UAS LIMITED OCCURRENCE INVESTIGATION REPORT – FINAL

Reference Number	CA18/2/3/10323					
Classification	Accident	**Date**	6 June 2023		**Time**	2247Z
Type of Operation	Remotely Piloted Aircraft Systems – Surveillance (Part 101)					

Location						
Place of Departure	Seriti Mine, Viljoensdrif, Free State Province	Place of Intended Landing		Seriti Mine, Viljoensdrif, Free State Province		
Place of Occurrence	Seriti Mine in Viljoensdrif, Free State Province					
GPS Co-ordinates	Latitude	26º44'02.1" S	Longitude	27º55'54.4" E	Elevation	4 761 feet

Aircraft Information				
Registration	ZT-XGK	Class	Class 3A	
Make; Model; S/N	Condor VTOL (Serial Number: CON0005)			
Damage to Aircraft	Substantial	Total UAS Hours	408.7	

Pilot-in-command						
Licence Type	Remote Pilot Licence (RPL)	Gender		Male	Age	29
Licence Valid	Yes	Total Hours	494.4	Total Hours on Type		229.3
Total Hours 30 Days	49.63		Total Flying on Type Past 90 Days		131.23	

People Controlling	1	Injuries	0	Fatalities	0	Fatalities (on ground)	0

What Happened

On 6 June 2023 at 2117Z, an Unmanned Aircraft System (UAS) with registration ZT-XGK was launched for surveillance overhead Seriti Mine in Viljoensdrif, Free State province. The flight was conducted beyond visual line of sight (BVLOS) rules by night and under the provisions of Part 101 of the Civil Aviation Regulations (CAR) 2011 as amended.

The pilot reported that he successfully conducted two surveillance flights that night; and the accident flight was the third flight. The UAS was flown autonomous during the third flight and the pilot was monitoring its tracks on the laptop, and its systems on the remote pilot station. The furthest range that was covered from the home point during the third flight was approximately 7.6 kilometres (km) and the UAS had covered a flight track of approximately 150 kilometres, which lasted approximately 1 hour and 36 minutes (96min). The pilot stated that during the return-to-home flight, the left-side battery power indicated 38%. As the UAS approached the landing zone in auto mode, the pilot noticed that it transitioned from fixed wing mode to multirotor mode. The pilot further stated that the UAS was approximately 15 metres (m) away from the departure take-off position (where the pilot was situated) which was outside the 10-metre radius required for auto landing. The pilot stated that during descent, the UAS gravitated towards a tree that was on its flight path and suddenly spun out of control and changed directions without the pilot's inputs. At this point, the pilot maintained visual of the UAS. There

were no flashing lights observed on the UAS and on the remote pilot station to indicate a fault/error. The pilot regained manual control of the UAS and brought it down from 60m (197ft) to 8m (26ft) above ground level (AGL) and away from the security guards that were on foot patrol. Again, the UAS suddenly failed to respond to the pilot's inputs, and it impacted the ground hard. The UAS sustained substantial damage; no persons on the ground were injured.

UAS Description (Source: Condor User Manual)

*The condor is an all-in-one solution for surveillance. The platform offers incredible endurance and scope of coverage, with **120 minutes of flight time and up to 135 kilometre range**. It is a perfect platform for regular surveillance, conservation, as well as search and rescue and emergency response.*

Note: *When RTL mode is activated, the condor will return to home, commence the descent and circle within a 100m radius above the home point. At a height of 50 metres the aircraft will transition and land at the RTL position.*

Low Battery Failsafe (Source: Condor User Manual)

Environmental conditions can affect power consumption. The Mission Planner Data Display should be used to monitor the battery voltage during the flight. The aircraft will automatically RTL should the battery capacity reach a critical level. Refer to the table below:

Table for RTL reserve battery		
Please note that these values include safe return and VTOL landing of the UAV		
	Head-wind speed in direction of base (from UAV position)	
	15km/h	25km/h
Mission max distance to Base	Battery capacity needed	
5km	6% or 1500mah	6,4% or 1600mah
10km	12% or 3000mah	12,8% or 3200mah
15km	18% or 4500mah	19,2% or 4800mah

IMPORTANT: The max mission distance must be pre-programmed on Mission Planner before flight.

