

# Recovery of an Unoccupied Aircraft System and Recommendations for Avoiding Communication Loss in a Forested Environment

Michael G. Wing\*, Matthew I. Barker, Katharine H. Nicolato

Department of Forest Engineering, Resources, and Management, Oregon State University, Corvallis, OR, USA  
Email: \*michael.wing@oregonstate.edu

**How to cite this paper:** Wing, M.G., Barker, M.I. and Nicolato, K.H. (2024) Recovery of an Unoccupied Aircraft System and Recommendations for Avoiding Communication Loss in a Forested Environment. *Journal of Geographic Information System*, 16, 431-442.

<https://doi.org/10.4236/jgis.2024.166025>

**Received:** November 19, 2024

**Accepted:** December 27, 2024

**Published:** December 30, 2024

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## Abstract

Unoccupied aircraft systems (UAS) are increasingly used to create spatial databases for use in natural resource research and in other disciplines. We describe our experience with the recovery of an UAS platform that became lodged in a tree located next to a small river island after experiencing communication loss. The UAS platform was a DJI M200 series aircraft that we had used for remote sensing applications over several years without issue. During remote sensing of a riparian restoration project, the M200 descended vertically downward after communication loss, became lodged in a tree crown, and was suspended above the river. A tree climber was temporarily able to grasp the platform but a landing support released and the platform fell into the river. Although being submerged for less than 30 seconds, inspection of the internal chassis later revealed at least some moisture had infiltrated into the chassis likely impacting electrical components. The sensor escaped without noticeable damage and operated without apparent impact after being subjected to prolonged drying. We were unable to determine the specific reason for communication loss after examining digital flight logs but investigated other similar reported loss occurrences to better understand what may have transpired. We provide some recommendations for minimizing loss based on our analysis of reported incidents with similar UAS platforms and from our experiences in using UAS for remote sensing in forested environments.

## Keywords

UAS, Natural Resources, Remote Sensing, Communication Loss, Safety

## 1. Introduction

Unoccupied aircraft systems (UAS) are becoming increasingly prevalent for a va-

riety of applications such as product delivery [1], search and rescue [2], law enforcement support [3], and agricultural and forestry remote sensing [4], among other purposes. The imagery that can be captured by UAS can provide very detailed databases for GIS and remote sensing applications that would be difficult to gather through piloted aircraft and satellites. Typically, UAS are conducted closer to the ground than other airborne or spaceborne imaging platforms, and are capable of creating higher precision databases. In addition, the ability to control the timing of a remote sensing field event is advantageous to those involved in spatially-oriented natural resource research [5]. The reasons for increased UAS prevalence are a combination of technological development and flight regulation maturation that allow UAS access to a growing number of potential users and applications. Technological developments include the growing sophistication of spatial programs that allow pilots to pre-program flights and ensure that an airborne sensor captures enough image overlap to cover an entire study area.

UAS technology, however, is far from perfect and relies upon a number of electrical, communication, and avionic technologies in order to function reliably. A component failure can lead to a situation where a UAS falls to the ground onto people's property and causes damage [6].

A primary group of technologies is communication between a ground station controller and an aircraft, and sustained contact with some portion of the Global Navigation Satellite System (GNSS) by a UAS platform. Communication between a ground station controller and a UAS in flight allows a remote pilot the ability to monitor aircraft status including remaining power and aircraft position. Very importantly, sustained communication can allow a remote pilot to terminate an automated flight plan or erratic aircraft and potentially manually return an aircraft using a controller to a landing location. Common communication frequencies for drone operation are 2.4 GHz and 5.8 GHz with 2.4 GHz providing coverage at a longer range but transmitting data at slower speeds. Potential obstacles to sustained communication include power lines, buildings, trees, and other aircraft.

