Section/division Accident and Incident Investigations Division Form Number: CA 12-58

UAS LIMITED OCCURRENCE INVESTIGATION REPORT – FINAL

Reference Number	CA18/3/2/1413						
Classification	Serious Incident		**Date**	1 June 2023		**Time**	2014Z
Type of Operation	Remotely Piloted Aircraft System – Surveillance (Part 101)						
Location							
Place of Departure	Glen Marais Warehouse, Gauteng Province		Place of Intended Landing			Glen Marais Warehouse, Gauteng Province	
Place of Occurrence	Open area at Glen Marais Warehouse, Gauteng Province						
GPS Co-ordinates	Latitude	26°03'36.24" S	Longitude	028°16'59.20" E		Elevation	5 282 feet
Aircraft Information							
Registration	ZT-YKI						
Make; Model; S/N	Arace; Sirin (Serial Number: SIR137)						
Damage to UAS	Minor			Total UAS Hours		1 046.33	
Pilot-in-command							
Licence Type	Remote Pilot Certificate		Gender	Female		Age	27
Licence Valid	Yes	Total Hours	598.63		Total Hours on Type		598.63
Total Hours 90 Days	150.0		Total Flying on Type Past 90 Days		150.0		
Injuries	None	**Injuries (on ground)**	0	**Fatalities**	0	**Fatalities (on ground)**	0
People Controlling	2						
What Happened							

On Thursday evening, 1 June 2023, two pilots were operating an unmanned aircraft system (UAS) for surveillance purposes at Glen Marais Warehouse in Gauteng province. The pilot flying (PF) was positioned in the operational room at the customers facility, and the second pilot was positioned at the UAS launch site. The flight was conducted at night under beyond visual line of sight (BVLOS) rules and under the provisions of Part 101 of the Civil Aviation Regulations (CAR) 2011 as amended.

The pilot flying (PF) stated that the UAS was launched with 99% battery power. After being airborne for 39 minutes and at approximately 200 metres (m) from the landing site, the PF activated the return-to-launch (RTL) function on the remote pilot station (controller). Upon reaching the landing site, the UAS hovered above the landing site and started a slow descent at a height of 29.6 feet (ft) (9m) above ground level (AGL). Thereafter, the pilot observed a message “potential thrust loss” on the controller screen (see Figure 4). Following this warning, the UAS entered a high rate of descent (ROD) and touched down hard on a level surface (landing site), bounced back into the air, and landed back on the landing site in an upright position. The hard landing resulted in the transponder unit dislodging from the UAS (*the transponder is a supplementary unit fitted to the UAS and is required by air traffic services when operating in controlled airspace. Part 101.05.3 of the CAR read together with the South African Civil Aviation Technical Standards [SACATS] under the same sub-heading* *require that such UAS be fitted with a mode C or S transponder*). The UAS sustained minor damage; no people on the ground were injured.

The serious incident occurred at night at Global Positioning System (GPS) co-ordinates determined to be 26°03'36.24” South 028°16'59.20” East, at an elevation of 5 282 feet (ft).

Figure 1: The yellow pin indicates the location where the UAS landed. (Source: Google Earth)

Figure 2: The transponder unit (in the yellow window) that dislodged from the UAS. (Source: Operator)

The UAS was fitted with a transponder, which was a supplementary unit to the main frame. The transponder consists of two major components (see Figure3): (i) antenna (the red device), and (ii) a transmitter/receiver (which was attached to the main frame and comprises carbon fiber with four screws). Electrical power to the transponder is drawn from the battery via a special connection.