Power on Pre-flight Checklist (Source: User Manual)

After Powering On

Check:

1. *Servos are moving using the RC to check they are functioning correctly.*
2. *Check all 5 control surfaces are free of play.*
3. *Connection to payload and telemetry is established and working.*
4. *Battery is full (should be over 49.5v)*

5. *Flight mode showing on the mission planner is Q Hover.*

6. *Live video is working correctly.*

7. *That there is 3DGPS fix and at least 10 satellites.*

8. *With the AS sensor covered, execute "pre-flight calibration" on mission planner to calibrate airspeed sensor. Once this is done you must remove the pitot tube cover and put it safely inside the plane, then cover and lock the front hatch.*

Regaining Manual Control (Source: User Manual)

To regain manual control during the mission, switch to Q Loiter mode using the controller. If the condor has lost GPS FIX, switch to Q Hover mode (Q Hover mode works independently and does not need a GPS Fix to be fully functional. Whereas Q Loiter mode is dependent on GPS Fix)

To select a Flight Mode (Source: Condor User Manual)

Press the required button to get the desired flight mode

Q Hover *– Multirotor mode without position hold*

Q Loiter *– Multi-rotor mode without position hold*

Auto *– Automated mode (Mission mode)*

Use the SF switch to select RTL

RTL *– Return to launch*

Loiter *– Fixed wing mode: Condor will loiter*

Figure 1: The UAS after the accident. (Source: Operator)

Figure 2: Damage to the airframe. (Source: Operator)

Civil Aviation Regulations 2011 Part 101.05.12:

Night Operations

For operations at night, the holder of a UASOC must demonstrate to the satisfaction of the Director, how in the instance of their UAS –

 (a) will meet the requirements for BVLOS operations below 400ft; and

 (b) have strobe lighting installed on the UA;

(c) for aeroplane operations, have navigation lights or in the instance of a helicopter or multi-rotor UA, have a beacon light installed.

RPAS Classifications

CLASS	TABLE 1: RPAS CLASSIFICATION			
	Line-of-Sight	Energy (kJ)	Height (ft)	MTOM (kg)
Class 1A	R-VLOS/VLOS	E < 15	h < 400	m < 1.5
Class 1B	R-VLOS/VLOS/EVLOS	E < 15	h < 400	m < 7
Class 1C	VLOS/EVLOS	E < 34	h < 400	m < 20
Class 2A	VLOS/EVLOS	E > 34	h < 400	m < 20
Class 2B	Experimental/Research			
Class 3A	BVLOS	E > 34	h < 400	m < 150
Class 3B	VLOS/EVLOS	Any	h > 400	m < 150
Class 4A	BVLOS	Any	h > 400	m < 150
Class 4B	Any	Any	Any	m > 150
Class 5	Reserved	Reserved	Reserved	Reserved

