ACCIDENT

Aircraft Type and Registration:	Freefly Systems Inc. Alta X
No & Type of Engines:	4 electric motors
Year of Manufacture:	2021 (Serial no: Q848350)
Date & Time (UTC):	29 June 2022 at 1124 hrs
Location:	Henley-on-Thames, Oxfordshire
Type of Flight:	Commercial Operations (UAS)
Persons on Board:	Crew - N/A Passengers - N/A
Injuries:	Crew - N/A Passengers - N/A
Nature of Damage:	Aircraft not recovered
Commander's Licence:	Other
Commander's Age:	53 years
Commander's Flying Experience:	831 hours (of which 18 were on type) Last 90 days - 73 hours Last 28 days - 28 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further AAIB enquiries

Synopsis

The UAS, an Alta X, was being operated commercially to provide video footage at the Henley Royal Regatta when a low voltage battery warning occurred in flight at a height of 50 m. As the aircraft was being flown back to the landing site, the aircraft battery voltage reduced to the point where controlled flight was lost. It fell, in near free fall, and impacted a boat on the river, causing damage. No persons were injured. The pilot could not recall checking the aircraft's battery voltage prior to takeoff, and the low voltage battery warning had been changed to trigger at a lower level than that recommended by the manufacturer.

History of the flight

The Alta X unmanned aircraft (UA) was being operated commercially to provide video footage of boat racing at the Henley Royal Regatta[1], Henley-on-Thames, which took place between 28 June 2022 and 3 July 2022. The aircraft was being operated from a pontoon on the River Thames, from where it was to be flown whilst filming the boats from approximately 150 m down-river from the pontoon's position to 250 m up-river (towards to race finish line).

The river was segregated by booms, which provided an area on the east side of the river for competition and support boats to operate, and on the west side, privately operated and commercial boats. The area on the east side of the river was considered by the pilot to be

Footnote

[1] https://www.hrr.co.uk/ [accessed September 2022].

a controlled area, within which he would operate the aircraft. He did not intend to operate the aircraft over the uncontrolled area.

The pilot was accompanied on the pontoon by a camera operator and an observer. They had filmed before at the regatta, in 2019 and 2021, with the Alta X being used in 2021. The pilot advised that the number of races scheduled during the first few days of the regatta had increased from previous years, with about 80 races per day starting at about 0830 hrs and finishing about 1830 hrs (UTC). The races were scheduled in blocks of five with each race starting five minutes apart, and a ten-minute gap between each block. It was the intention of the pilot to be able to film at least every second race, which meant that the aircraft would be flown about every ten minutes, with the aircraft landed back onto the pontoon between each flight.

The pilot had intended to replace the aircraft's two batteries after every third flight with a fully charged set. This was based on his experience that the dynamic nature of the flying could more quickly deplete the aircraft's batteries. The battery voltage level was displayed to the pilot on his flight controller. When fully charged, the batteries were at 50.4 V and the pilot had configured the aircraft and hand-held controller to provide a warning when the voltage reached 42 V.

The first day's flying on the 28 June 2022 passed without incident and the pilot, camera operator and observer arrived on the pontoon to prepare to film the second day of racing scheduled to start at 0830 hrs. The weather was dry, 19°C with good visibility and a wind from the south-east of about 10 kt.

At 1120 hrs, the aircraft took off on its 21st flight of the day, which was to film race 35. The flight initially proceeded as normal, with the pilot flying the aircraft overhead two competing boats (Figure 1) at a height of about 50 m (164 ft agl). Operating on the uncontrolled side of the river were several privately operated boats. This included The Celtic Queen (Figure 2), which was travelling down-river. Onboard this boat were six people, of which two were seated near the bow of the boat.

When the aircraft was about 250 m up-river from the pontoon, the aircraft's low voltage battery warning activated. The pilot responded by flying the aircraft back towards the pontoon to expedite its landing. However, when the aircraft was almost overhead the pontoon at a height of about 50 m, it stopped responding to the pilot's commands and started to rotate whilst also descending rapidly. The aircraft struck The Celtic Queen, which was now almost abeam the pontoon, before falling into the river. No persons were injured. One of the aircraft's batteries came to rest between the two passengers seated near the bow, which was about 2 m away from where the aircraft had struck the boat. The aircraft was not recovered from the river.

