drone. It was pointed out to and seen by the captain and the copilot. No avoiding action was required as the drone was below the aircraft. The reported separation was: 100ft V/30-100m H. A report was made to Thames Radar.

[2] A report has been published by the UK Airprox Board about the occurrence dated 19 April 2015 in EGLC, reference 2015049 under the following link:
http://www.airproxboard.org.uk/Reports-and-analysis/Airprox-reports-2015/

Location	UTC date	Aircraft model	Occurrence Report
ELLX	02/12/2017	BOEING 747	The aircraft was established on the localizer for RWY 06, shortly prior passing WLU, when the crew reported a drone heading in opposite direction, estimated 300-400 ft below. (Shortly thereafter LXAIE, initially planning to perform an ILS approach to RWY 06, cancelled IFR and proceeded visually towards the field in order to stay clear of the drone.) The crew informed TWR and called police via 113 to provide position information about the drone activity.
KLAX	10/04/2018	BOEING 747	While descending through 12000ft between the fixes CRCUS and KRAIN, the crew saw a bright red drone briefly below the aircraft's nose. The crew informed.
EDFM	11/04/2018	MD HELICOPTERS MD900	On a direct approach to EDFM, about 1 NM on final to RWY 09, the medical crew reported a drone, possibly a DJI Phantom II, approximatively five meters below on the left side (horizontal distance about two meters). The drone had not been noticed by the pilot. The occurrence was reported immediately via radio to the tower controller who forwarded the information to the police. After landing the crew went to the local police office at the airport where the incident was officially reported.
Wanquetin (F)	06/05/2018	Robin DR400-180 Regent	On a flight from LFAT to ELLX, in the area near Wanquetin (F) 5NM South West of the town of Arras (F), and at an altitude of 5500ft, the pilot had a near miss with a white and blue drone, which he passed at maximum 2 meters at a ground speed of 115kts. The size of the drone was approximately 20x20cm. The pilot informed Lille Info 126.475 immediately.

Table 1: Near misses between aircraft and drones since the date of the occurrence, source: ECCAIRS database. (The text of the column "occurrence report" has been edited for better understanding.)

2.6 Regulations on RPAS

At the time of the occurrence, there was no national regulation regarding non-commercial RPAS operations and there was no regulation regarding RPAS operations at EU level.

2.6.1 National Regulations

An authorization form for UAS and a link to the map on the government geoportal displaying the RPAS Luxembourg Airspace Restrictions chart (see 4 APPENDIX - RPAS) were published on the DAC website on 3 November 2016.

The commercial operation of a drone is considered as aerial work according to the law of the 31 January 1948 regarding air navigation and according to the Grand-Ducal Regulation of the 8 August 1985 regarding the authorizations for aerial transport. The specific requirements for this type of operation are detailed on the DAC webpage on aerial work[3]. The operation of the occurrence drone was not authorized by the DAC.

If a commercial drone operation is authorized by the DAC as aerial work, the ANA will be informed and will decide whether or not to issue a related NOTAM.

[3] Link to the DAC webpage: https://dac.public.lu/services/Espace_operateurs/travail_aerien/index.html

2.6.2 Regulations at EU level

With the steadily growing market of private, commercial and military drones, the number of reports regarding near misses with drones has increased and is likely to constitute a safety issue for aviation. EASA started to work on a draft regulation to address, amongst others, the safety aspects of RPAS operations. On 4 May 2017 EASA launched a Notice of Proposed Amendment[4], followed by a proposal to the Commission on 6 February 2018.

The proposed EASA regulation sets out the following specific objectives for the safe operation of RPAS:

- *ensure a high level of protection of sensitive areas (e.g. nuclear plants, aerodromes);*
- *develop proportionate technical requirements taking into consideration the safety risk and rapidly changing UAS technologies;*
- *contribute to a system for low-level UAS operations;*
- *ensure a proportionate and adequate level of remote-pilot competences, taking into account the new actors in the market (versus manned aviation);*
- *clarify to what extent registration and electronic identification are needed;*
- *develop a proportionate regulatory framework that takes into account special categories such as model aircraft;*
- *harmonise the UAS regulation across MSs[5] especially for cross-border UAS operations.*

2.7 Crew response

Near misses between commercially operated aircraft and drones often occur in a controlled airspace, generally prohibited for the operation of RPAS, during parts of the flight with increased workload for the flight crew and in the vicinity of airports.

The trajectory of a drone cannot be predicted. This makes it difficult for a flight crew to perform an effective avoidance manoeuvre to maintain a safe separation. In fact, the captain of the occurrence flight stated that after spotting the drone, the flying pilot was unsure whether he should react or how to react to such a near-miss.

If an avoidance manoeuvre is considered to be the safest course of action, a substantial deviation from the planned flight path is likely to ensue. In the final approach phase of a flight, such a manoeuvre may lead to the deviation from the stabilized approach criteria and a subsequent go-around can be expected.

