ACCIDENT

Aircraft Type and Registration:	DJI M600 Pro (UAS, registration N/A)	
No & Type of Engines:	6 electric motors	
Year of Manufacture:	2019 (Serial no: 2016DP6137)	
Date & Time (UTC):	13 December 2019 at 1521 hrs	
Location:	Wallsend, Tyne and Wear	
Type of Flight:	Aerial Work	
Persons on Board:	Crew - None	Passengers - None
Injuries:	Crew - N/A	Passengers - N/A
Nature of Damage:	Propellers, arms, landing gear, gimbal and camera lens damaged	
Commander's Licence:	Not applicable	
Commander's Age:	31 years	
Commander's Flying Experience:	44 hours (of which 6 were on type) Last 90 days - 8 hours Last 28 days - 4 hours	
Information Source:	AAIB Field investigation	

Synopsis

The UAS, a DJI M600 Pro, was being operated in an automated flight mode to survey a construction site when a GPS-compass error caused the aircraft to revert to a flight mode that required manual control. By the time that the pilot and observer realised that it was not responding to the return-to-home (RTH) function, visual line of sight was lost when the aircraft drifted with the wind beyond a line of trees. It subsequently collided with the roof of a house before falling into the property's rear garden. No persons were injured.

The pilot, and the observer who was also a pilot, had operated UASs since 2018 and had the required permissions from the UK CAA. Both pilots had relied predominantly on the automated flight capability of their aircraft and had not, nor were required to have, practised for emergencies since completing their flying training in 2018. One Safety Recommendation is made to the UK CAA.

History of the flight

The UAS, a DJI M600 Pro, was being operated commercially[1] to survey a construction site. The aircraft was to be flown using its automated flight mode[2] with the survey scheduled

Footnote

[1] A commercial operation involves a flight or flights 'in return for remuneration or other valuable consideration'. The full definition is available at http://www.legislation.gov.uk/uksi/2016/765/article/7/made (November 2019).

[2] In automated flight mode the aircraft would takeoff, fly between preset positions and then land without the intervention of the pilot.

to take place over two days. The first day's flying passed without incident and, on 13 December 2019, the pilot[3], and an observer who was also a pilot, returned to complete the site survey.

By 1500 hrs, three flights had been completed without incident and the aircraft, with batteries that were almost fully charged at 97%, was being prepared for its final flight of the day. It was positioned to take off from the same location as the previous flight and was configured to climb to 400 ft amsl where it was to then automatically follow a route around the site before returning to land. The pilot held the controller and the observer stood a short distance away. There was no precipitation and the visibility was estimated at 2 km with the wind from a west-south-westerly direction at about 13 kt.

The takeoff was normal but, as the aircraft approached 100 ft amsl (a height of about 65 ft agl), the pilot noticed that a GPS-COMPASS ERROR was displayed on the controller. The aircraft stopped climbing and proceeded to fly in an east-north-easterly direction at a ground speed of about 13 kt, whilst maintaining an altitude of about 100 ft amsl (Figure 1). The pilot and observer reported that they were initially taken by surprise. The pilot then selected the return-to-home (RTH)[4] function on the controller several times, but the aircraft did not respond. Within about ten seconds, the pilot and observer lost visual line of sight (VLOS) with the aircraft when it travelled beyond a line of trees located at the boundary of the construction site. No manual flight control inputs were made using the controller.

The aircraft proceeded to fly overhead a large industrial area before approaching a housing estate located 300 m from where it had taken off. The aircraft had continued to maintain its altitude; however, its relative height above the ground reduced as it approached the housing estate due to the rising terrain. The recorded logs from the aircraft showed that, at 1521:07 hrs, the aircraft collided with the roof of a house before falling into the rear garden of the property (Figures 2 and 3). There were no persons in the garden at the time. The aircraft's propellers, arms, landing gear, gimbal and camera lens were damaged. The flight time from when the GPS-compass error had occurred and the aircraft colliding with the house was 75 seconds. The controller had remained in radio contact throughout the flight.

The pilot subsequently notified the police that the aircraft was missing, before preparing another aircraft to search the immediate area. However, shortly after takeoff, a SIGNAL-INTERFERENCE error message was displayed on the controller and the pilot immediately landed the aircraft. The accident aircraft was subsequently found by the owner of the house who notified the police. The pilot and observer, in accordance with procedures, submitted a safety report within 48 hrs to the EASA[5].

Footnote

[3] The Air Navigation Order 2016 (Amendment 13 March 2019) refers to a person in control of an unmanned aircraft as a remote pilot. In this report, the remote pilot is referred to as 'pilot'.
[4] In normal operation the RTH function would automatically land the aircraft at its takeoff position.
[5] www.aviationreporting.eu (the appropriate website in December 2019).