GNSS is a combination of global positioning satellite systems and includes most notably the NAVSTAR, GLONASS, and BEIDOU systems [7]. These GPS constellations can provide accurate and precise locations for UAS given that a sufficient number of satellite signals can be maintained and processed by an on-board GPS receiver. Obstacles that can interfere with sustained satellite signal communication include metallic objects and any other structures or landscape features that come between a satellite signal and receiver.

A gap or break in the UAS supporting "circle of technology" can result in failed flight operations leading to an aborted flight or worse, such as a crashed or unscheduled landing. These occurrences can place not only UAS operation participants in danger, but also others in the vicinity who are not part of the flight operation. There is also the possibility of damaging structures and other infrastructure as a UAS platform descends without control.

Outside of areas near airports and metropolitan centers, no other environment

may pose as daunting flight safety challenges than operating in and near forested riparian areas. This is particularly true in non-plantation forests where barriers to instrument communication include irregular tree heights and spacing in uneven-aged stands, uneven terrain, and mountainous topography. These conditions can potentially interfere with radio communication or satellite provided positioning.

We describe our experiences in attempting recovery of a DJI M200 series UAS platform that lost radio communication with a ground station controller and landed in a tree surrounded by a rapidly moving stream within a mature forest. Our digital flight-logs did not indicate evidence of failure. We researched other reported incidents of failure with the same UAS platform that we used in order to better understand what may have led to our loss of aircraft control. Based on our research of similar UAS incidents and our experiences in applying UAS for remote sensing in forested landscapes, we offer recommendations to others hoping to avoid flight difficulties.

## 2. Methods

Our UAS platform was the DJI M200 v2 quadcopter which had an approximate price of \$5000 (**Table 1**) [8]. Our sensor was the MicaSense Altum which cost approximately \$11,000. We had flown this platform and sensor combination for research flights approximately 30 times over a three-year period without any loss of communication or control of the platform during flight. The only challenges we experienced with the platform and sensor combination occurred on the ground. These challenges included establishing Wi-Fi communication with the sensor to establish sensor triggering parameters and obtaining sufficient satellite reception to establish reliable positioning. Our flight landscapes occurred in both forest and agricultural areas, and flights were not conducted during precipitation events, in accordance with manufacturer recommendations.

**Table 1.** DJI Matrice 200 quadcopter specifications [9].

Dimensions (unfolded)	887 × 880 × 378 mm
Dimensions (folded)	716 × 220 × 236 mm
Number of Batteries	2
Max Payload (2 TB55)	Approx. 1.61 kg with two TB55 batteries
Max Flight Time (No Payload, with TB55)	38 min
Max Flight Time (Full Payload, with TB55)	24 min

Flight planning software was used to create a flight pattern that would allow for sufficient image overlap to create an orthomosaic and other spatial products of our forested research area. Weather conditions during our flight day, which occurred in May 2022, were excellent with clear skies and very light wind speeds. The platform lifted upon launch to a pre-programmed altitude and began its flight

pattern without incident. During a flight line, the ground station controller indicated that communication had been lost with the platform. Our pre-programmed response to sustained communication loss was that the platform would ascend to an altitude securely above the forest canopy and return in a straight line to hover above the takeoff location. Once reaching the point above the takeoff location, the platform was to descend and land at the takeoff location.

Instead, what occurred after communication loss was that the platform began a steady descent downwards into a tree crown, behaving as if it was losing power. This descent was clearly visible on the controller display screen as were the decreasing altitude readings. While the platform was partially obscured from the remote pilot in command during this descent, a nearby observer was in full view of the platform and advised the remote pilot to increase platform altitude. The remote pilot found that flight controls were unresponsive and resultingly, the platform continued its descent until it became lodged in a deciduous cottonwood tree canopy approximately 15 m above the surface of a stream. The descent appeared to increase in speed as the platform approached the canopy.