The pilot stated after the accident that he did not recall checking the aircraft's battery voltage prior to taking off, and that his records indicated that it was making its sixth consecutive flight since the batteries had last been changed.

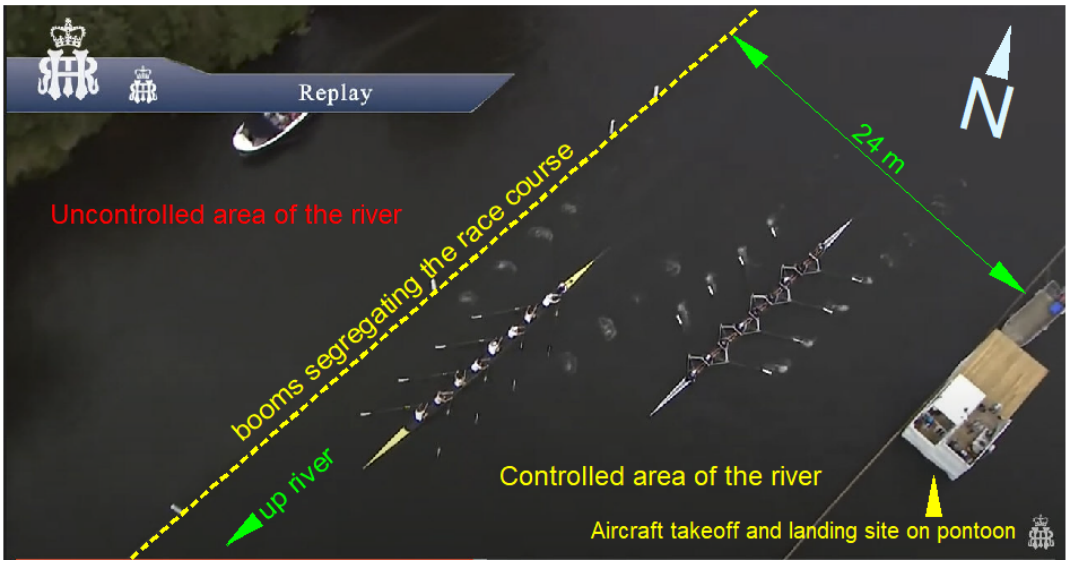

Figure 1

Image taken from the aircraft's camera showing the takeoff and landing pontoon and the adjacent controlled/uncontrolled sides of the river