At the time of the occurrence, the Luxair S.A. Operations Manual part B (OM-B) of the Bombardier DHC-8-402 contained non-exhaustive guidelines in the ‘Abnormal and Emergency Procedures’ chapter for dealing with consequences of unusual events, such as a mid-air collision. In the investigated case, these guidelines were not relevant, as a collision did not take place.

The crew of the occurrence flight did not perform an avoidance manoeuvre and landed safely.

[4] Link to document:
https://www.easa.europa.eu/sites/default/files/dfu/NPA%202017-05%20%28A%29_0.pdf
[5] MSs: Member States

2.8 Corrective actions by the operator

After the occurrence, two objectives were included the Luxair Airline Safety Plan 2017-2021:

- *support DAC-L and industry in development of regulations for the operation of RPAS,*
- *support DAC-L and industry in safety awareness campaign on safe operation of RPAS.*

On 27 April 2017, during a seminar about drones, Luxair held a conference to explain the safety aspects of drone operations from an airline point of view and with the aim of raising the public and users' awareness.

2.9 Research projects

Several research institutes have evaluated the effects of a mid-air collision between small RPAS and manned aircraft. Modelling and simulations were conducted and compared to the results of collision tests performed in laboratories and drop towers.

In the UK, the Department for Transport, the Military Aviation Authority and the British Airline Pilots' Association commissioned a study into the effects of a mid-air collision between small RPAS and manned aircraft.

The results showed that:

- helicopter windscreens and tail rotors can be severely damaged by collisions with a drone in several realistic scenarios;
- airliner windscreens can be critically damaged by mid-air collisions with 4 kg class quadcopter components, and 3.5 kg class fixed-wing drones with exposed metallic components at high, but realistic speeds;
- the construction of a drone can make a significant difference in the impact of a collision;
- drones can cause significantly more damage than a bird of equivalent mass at the same speed.

The report can be found under:

https://www.gov.uk/government/publications/drones-and-manned-aircraft-collisions-test-results.

Cranfield University and Virginia Tech both conducted similar studies, testing different impact speeds or modelling the damages caused by the ingestion of unmanned aircraft system (UAS) into airplane engines. These studies showed that the aircraft structures and engines are very vulnerable to a collision with a drone.

The Alliance for System Safety of UAS through Research Excellence (ASSURE) is comprised of twenty-three of the world's leading research institutions and more than a hundred leading industry and government partners. Its mission is to provide the Federal Aviation Administration (FAA) with research data to safely and efficiently integrate RPAS into the airspace with minimal changes to the current system.

ASSURE simulated collisions in different configurations (type, velocity, mass), both with regard to the aircraft and the RPAS. The main conclusions were the following:

- RPAS collisions cause greater structural damage than bird strikes for equivalent impact energy levels;

- aircraft velocities above landing speeds are considered critical for RPAS masses equal to or above 2.7 lbs[6];
- RPAS designs which incorporate energy-absorbing components (materials and/or structural features) could reduce the damage to the target aircraft;
- an airborne collision between a business jet and a 4.0 lbs[7] fixed-wing RPAS may result in a high damage severity level for the horizontal and vertical stabilizer and medium for the leading edge of the wing;
- a high damage severity level may occur for impacts to the windshield.

Regarding the scenario of a RPAS engine ingestion:

- the take-off is the worst case scenario since the fan has the highest rotational speed;
- the damage from a fixed wing RPAS ingestion is larger than from the quadcopter ingestion due to its heavier and larger core components, particularly the motor and the camera;
- the trend observed from both the quadcopter and the fixed wing ingestions is that the damage increases significantly as the ingestion moves from the centre (nosecone), to the inner blade and then to the outer blade;
- the fixed wing ingestion for the baseline take-off case results in the loss of multiple blade tips as well as damage to multiple other blades.

The study and the associated results can be found under the following link:

http://www.assureuas.org/projects/deliverables/sUASAirborneCollisionReport.php.

[6] 2.7 lbs = 1.22 kg
[7] 4.0 lbs = 1.81 kg

3 CONCLUSIONS

3.1 Findings

- The weather conditions and the visibility on the day of the occurrence were good.
- The aircraft crew could clearly see the RPAS.
- The pilot flying (PF) did not perform an avoidance manoeuvre.
- The Luxair operational documentation did not contain guidelines on how to react to a near miss with an RPAS.
- The operation of the occurrence drone was not authorized by the DAC as aerial work.
- There was no national regulation regarding non-commercial RPAS operations at the time of the occurrence and there was no regulation regarding RPAS operations at EU level.
- Several operators registered in Luxembourg notified similar occurrences at airports worldwide.
- Studies have shown that RPAS collisions and engine ingestions may cause high structural damages to airplanes and engines, which can exceed those caused by bird strikes of similar masses.
- Studies have shown that damages to aircraft resulting from collisions with RPAS could be reduced by adapting the RPAS design (materials, mass repartition).

3.2 Causal and contributory factors

- The drone has been operated without authorization in a class D airspace, close to the flight path of the aircraft.

4 APPENDIX - RPAS LUXEMBOURG AIRSPACE RESTRICTIONS