Reserved – means to be defined in the future

h – means height above the surface

E – means energy at impact

Note: All operations are limited to radio line-of-sight

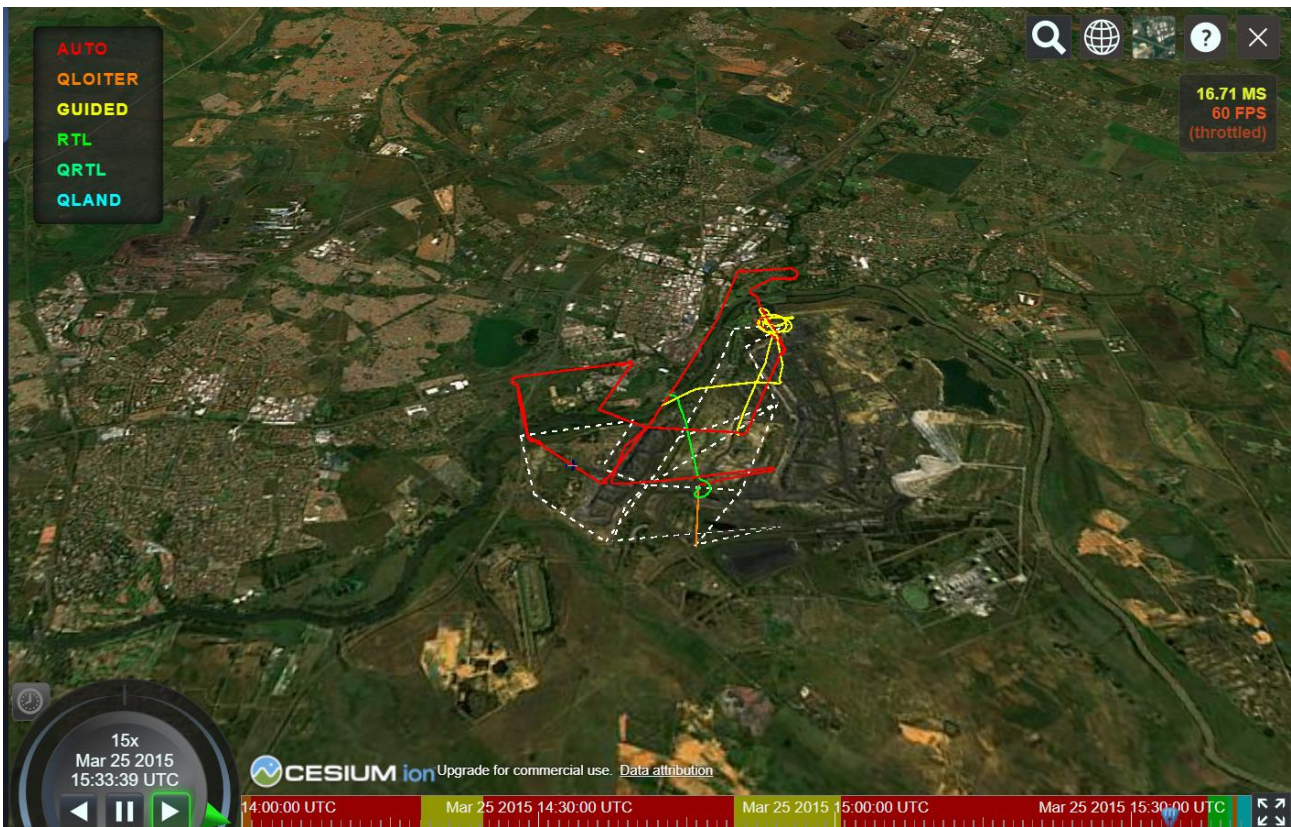[TS 101.01.5 substituted by the Director of Civil Aviation through SA-CATS 2/2023 w.e.f. 17 March 2023.]

Figure 3: An overlay of waypoints and the mission track. (Source: UAV Log Viewer (ardupilot.org))

Post-accident

After the accident, the operator shared a flight log data with the investigator-in-charge (IIC). Figure 3 depicts the mission flight and the waypoints. For this mission, the pilot created the desired flight route and waypoints: the red line represents the track on **auto** mode; the yellow line indicates the **guided** mode; the green line indicates **RTL;** and orange line represents the **loiter** mode. At the end of the track, the RTL was activated and the Condor was commanded to loiter instead of engaging Vertical Take-Off and Landing (VTOL) to land automatically. According to the Unmanned Aircraft Vehicle (UAV) log viewer, there were no errors recorded prior to impact.

Sequence of Events (Source: Technical Report)

At 21:09 UTC: The pilot armed the aircraft in "Auto" mode and started the operation.