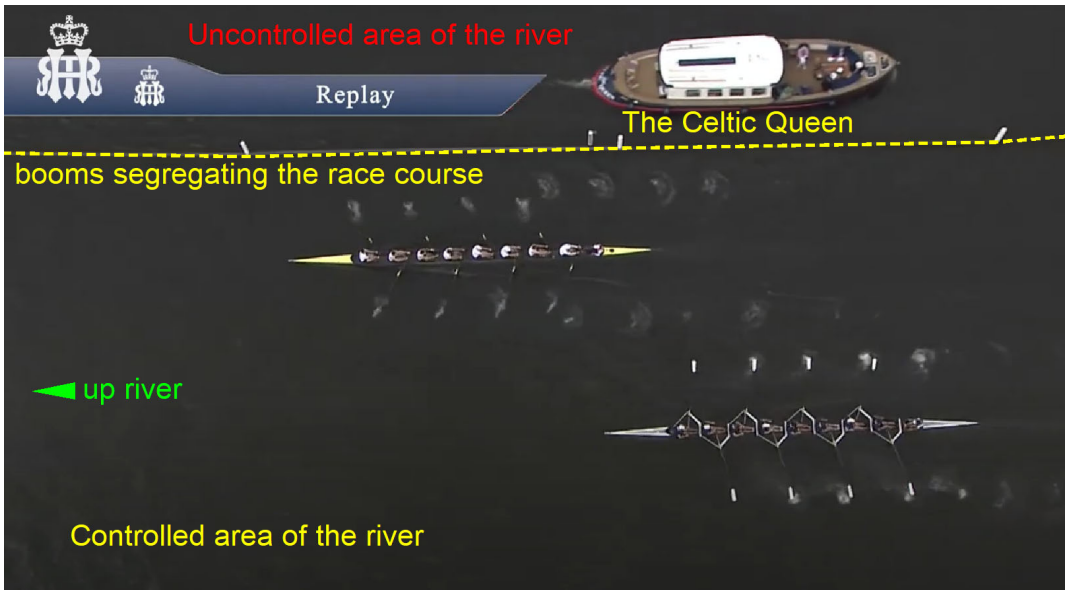

Figure 2

Image from the aircraft, with The Celtic Queen travelling down-river.

Figure 3

Image from the aircraft taken shortly before its loss of control

Damage to The Celtic Queen

The Celtic Queen is a boat of approximately 20 m in length and 3 m wide (Figure 4), with a cabin of metal construction. At the bow and stern are seating areas for passengers.

The aircraft had initially collided with the forward left side cabin roof causing deformation in a section of the stainless-steel handrail and damage to the surface of the roof (Figure 5). The aircraft then struck the left side of the cabin and adjacent gunwale, prior to it falling into the river and sinking. Composite material from the aircraft had been embedded into the wooden surface on the gunwale (Figure 6) and one of its batteries had detached from the aircraft and come to rest on the forward deck (Figure 7).

Figure 4

The Celtic Queen (Photograph used with permission)