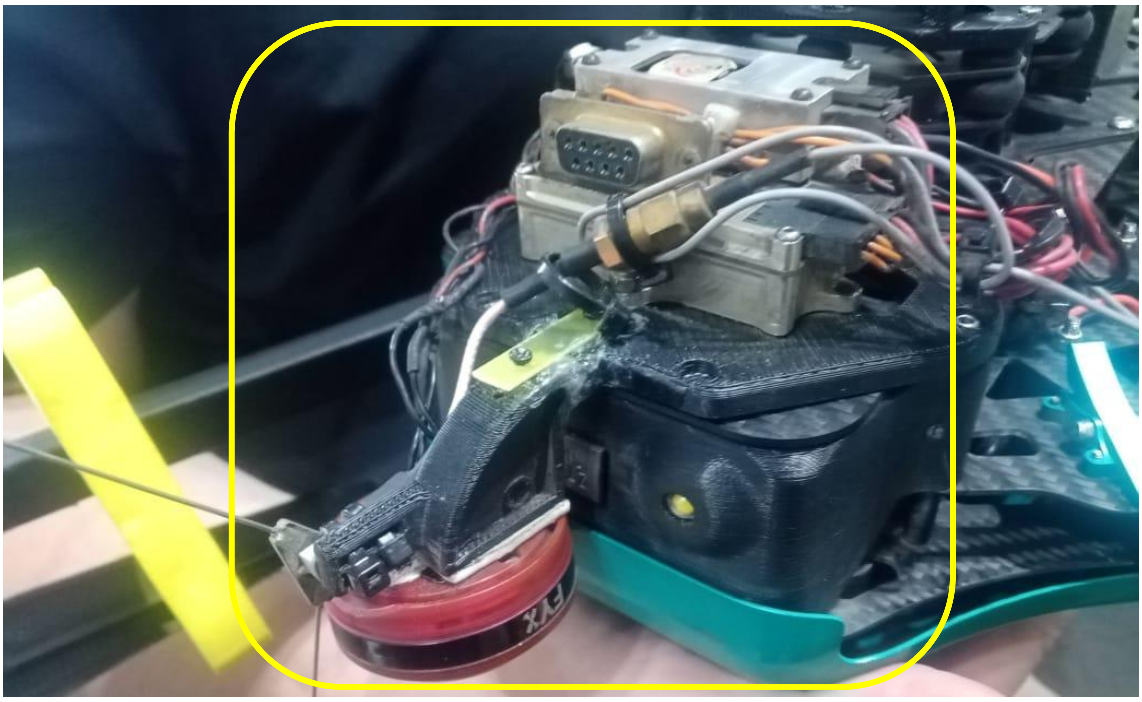


Figure 3: The transponder and antenna unit that was attached to the UAS are depicted in the yellow window. The picture was taken with the UAS in an inverted attitude. (Source: Operator)