At 22:43 UTC: 1 hour and 33 minutes into the operation, the aircraft switched to "RTL" mode and started to descend from 120 ft AGL to 70 ft AGL.

At 22:45 UTC: The aircraft reached the home location and transitioned to "QRTL" mode where it started to descend for landing.

At 22:46 UTC: 20 ft AGL the aircraft started to wobble as it was descending. The pilot then switched the aircraft to "Q Loiter" mode and made erratic stick movements.

At 22:47 UTC: The aircraft continued to descend as the pilot made forward pitch inputs. The aircraft impacted a nearby by fence.
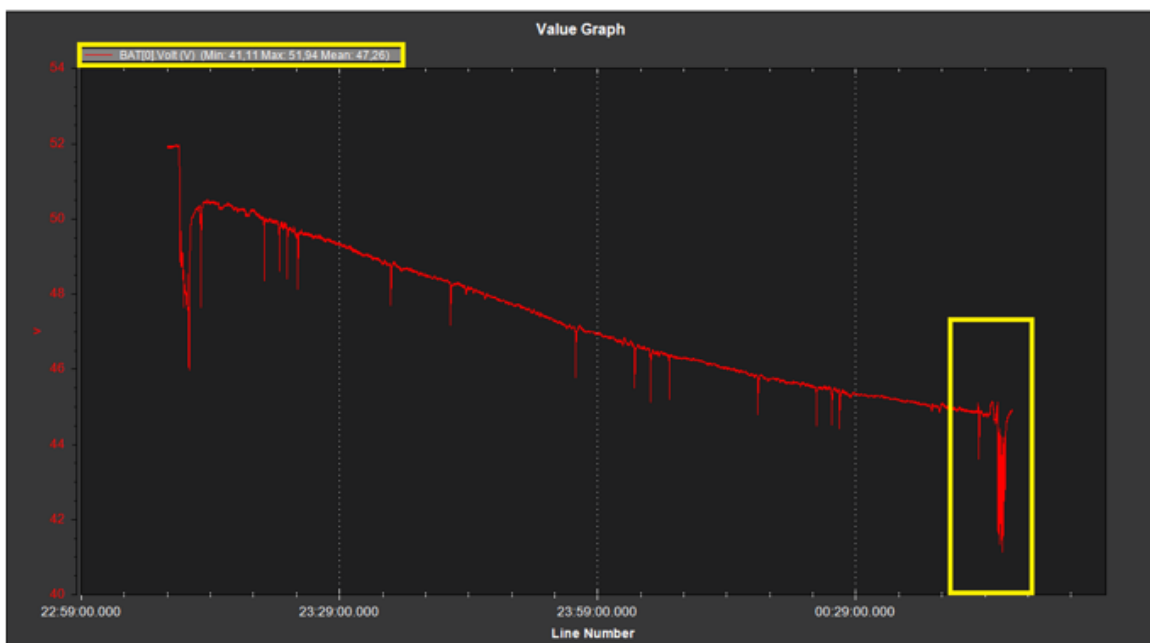
Graph 1: Battery depletion graph depicted in the yellow box. (Source: Technical report)

HIGH VOLTAGE LITHIUM POLYMER (LiHV)									
Auto LiPo Cell Detection			3.2			3.2	3.8	4.35	
Auto LiPo Min Voltage	Auto LiPo Max Voltage	# of Cells Detected	Cutoff Voltage Default	LiHV # of Cells	# of Cells Detected	Cutoff Voltage Default	LiHV Cells Nominal	LiHV Cells Peak	Premature Cutoff
>4.7	≤8.9	2	6.4	2	2	6.4	7.6	8.7	
>8.9	≤13.1	3	9.6	3	3	9.6	11.4	13.05	
>13.2	≤17.3	4	12.8	4	5	16	15.2	17.4	X
>17.4	≤21.5	5	16	5	6	19.2	19	21.75	X
>21.5	≤25.7	6	19.2	6	7	22.4	22.8	26.1	X
>25.7	≤29.9	7	22.4	7	8	25.6	26.6	30.45	X
>29	≤34.1	8	25.6	8	9	28.8	30.4	34.8	X
>34.1	≤38.3	9	28.8	9	10	32	34.2	39.15	X
>38.3	≤42.5	10	32	10	11	35.2	38	43.5	X
>42.5	≤46.7	11	35.2	11	12	38.4	41.8	47.85	X
>46.7	≤50.9	12	38.4	12	13	41.6	45.6	52.2	X