Although lodged in the tree canopy, the platform continued to transmit location data and a live camera feed which allowed the flight crew to determine an approximate platform location. The crew was able to navigate to the location of the platform using the map in the flight planning software. Additionally, the software provided a settings option to enable the platform to produce a continuous beeping sound that allowed the crew to identify the platform's precise location. The flight crew was able to view the area below the platform from across the stream channel and determined that rope and tarps would be helpful in a possible platform recovery effort. These items were purchased at a nearby store and once procured, the recovery team proceeded across two stream channels until reaching a small island adjacent to the stem of the cottonwood. Navigating the second stream channel was extremely rigorous and required caution. It became evident that the platform could only be recovered by a certified or otherwise professional tree climber given the 15 m distance from the ground. A tarp was tied so that it lay flat approximately one meter above the island and surrounding stream surface. The tarp was intended to cushion the platform should it fall and hopefully, prevent it from entering the stream.

A graduate student who belonged to the flight laboratory had become certified as a tree climber and agreed to aid in recovery efforts the following day. Not surprisingly, when we returned to the launch site, we discovered that the aircraft batteries had been fully discharged. Climbing ropes and other supporting gear were transported to the island using inflatable boats. The tree climber attempted to use a guide rope attached to a weight to loop over a primary branch located approximately seven meters above where the platform landed. Throwing attempts could not successfully go over the branch. The tree climber suggested that a rubber band powered projectile could be used to launch a guideline over the branch and could likely be secured two days later.

The recovery team returned to the island and after a few attempts, the guideline was successfully launched over the supporting branch and a climbing rope was raised and secured. This began a process whereby the tree climber would wear a rope harness and use a rope walking system to climb to the supporting branch and, once there, use climbing lanyards to link to a higher branch (**Figure 1**). This process continued until the tree climber was able to stand on the branch that held the platform, once they had secured their climbing harness to other supporting branches.



**Figure 1.** Tree climber and lodged UAS platform with circle indicating platform position.

The tree climber limb walked outwards on the branch until in reach of the aircraft with an extendable grabber. The grabber end was clamped to one of the landing gear supports and the climber attempted to secure the aircraft to their harness. The landing gear support loosened, and the aircraft fell downwards onto the tarp and bounced into the stream becoming fully immersed. A recovery crew member was able to extract the aircraft within 30 seconds of becoming submerged. Visually apparent damage to the aircraft included the rear two engine speed controllers (ESCs) and the frame extensions that support the ESCs (**Figure 2**). Other damage to the aircraft frame was minimal and the sensor appeared to escape physical damage.



**Figure 2.** Recovery team member with UAS platform after retrieval from the river.

### **3. Results**

#### **3.1. Sensor Damage**

We covered the sensor in a bowl of rice upon returning to our laboratory during the afternoon of the aircraft recovery and let it sit for 10 days before attempting to turn it on. The sensor was able to capture imagery and appeared to show no impact from the fall and immersion. Multiple flight operations have since occurred with the sensor and no aftereffects have been observed in collected imagery.

#### **3.2. Platform Damage**

Our laboratory inspection of flight log files revealed no obvious cause for the interrupted flight and landing. This was surprising as we had expected to see some evidence of what had led to failure.

We searched Internet resources to determine whether others had experienced similar failures. Our searches involved looking for all versions of the M200 series and looking for evidence of failure that was reported since 2018. This includes both the M200 and M210, their different versions (1 and 2), and the M210 RTK which adds RTK capabilities.

The M210 was designed to replace the M200 (V1 and V2). There are very few physical differences between the two platforms in terms of physical measurements but the M210 does offer a slightly higher payload of 1.57 kg as opposed to the 1.45 kg M200 V2 capacity [10]. Beyond these slight differences, there is nothing else that appears markedly different according to DJI specifications. Another non-DJI source reported that the M210 RTK would offer a more stable GPS fix when operating near strong electromagnetic sources such as powerlines [11].

We did not find anything in peer-reviewed literature that detailed M200 series failures. Our searches did find that a number of M200 incidents with loss of control and sometimes subsequent crashes had been reported on the DJI [12] and Matrice Pilots [13] Internet forums.