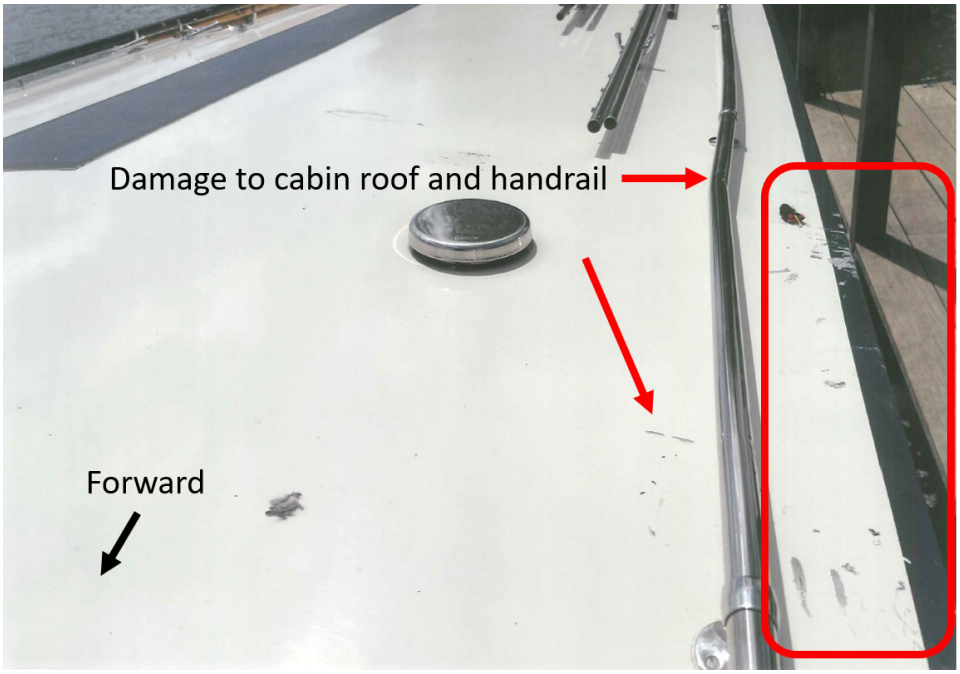

Figure 5

Damage to cabin roof and left side handrail

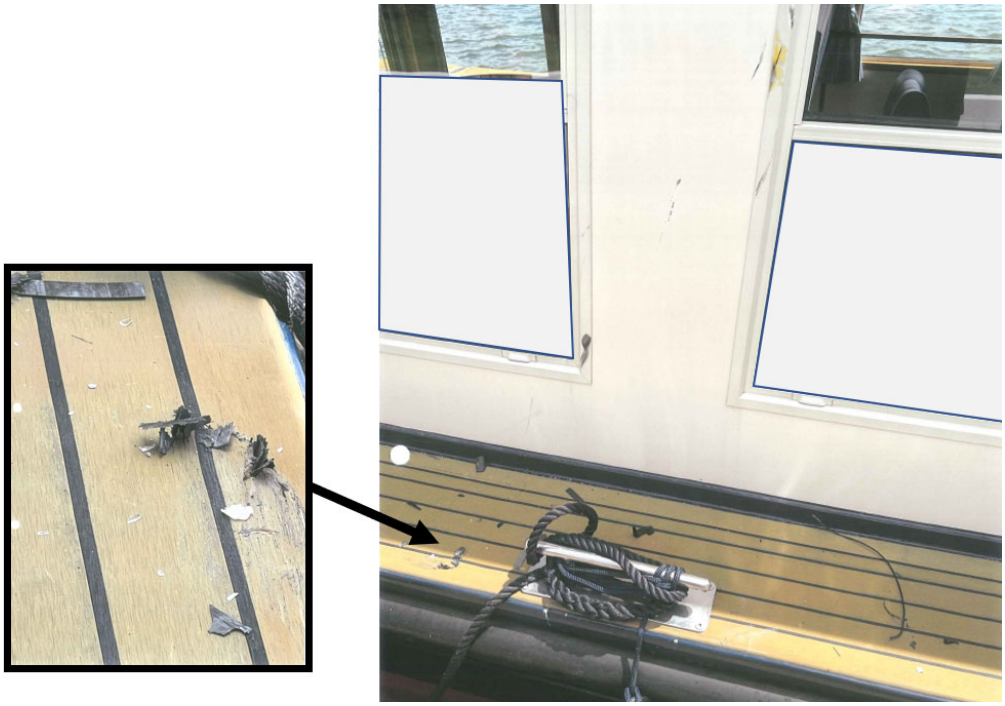

Figure 6

Damage to the cabin and gunwale

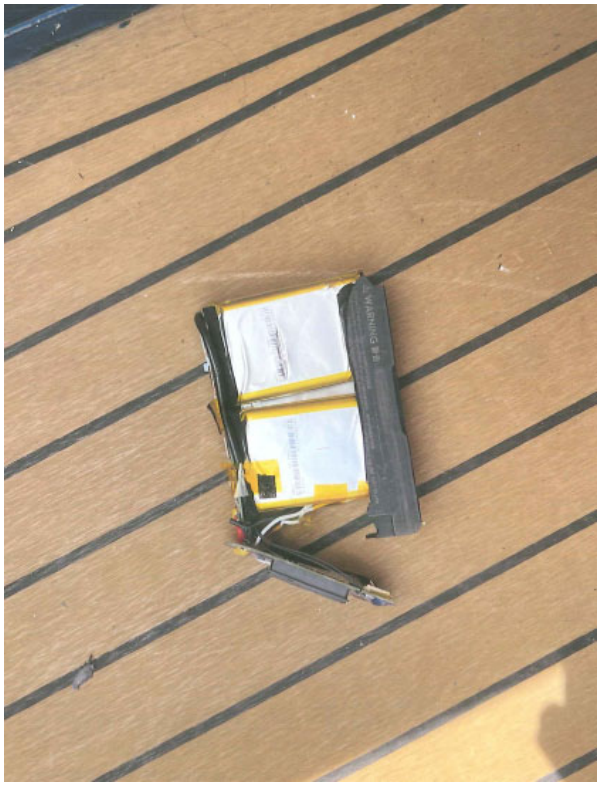

Figure 7
Aircraft battery on forward deck

Recorded information

Video footage transmitted from the aircraft to the ground during the accident flight was available. This commenced when the aircraft was overhead the pontoon, as it was flying up-river, and ended three seconds after it had started to descend out of control.

If the last images from the footage coincided with the aircraft colliding with the boat, this would be consistent with the aircraft having descended from a height of 50 m in near free fall. This would have equated to a speed at impact of about 30 m/s (~60 kt) and a kinetic energy of about 13,700 Joules.