Table 1: Battery power indication. (Source: Technical report)

Findings

1. The pilot was issued a Remote Pilot Licence on 28 February 2023 with an expiry date of 29 February 2024. The pilot was issued a Class 3 aviation medical certificate on 23 July 2020 with an expiry date of 31 July 2024 with no medical limitations. The pilot was issued a rating for BVLOS and multi-rotor, which was endorsed on his licence.

2. The UAS was registered to the owner on 7 October 2021.

3. The last (minor) inspection was conducted on 14 April 2023 at 206.5 flight hours with an expiry date of 14 October 2023 or at 406.36 flight hours, whichever comes first. At the time of the accident, the total hours flown since new were 408.43 hours. Since the last inspection, the UAS was flown a further 202.09 hours. On the day of the accident, the UAS flew a total of 1 hour and 36 minutes (96min).

4. The UAS Letter of Approval (UASLA) certificate was renewed after the mandatory periodic inspection (MPI) and was reissued on 14 July 2022 with an expiry date of 13 July 2023.

5. The remote maintenance technician (RMT) who certified the last inspection was issued a Remote Maintenance Technician certificate on 27 July 2022 with an expiry date of 26 July 2024, and had a multirotor rating endorsed on his licence.

6. The operator was issued an Unmanned Aircraft System Remote Operator Certificate (UASROC) on 31 October 2022 with an expiry date of 31 October 2023. The UAS type was included in the operations specifications dated 5 April 2023.

7. According to the Condor User Manual, *the condor is programmed with a set of failsafe behaviours to prevent a crash in the event of loss of communication channels required for*

autonomous flight. Although certain failsafe parameters have assigned LED indicators and tones, it is unlikely that you will be able to see these at a distance. In the event of the UAS losing a GPS Fix signal, the pilot could regain manual control during the mission by switching to Q Hover mode (*Q Hover mode works independently and does not need a GPS FIX to be fully functional*). According to the flight log data, the input that was selected was Q Loiter, which was not what the manual suggests. The User Manual further states that once the last mission is complete, the Condor will RTL (return to land), transition and VTOL land.

8. According to the User Manual, there must be at least 10 satellites detected to get 3D GPS Fix mode functioning to gain manual control in Q Loiter mode. At the time when the RTL was selected, the system was picking up only three satellites. During the transition from fixed to multi-rotor mode, the pilot selected Q Loiter instead of Q Hover which works independently from the GPS Fix.

9. The User Manual states that *flying with a low battery is a safety risk and can render the battery permanently unusable. Always fly with a fully charged battery.* During the descent, the UAS spun uncontrollably. According to the flight data log, the UAS flew for 1 hour and 36 minutes and the scope of coverage is 120 minutes as stated in the manual, this meant that it was 16 minutes over the limit. It is likely that when the UAS was spinning out of control, the battery power was critically low.

Probable Cause(s)
During transition to land, the UAS spun out of control due to low battery voltage before it crashed.
Contributing Factor(s)
- Uncommanded transition after an RTL.   - Low-battery voltage.   - Loss of situational awareness.   - Incorrect input during the last phase of flight.
Safety Action(s)
None.
Safety Message
Pilots operating the Condor VTOL are urged to familiarise themselves with the User Manual and failsafe procedures as stipulated in the manual to safely operate the UAS and prevent damage to property.
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 CA 12-57 21 April 2022 Page 9 of 9 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 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

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