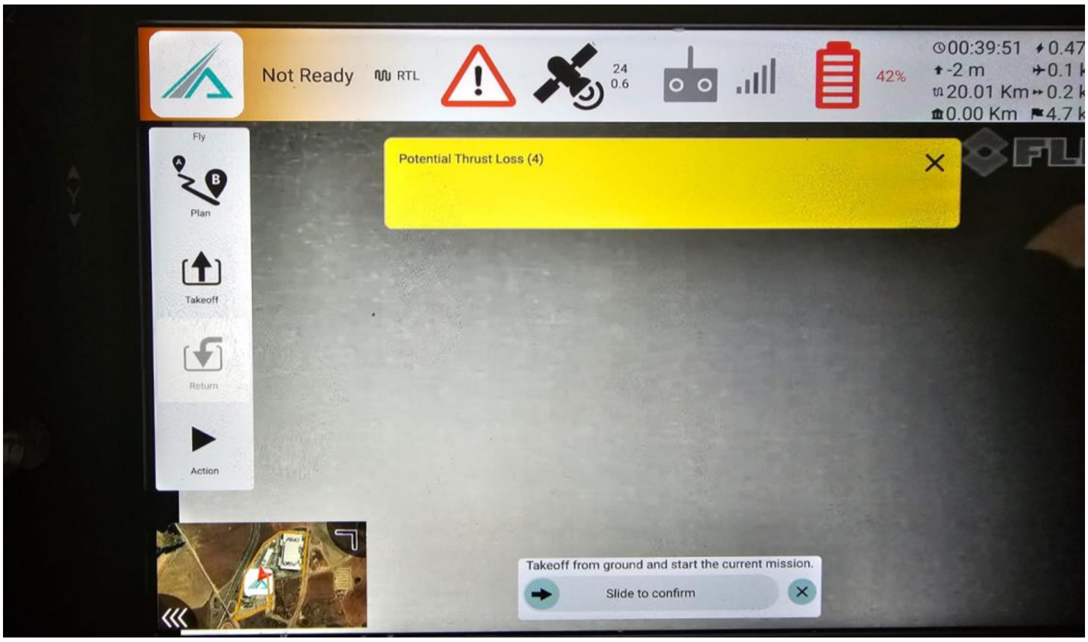
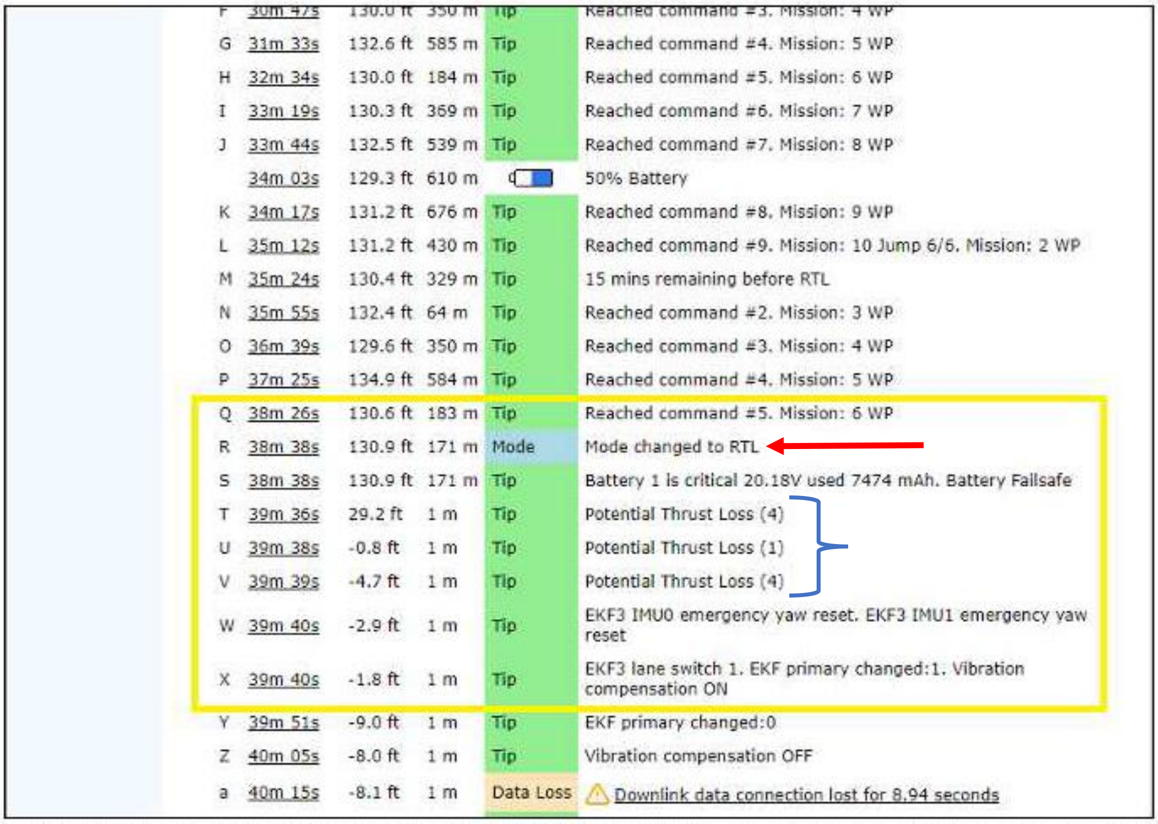


Figure 4: "Potential thrust loss" warning message displayed on the remote pilot station. (Source: Operator)