DJI forum posters reported seven situations when power failure and/or control was lost with M200 series platforms in 2018 in a single thread [14]. A subsequent thread [15] revealed two more failures occurred in 2018. All reported that the platform descended downwards with sometimes serious impacts to the platform. Some reported that the aircraft did not respond at all to the controller during descent and there were no accounts of being able to determine the cause through examining flight logs. Several posters reported that control loss occurred either shortly after liftoff and/or with batteries still having significant charge levels.

The Civil Aviation Authority (CAA) regulates aviation in the United Kingdom (UK). In 2018, the CAA issued a safety notice that suspended the M200 series from flights within 50 m of people, vessels, vehicles, and structures [16]. In addition, flights within 150 m of assemblies of more than 1000 people were also suspended. The reason for these suspensions is that the CAA recorded a “small” number of incidents in which Matrice 200 series platforms lost power and immediately descended. Reportedly, a police force was the first to report such an incident to the CAA when a Matrice 200 series landed on a rooftop. Some DJI resellers operating in the UK recommended grounding all Matrice 200 series until an investigation could be completed. Drone Photography Services [16], a CAA approved UAS firm, reported that failures happened with TB55 (as opposed to TB50) batteries even when loaded with the latest firmware.

In response to the CAA’s suspension rules, DJI created a firmware update that was intended to better monitor and manage M200 series batteries so that power losses were minimized. The CAA issued an update that removed the suspensions given that pilots installed and verified the installation of the updated firmware. Interestingly, we need not find evidence of such concentrated and frequent M200 series failures during the 2018 time period outside of the UK.

An M210 flipped over and fell to the ground from a height of approximately three meters while attempting to land in the UK in March 2019. The aircraft experienced significant damage. The Air Accidents Investigation Branch (AAIB) investigates aircraft accidents in the UK and issued a safety bulletin detailing their investigation. The AAIB [17] reported that the pilot began returning the aircraft to the landing site as rainfall began. The pilot had flown the aircraft several times earlier in the day during light rainfall, and had previously flown several times dur-

ing light rainfall without incident. Aircraft examination by a DJI dealer revealed that an ESC motor interior moisture tag had activated (moisture present) and moisture presence existed on the ESC circuit board. Flight logs indicated that faults had occurred with the two ESCs and were coincident with aircraft control loss.

The M200 series is reported to have an IP43 protection rating by IEC60529 standards and the capability to fly when rainfall does not exceed 10 mm/h [9]. This protection rating is also described as not being permanent and subject to degradation over time.

DJI was presented with incident investigation preliminary results by the AAIB and asked to respond. DJI reported being informed of 44 accidents involving the M200 series worldwide between October 2018 and March 2019 [17]. DJI was unable to determine a failure cause for 17 (39%) of the incidents but the largest number of identified failure causes was 12 (27%) for propeller motor and 4 (9%) each for water damage and hardware damage. Propeller motor failures were claimed to be caused by the motor becoming clogged with dust or other small particles, or through previous damage.

The AAIB recorded 59 UAS accidents occurring between February 2015 and July 2019 with 18 (31%) of these involving a M200 series aircraft [17]. Among the 59 accidents, the largest failure type was technical fault leading to aircraft control loss with 34 (58%) occurrences. Sixteen (47%) of these involved a Matrice 200 series aircraft.

The AAIB [17] attributed the M210 crash to the likelihood that moisture had entered one of the ESC compartments as rainfall increased during the pilot's attempt to land. They recommended that the CAA notify M200 series owners that rain could enter the aircraft compartment and cause sudden control loss.

Reported M200 series failures appear to have peaked in 2018 but there have been additional failures that occurred (Table 2).