Flight logs stored in the aircraft were not available as the aircraft has not been recovered.

Aircraft information

The Alta X (Figure 8) is an unmanned, electrically powered quadcopter with a maximum takeoff weight of 34.9 kg[2]. This type of aircraft relies upon its propulsion system for lift. The aircraft's rotors are 84 cm in length and, when the motor arms are extended for flight, the aircraft measures 2.28 m from rotor tip to rotor tip. During the accident flight the aircraft's takeoff weight was 28 kg, which included an underslung camera mounted on a gimbal.

Footnote

[2] Based on operating at a pressure altitude of between sea-level and 1,000 ft, and at temperatures of between 0°C and 20°C.

Figure 8
Alta X (not the accident aircraft)

Operational information for the aircraft is provided online[3] by its manufacturer. This showed that at a takeoff weight of 28 kg the flight time available would be about 25 minutes. This was based on the aircraft taking off with its two 12S lithium polymer batteries fully charged to 50.4 V, and subsequently landed when the voltage had reduced to 44 V. The manufacturer had configured the aircraft to provide a warning when the voltage was at, or less than, 44 V. The warning caused lights at the end of the aircraft's motor arms to flash on-and-off and a battery symbol to be displayed on the manufacturer's Ground Control Application (GCA)[4].

The manufacturer's operational procedure *'Before Starting',* stated that the battery voltage was to be *'ABOVE 48V'*. The manufacturer advised that this was the minimum voltage that it recommended prior to flight. Its online information also stated that if the low battery voltage warning occurred, to *'LAND as soon as possible'* and included the following:

> ⚠ Recommended landing voltage is 44V.

The manufacturer stated that the landing voltage of 44 V was based on an aircraft operating at close to its maximum weight, but at lower operating weights with a reduced load on the batteries, the 44 V provided a conservative limit. Performance data on operating the aircraft at battery voltages of less than 44 V was not published. However, the manufacturer advised that it was aware that some operators flying the aircraft at 10.4 kg (no payload),

Footnote

[3] https://freefly.gitbook.io/freefly-public/products/alta-x [accessed August 2022].
[4] Software that could be operated on a PC and through which the pilot could also control the aircraft.

were continuing to fly the aircraft for approximately 15 minutes after the battery voltage had reduced to 44 V.

Various aircraft settings could be adjusted by their owners, which included the trigger level for the low voltage battery warning. The accident pilot had changed this from 44 V to 42 V, which he stated was based on his experience of operating the aircraft.

Accident aircraft control and display systems

The Alta X can be operated using remote control modules from different manufacturers. The accident aircraft was being operated using a JETI DS24 handheld remote-control module. This displayed the aircraft's battery voltage level on an integral LCD and was set by the pilot to provide an aural alert when the battery voltage reached 42 V. The pilot was not using the manufacturer's GCA software. Total flight time between each battery change was not displayed, but an individual flight timer was available. This was automatically reset after landing.

The underslung camera was controlled by the camera operator using a separate controller. This did not display aircraft status information, such as its battery voltage.

The aircraft was being operated in manual mode at the time of the accident, which provided attitude stabilization, but the aircraft would drift with the wind unless manual corrections were made.

Regulations for UA operations

UK guidance for Unmanned Aircraft System operations

Detailed guidance for operating Unmanned Aircraft Systems (UASs) in UK airspace is contained within the CAP 722 document series which references the basic regulations and is published by the CAA. CAP 722 is the lead document and CAPs 722A-E cover wider topics such as risk assessment methodology, training policy and a glossary of terms relating to UAS operations.

CAP 722D definitions relevant to this accident were:

- UAS operator: '*any legal or natural person operating or intending to operate one or more UAS*.' The UAS operator is responsible for the overall operation of the UAS, and most specifically the safety of that operation. This includes the conduct of any safety risk analysis of the intended operations.
    - Provided they hold the correct CAA-issued IDs, an individual can act as both remote pilot and operator for the UA they are flying.
- Uninvolved persons: '*persons who are not participating in the UAS operation or who are not aware of the instructions and safety precautions given by the UAS operator'.*

UAS operational categories

UAS operations in the UK are regulated according to the perceived level of risk that the intended operation presents. Operations are deemed to fall within one of the following three broad categories:

- Open: operations presenting a low risk to third parties.
- Specific: operations requiring a CAA-issued operational authorisation because they present a greater risk than those in the Open category.
- Certified: operations that present an equivalent risk to that of manned aviation.