F	30m 47s	130.0 ft	350 m	Tip	Reached command #3. Mission: 4 WP
G	31m 33s	132.6 ft	585 m	Tip	Reached command #4. Mission: 5 WP
H	32m 34s	130.0 ft	184 m	Tip	Reached command #5. Mission: 6 WP
I	33m 19s	130.3 ft	369 m	Tip	Reached command #6. Mission: 7 WP
J	33m 44s	132.5 ft	539 m	Tip	Reached command #7. Mission: 8 WP
	34m 03s	129.3 ft	610 m		50% Battery
K	34m 17s	131.2 ft	676 m	Tip	Reached command #8. Mission: 9 WP
L	35m 12s	131.2 ft	430 m	Tip	Reached command #9. Mission: 10 Jump 6/6. Mission: 2 WP
M	35m 24s	130.4 ft	329 m	Tip	15 mins remaining before RTL
N	35m 55s	132.4 ft	64 m	Tip	Reached command #2. Mission: 3 WP
O	36m 39s	129.6 ft	350 m	Tip	Reached command #3. Mission: 4 WP
P	37m 25s	134.9 ft	584 m	Tip	Reached command #4. Mission: 5 WP
Q	38m 26s	130.6 ft	183 m	Tip	Reached command #5. Mission: 6 WP
R	38m 38s	130.9 ft	171 m	Mode	Mode changed to RTL
S	38m 38s	130.9 ft	171 m	Tip	Battery 1 is critical 20.18V used 7474 mAh. Battery Failsafe
T	39m 36s	29.2 ft	1 m	Tip	Potential Thrust Loss (4)
U	39m 38s	-0.8 ft	1 m	Tip	Potential Thrust Loss (1)
V	39m 39s	-4.7 ft	1 m	Tip	Potential Thrust Loss (4)
W	39m 40s	-2.9 ft	1 m	Tip	EKF3 IMU0 emergency yaw reset. EKF3 IMU1 emergency yaw reset
X	39m 40s	-1.8 ft	1 m	Tip	EKF3 lane switch 1. EKF primary changed:1. Vibration compensation ON
Y	39m 51s	-9.0 ft	1 m	Tip	EKF primary changed:0
Z	40m 05s	-8.0 ft	1 m	Tip	Vibration compensation OFF
a	40m 15s	-8.1 ft	1 m	Data Loss	Downlink data connection lost for 8.94 seconds

Figure 5: Data retrieved from the UAS flight log after the RTL mode was activated. Three "potential thrust loss" messages followed 58 seconds later. (Source: Operator)

Figure 6: The Sirin remote pilot station with the RTL buttons below the display screen.

Findings

1. Personnel Information

1.1 The PF had a Remote Pilot Certificate (RPC). The certificate was initially issued on 21 December 2021 with an expiry date of 31 December 2023. The PF had flown a total of 598.63 hours on the UAS type.

1.2 The PF had a Class 3 aviation medical certificate that was issued on 4 December 2021 with an expiry date of 4 December 2025.

1.3 The PF was certified and medically fit to conduct the flight in accordance with the existing regulations.

1.4 The second pilot had a valid RPC that was issued on 25 May 2017 with an expiry date of 31 July 2023. The second pilot had a Class 3 aviation medical certificate that was issued on 22 October 2021 with an expiry date of 31 October 2023.

1.5 None of the pilots was injured.

2. Aircraft Information

2.1 The last maintenance inspection that was carried out on the UAS prior to the incident flight was certified on 29 May 2023 at 1 033 hours and 5 minutes. Since the inspection, a further 13 hours and 28 minutes were flown.

2.2 The UAS was issued a Remotely Piloted Aircraft System Letter of Approval (RLA) on 6 September 2022 with an expiry date of 5 September 2023. The UAS was airworthy when it dispatched for the flight.

2.3 The Certificate of Registration (C of R) was issued on 18 August 2022.

2.4 According to a weighing report provided by the operator, the UAS was last weighed on 1 August 2022 with the weight recorded as 2.8kg (this weight excludes the transponder).

2.5 According to the operator, the weight of the transponder unit is 106 grams (g). The maximum take-off weight of the UAS is 2.98kg. The take-off weight on the day of the incident was 2.906kg.

2.6 Apart from the transponder unit that detached from the UAS during the hard landing, no other damage was caused to the UAS.

2.7 Flight time according to the manufacturer with high-end components fitted is as follow:

Maximum Flight time without payload – 85 minutes.

Maximum Flight time with payload – 65 minutes.

3. Weather

3.1 The weather information below was obtained from the Meteorological Aerodrome Report (METAR) that was issued on 1 June 2023 at 2030Z for O.R. Tambo International Aerodrome (FAOR).
FAOR is 8 nautical miles (nm) to the south of where the UAS was being operated.