**Table 2.** DJI Matrice 200 (M200) failures reported on DJI and Matrice Pilots forums from 2018-2014.

Year	Failures	Location
2018	5	US
	2	Canada
	1	Columbia
	1	Costa Rica
2019	1	US
	1	Brazil
2020	2	US
	2	Germany
	1	Trinidad and Tobago
	1	United Arab Emirates
2022	1	Japan

We verified field-based perceptions of platform damage to the ESCs and supporting extensions (**Figure 3**). Other minor damage was also observed but did not appear to be noteworthy. We established contact with potential repair organizations. One offered a diagnostic exam to determine what repairs would be needed and their approximate cost. The price for the diagnostic exam would be approximately USD 200 and shipping costs would be an additional expense. Another potential service provider suggested that we consider contacting a DJI affiliated repair center but cautioned that they would not be likely to consider repair if the platform chassis had evidence of water penetration. We were advised that DJI places adhesive labels inside the M200 chassis, and these labels would become red in color when exposed to moisture. We disassembled the chassis and discovered a red label.



**Figure 3.** Matric 200 platform during laboratory damage inspection.

We decided not to proceed with platform repair given the risk of moisture potentially impacting both external and internal electrical components, and the nearly three years of flight operations we experienced with the M200. In addition, the M200 was no longer being manufactured and was replaced by the updated M210 version.

#### 4. Recommendations

We experienced technological failure in some portions of the communications, flight, and electrical components that were part of our flight operation. The flight log examination provided no insight into the cause of the failure.

The M200 uses automatic dual frequency band switching between 2.4 and 5.8 GHz for communications, and we are uncertain as to what band was in use at the time of communication failure. Whereas 2.4 GHz has a greater range and is better at penetrating solid objects than 5.8 GHz, it is more prone to interference from other radio emissions [18].

Our belief is that communication between the ground controller and aircraft became interrupted, either due to substantial forest cover causing interference or some electrical component failure. Resultingly, we recommend that pilots operat-

ing in similar landscapes attempt to position themselves in locations that are higher than the flight paths such that tree canopy does not provide potential interference. If this is not possible, pilots might consider positioning themselves in locations that are in larger forest openings or nearer the center of a flight operation such that distances between the controller and platform are minimized. In addition, we recommend that pilots consider limiting communication from the controller to the aircraft to 2.4 GHz rather than 5.8 GHz when operating in conditions similar to ours, which includes operating in an area that does not have other substantial radio communication. We also advise that pilots consult their aircraft user manual for specific controller antenna placement. The M200 manual recommends different controller antenna orientations for the 2.4 and 5.8 GHz frequencies [10].

The numerous 2018 M200 incidents in the UK appear to be the result of battery firmware that required an update. Newer “intelligent” batteries are capable of advanced battery measurement that adaptively delivers power [19]. The two battery models that power the M200 series are examples of intelligent batteries and this trend is likely to continue and develop, as it has with the DJI M300 series aircraft, in subsequent years. These intelligent batteries often require firmware updates so that potential failures can be reduced. Our recommendation is that pilots check regularly to see whether both aircraft and battery firmware are up to date.

Although the M200 series had received an IP43 protection rating that suggested it could be operated in light rain, the AAIB [17] incident report found that this protection is not permanent and is subject to reduced effectiveness over time. Given that electronics are a core function of any UAS operation, flying during any precipitation event should be avoided unless a platform manufacturer can guarantee against moisture damage.

There is also the possibility that dust had accumulated in the chassis of our M200 and interfered with a propeller motor, a potential cause for M200 failure as suggested by DJI in the AAIB [17] report. We had previously flown in dusty conditions during previous riparian restoration studies, but this was not a common occurrence. Our failure experience was most similar to those that were reported in 2018, and there was no evidence of motor clogging in our flight logs, which was evident in the AAIB [17] investigation.

## 5. Conclusion

UAS safety should be a paramount concern for all remote pilots. The threat of an uncontrolled landing could pose threats to human safety and property that may also incur regulatory fines. There were no injuries or property damage that resulted from our flight operation, so no accident reporting was necessary with current FAA regulations [19].

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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