The accident aircraft was being operated in the Specific category at the time of the accident.

Specific category

The operational authorisation document sets out the privileges and limits of the operation. Each operational authorisation is specific to the named UAS operator and is dependent on the risk assessment and evidence supplied to the CAA by that operator.

The operational authorisation issued to the pilot of the accident aircraft specified that he could overfly uninvolved persons with the aircraft, as long as it was no closer than 50 m to them (ie a 'bubble'), except that during takeoff and landing this distance could be reduced to 30 m.

Risk assessment

The operator of the aircraft had produced a risk assessment and method statement for fights scheduled to take place at the regatta. This covered the use of three UAS, which included the Alta X, an Alta 8 and a DJI Inspire 2. The following statement regarding monitoring of the aircraft batteries was included within the *'Safety - Technical'* section: '*Battery levels are constantly monitored by both pilot and ground crew, in the event of a sudden loss of power the UAS will descend in a controlled manner*'.

The documentation also included a 5 x 5 risk matrix and the following risks and mitigations concerning loss of aircraft battery power, and risk of injury to person or damage to property:

			Severity of injury / fatality				
0-6=Low risk			Negligible	Minor	Major	Hazardous	Catastrophic
6-10=Moderate risk							
11-15=High risk							
16-25=Unacceptable risk		Score	1	2	3	4	5
Likelihood of Safety Risk Occurring	Frequent	5	5	10	15	20	25
	Occasional	4	4	8	12	16	20
	Remote	3	3	6	9	12	15
	Improbable	2	2	4	6	8	10
	Extremely Improbable	1	1	2	3	4	5

Risk	Probability of hazard	Severity of injury / fatality	Risk Score	Mitigations	Residual probability	Residual Severity	Residual risk score	ALARP (Y/N)	Remarks
Loss of power due to flight batteries running low resulting in an unplanned descent onto property or people.	4	5	20	• Flight batteries checked for state of charge immediately prior to taking off • Aircraft is fitted with a sensor that measures the capacity used with audible warnings on the pilot's TX when pre-defined levels are reached. • Flight times are monitored with a warning to the pilot when pre-defined times are reached. • Flight pack voltage is monitored with audible warnings set at pre-defined levels. • Motor cut-offs set to 'soft' meaning that power is gradually reduced as batteries reach critical levels. This results in a more controlled descent.	1	3	3	Y	
Aircraft failure. Damage is caused to property, people are injured or killed.	4	4	16	• Specific, preventative maintenance schedules. • Single points of failure minimised. • Pre-flight checks. • Site survey to identify alternative landing areas/ areas to avoid. • Flight planning. • Cordoned off main take-off / landing area. Where possible • Spotter employed to forewarn of encroachments into flying area. • Minimum distances applied to maintain from people and property • Maximum speed reduced as distances close	1	4	4	Y	

The assessment also included the following (redacted) text concerning operational pressures.

Pressure on pilot by client leading to flying errors resulting in injury or death or damage to property	4	5	20	• [redacted] Pilots are experienced with handling clients and resulting production pressure. • [redacted] Pilots are experienced at operating under pressure • [redacted] aims to send its most experienced pilots to jobs where pressure is expected.	3	5	15	Y	
ALTA X @34.86Kg				• Pilots will only conduct flights if they are safe • [redacted] operates a 'Just culture' • [redacted] fully supports the decision by the pilot not to fly if the pilot is concerned about safety • In Live Outside Broadcast environments where it is necessary for the flights to be "directed" from the Outside Broadcast Vehicle, communications whilst the aircraft is in flight such as shot requirements will be filtered through the Aerial Camera Operator. • At all times the pilot's decision is final. • In Pre-record situations the pilot will not deviate from pre-briefed shots. • Production attention is drawn to the final 2 paragraphs of the Crew Safety Briefing - *Appendix G* [redacted] *Operating Safety Case or* [redacted] *Risk Assessment and method Statement.*					

Risk of injury to persons

A research paper[5] from the Australian Civil Aviation Safety Authority (CASA) states that the highest risk of injury to persons being struck by an UA, is an impact to the head, with energies of between 40 and 120 Joules being '*dangerous*' and more than 120 Joules as '*causing severe damage to humans*'.