FAOR 012030Z 21003KT CAVOK 07/02 Q1023 NOSIG=

Wind:	210°/3 knots
Temperature:	7°C
Dew point:	2°C
Visibility:	CAVOK

3.2 The density altitude at the time of the incident was calculated at 5 350ft.

4. Operator

4.1 The operator was issued an Unmanned Aircraft System Operating Certificate (UASOC) by the Regulator (SACAA) under the provisions of Part 101 of the CAR 2011 on 31 October 2022 with an expiry date of 31 October 2023.

4.2 The UAS was endorsed on the Operations Specifications that was issued by the Regulator with an effective date of 5 April 2023. The UAS is a Category A3 which can be operated at night to a maximum horizontal distance of 15 kilometres (km) and 400ft above the highest obstacle.

5. The Original Equipment Manufacturer (OEM)

5.1 The OEM facility is located in Páty, Hungary, where the elevation is approximately 656ft (200m).

5.2 According to the OEM's website (www.araceaus.com) the maximum take-off weight (MTOW) for the Sirin is 2.98kg (EU RPAS Class 2) with a maximum payload of 500g.

5.3 The operator engaged the OEM after encountering several incidents related to "potential thrust loss" over a brief period.

The OEM's feedback raised several factors:

(i) The atmospheric conditions in which the UASs are flown in South Africa differ substantially from the European conditions. The density altitude conditions in South Africa and, especially in the highveld areas, are approximately eight times higher than in the European regions.

(ii) The OEM fly UAS fitted with new batteries and new motors. Battery power (voltage) is of paramount importance to ensure optimal effectiveness of the four motors at all times. The OEM recommended that the operator limit their flight time to levels above 50% battery power.

(iii) The UAS in question was fitted with a transponder, which increased the take-off weight. The OEM does not fit any supplementary devices to their UAS.

(iv) Pilots must avoid flying in strong wind conditions.

(v) The OEM is continuously monitoring data provided to them by operators around the world and is constantly striving to improve reliability. Several of the components (i.e., the motors) are obtained from vendors and the reliability of these components are only tested during operation (when flown). One of the critical parts of a motor is the bearing, which is sourced from different vendors, although the OEM strives to use only one supplier which they had found (since they have been in production) to offer quality bearings.

(vi) The four motors fitted to the UAS have a service life of 500 hours and should be replaced thereafter.

6. <u>Transponder</u> (Source: https://www.skybrary.aero/sites/default/files/bookshelf/2711.pdf)

6.1 *A transponder is an avionic system located on-board the aircraft that provides information about the aircraft identification and barometric altitude to the air traffic control system on the ground and to traffic alert and collision avoidance system (TCAS) on other aircraft. The transponder is also used by radar on the ground to determine the position of the aircraft. The information to the radar on the ground is provided in response to an interrogation by systems such as secondary surveillance radar (SSR) or multiliterate systems. Automatic Dependent Surveillance – Broadcast (ADS-B) capable transponders also allow the aircraft to 'broadcast' information to ground stations and other aircraft without interrogation. Transponders are not* *just carried by commercial aircraft, they are also used by helicopters, military aircraft, General Aviation, gliders and UAS.*

8. <u>Vortex Ring State</u>

(Source: https://blog.uavhub.com/what-is-vortex-ring-and-how-do-i-avoid-it-with-my-drone)

8.1 *Vortex Ring affects all rotary based aircraft, including Drones. It can cause total loss of control and, ultimately, loss of the platform. Have you ever experienced this when you have been descended vertically at a rapid speed?*

It is caused by the re-circulation of air from under the rotor-disc back into the top of the disc during a rapid descent. This causes a loss of lift in the affected portion of the rotor-disc which is exacerbated as the aircraft descends more quickly.