Personnel

The accident pilot was an experienced UAS operator and was aware that there was a risk associated with operational pressures from the client. However, he advised that there was also a desire to "keep the client happy and not miss filming races". The pilot also considered that fatigue may have been a factor, advising that the flights were complex in their nature, often operated in variable wind conditions and from a small landing site surrounded by water. The previous working day had also been long, whilst covering an increased number of races compared to those in 2019 and 2021.

During pre-flight checks, the pilot stated that his normal practice was to verbally call out the aircraft's battery voltage. This, he explained, was intended to provide self-confirmation that he had completed the check, and so that the camera operator and observer nearby were informed. However, the pilot advised that neither the camera operator nor observer had been briefed as to what level of voltage was acceptable. The pilot stated that he would takeoff at battery voltages of less than 48 V, which he considered acceptable when performing shorter duration flights.

Analysis

The risk assessment performed by the operator had identified that a loss of battery power in flight could result in a '*catastrophic'* outcome and was classified as an '*unacceptable risk'*. However, the operator's classification reduced this to *'Low Risk'* when mitigations were applied. These mitigations included checking the battery voltage level prior to takeoff. However, the pilot, could not recall performing this check. The aircraft was operating its sixth flight since the batteries had been changed, which was twice that intended by the pilot. He suggested that he may have been fatigued and perhaps the desire to film as many races as possible provided further pressure which may have also distracted him. This may provide possible explanations as to why the aircraft's batteries were not changed prior to the accident flight as intended by the pilot.

The pilot stated that he would takeoff when the battery voltage was less than 48 V, which he considered was acceptable when making short flights. This differed from the manufacturer's guidance of '*above 48 V'*, although this value was based on the aircraft being operated at its maximum weight.

Although, the operator's risk assessment stated that the pilot and ground crew would monitor battery voltage, neither the camera operator nor observer had been briefed prior to takeoff

Footnote

[5] https://www.casa.gov.au/human-injury-model-small-unmanned-aircraft-impacts [accessed September 2022].

as to what voltage was acceptable. Therefore, neither would have been able to assist the pilot in identifying that the battery voltage was getting low.

The manufacturer's default trigger threshold for the low voltage battery warning was 44 V, and this was also the level at which it recommended that the aircraft should be landed as soon as possible. This warning threshold had been changed by the operator to trigger at 42 V. Shortly after the low voltage warning had occurred in flight, the battery reached a critical voltage level at which point controlled flight was lost and the aircraft then descended in near free fall.

The aircraft's kinetic energy when it collided with the boat was estimated to have been about 13,700 Joules. The CASA research paper indicates that fatal injuries would have occurred if the 28 kg aircraft falling at 30 m/s had struck a person on the boat.

Conclusion

Whilst returning to land following a trigger of the low battery voltage warning, the aircraft's battery voltage depleted to the extent that controlled flight was no longer possible. The aircraft descended, in near free fall, and impacted an occupied private boat on the river. If the aircraft had struck a person on the boat, it is likely that fatal injuries would have occurred.

The pilot did not replace the aircraft batteries when he had intended to, and a pre-flight check of their voltage before the accident flight was most likely not performed. In addition, the low voltage battery warning had been set to a level below that recommended by the manufacturer.

Had the battery warning been set to the manufacturer's recommended setting, the aircraft may have been landed safely under the pilot's control.

Bulletin Correction

Prior to publication it was noted that the aircraft manufacturer was incorrectly stated to be 'Free Fly', whereas the correct description is 'Freefly Systems Inc.'.

The online version of the report was corrected before the report was published on 12 January 2023.