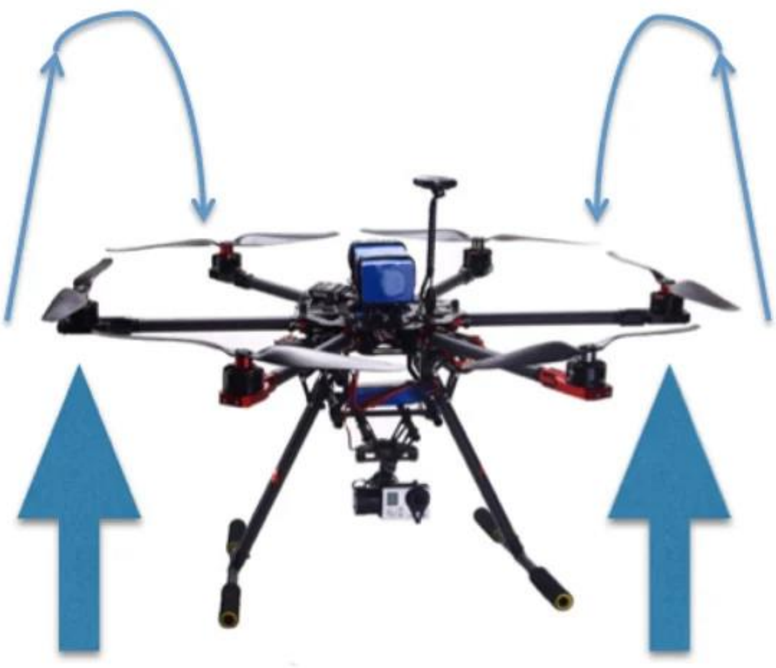


Illustration 1: The effect of vortex ring on a UAS.

8.2 *Entry Parameters for Vortex Ring*

There are a number of entry parameters that can cause you to go into Vortex Ring, these are:

- *High Rate of Descent*
- *Power Applied*
- *Little or No Forward Speed*

8.3 *Symptoms of Vortex Ring*

Usually, there are symptoms that you have entered Vortex Ring. If you experience any of these, it is likely you are in Vortex ring and you will have to take action to recover from it.

- *'Mushy' Controls*
- *Aircraft 'swaying' side to side*
- *Accelerating descent*
- *Loss of control*

8.4 How to recover from Vortex Ring

If you believe that your aircraft has entered Vortex Ring, there is a simple set of actions you can do to try and recover. You must take these actions as soon as possible.

- *Reduce Power - DO NOT APPLY THROTTLE!*
- *Gain Airspeed - Move the aircraft in any horizontal direction.*

Failure to recognise, avoid and ultimately conduct the appropriate recovery actions if required is likely to lead to total loss of your aircraft, in which case you will likely stand by helpless watching your expensive aircraft fall to the ground.

Although it may sound counter-intuitive to reduce the power when your aircraft is descending rapidly, but you need to stop 'fighting' the descent and move the aircraft away, getting some clean, un-circulated air over the blades.

Probable Cause

The rate of descent (ROD) increased substantially after the activation of the RTL mode. It is possible that during this phase of flight, the UAS entered vortex ring state (settling into its own "dirty air") which resulted in a hard landing.

Contributing Factor(s)

The UAS was operating near its maximum take-off weight, which resulted in an increase in thrust-to-weight ratio to sustain the flight.

Safety Action(s)

None.

Safety Recommendation
A substantial number of accidents and serious incidents were reported by the operator since the beginning of the year. It is recommended to the Director of Civil Aviation that an oversight inspection be conducted at the operator to find common ground for a joint corrective action plan to reduce the high accident/serious incident rate at this operation.
About this Report
The decision to conduct a limited investigation is based on factors including whether the cause is known and the evidence supporting the cause is clear, the level of safety benefit likely to be obtained from an investigation and that will determine the scope of an investigation. For this occurrence, a limited investigation has been conducted, and the Accident and Incident Investigations Division (AIID) has relied on the information submitted by the affected person/s and organisation/s to compile this limited report. The report has been compiled using information supplied in the initial notification, as well as from follow-up desk top enquiries to bring awareness of potential safety issues to the industry in respect of this occurrence, as well as possible safety action/s that the industry might want to consider in preventing a recurrence of a similar occurrence. *All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.*
Purpose
In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011 and ICAO Annex 13, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and not to apportion blame or liability.
Disclaimer
This report is produced without prejudice to the rights of the AIID, which are reserved.

This report is issued by:
Accident and Incident Investigations Division
South African Civil Aviation Authority
Republic of South Africa