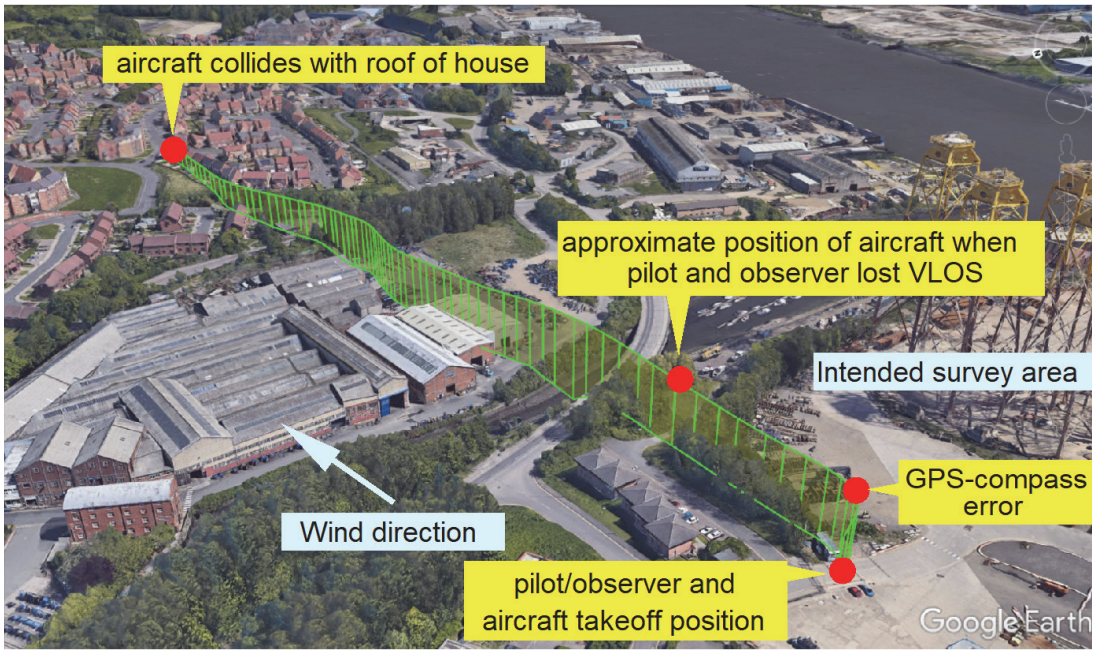

Figure 1

Recorded GPS flightpath of aircraft

Figure 2

Accident location

Figure 3

The aircraft after falling into the garden

UAS information and previous GPS error

The M600 Pro is a six-rotor aircraft and has a maximum takeoff mass of 15.1 kg (Figure 4) and its flight controller is shown in Figure 5. During the accident flight, the aircraft's mass was 12.8 kg, which included an underslung camera. The accident aircraft had been purchased new in August 2019 and had accumulated just over six hours flight time.

Figure 4

M600 series aircraft
The accident aircraft was fitted with three GPS antenna (white circular components)
(photograph used with permission)

Figure 5

M600 Pro aircraft controller

GPS–compass error

The aircraft used a combination of GPS, inertial and magnetic heading (referred to by the manufacturer as 'compass') information to maintain a fixed position when hovering, automatically navigate and to RTH. If either the GPS or compass information is lost, the aircraft will revert to a manual flight mode referred to as attitude (ATTI). In ATTI mode, the aircraft will maintain its altitude and attitude using its internal barometric and inertial sensors, but its position is no longer stabilised by the GPS. This means that the aircraft will drift with the wind in ATTI mode.

When in ATTI mode, the pilot uses the controller's two joysticks to control the aircraft's lateral and vertical position. If ATTI mode is lost, the aircraft will revert to full-manual mode, whereby altitude and attitude stabilisation is not available. The DJI 600 could be placed in ATTI mode by a selection on its controller but it was not possible to select full-manual mode.

The recorded log from the accident flight was analysed by the aircraft manufacturer, who stated that the reversion to ATTI mode had been caused due to a mismatch between the aircraft's GPS derived heading and its magnetic compass heading data. This was attributed by the manufacturer to have been caused by signal interference that had affected the magnetic compass. The error had continued throughout the flight. The manufacturer advised that if the error had subsequently cleared, the automated flight modes would have been re-established.

The pilot reported that some weeks before the accident the aircraft had also reverted to ATTI mode when a problem occurred with the GPS. However, on this occasion the aircraft was being flown in a GPS-assisted mode in combination with joystick control inputs and therefore it had not been necessary for the pilot to quickly transition to using the joysticks as was required during the accident flight. The aircraft was landed safely during this previous event.

Pilot training and emergency procedures

The CAA required that any person or organisation operating a UAS with a mass of no more than 20 kg[6] for commercial work in the UK required permission, which was commonly referred to as Permissions for Commercial Operations (PfCO). The applicant for a PfCO needed to show pilot competence and provide an operations manual, which was required to include actions to take in an emergency. The operator of the accident aircraft held a PfCO and had several trained pilots that operated under this permission.

Pilot competence was demonstrated through a combination of ground training and a practical flight assessment by an authorised training facility. Both the pilot and observer had completed their training in November and October 2018 respectively, which had included flying a multirotor UAS in ATTI mode and dealing with emergency situations such as an uncommanded fly-away.

Footnote

[6] The ANO refers to a UAS falling into this category as a Small Unmanned Aircraft (SUA).

A PfCO was renewed annually and required that each pilot was to have flown at least two hours in the last three months prior to renewal. The CAA did not require, nor provide guidance on, practising for emergencies or maintaining manual flying skills as part of the PfCO renewal. Despite not being a requirement, the pilot and observer had undertaken an additional day of training, part of which involved ATTI mode flying, prior to being assessed.

The operations manual provided by the operator of the accident aircraft included emergency actions to take if an error resulted in reversion to ATTI mode. These instructed the pilot to '*Call ATTI mode and initially maintain the hover to assess the controllability'* and '*If content that control can be maintained then recover the aircraft to the landing point'*.

Discussions with a pilot training organisation for multi-rotor UAS indicated that, like other forms of aviation, manual flying is a perishable skill and that they recommended that UAS pilots should routinely practise manual flying in conjunction with actions to take in an emergency.

Pilot and observer recency

The pilot and observer stated that although they flew their multi-rotor UASs frequently, they were predominantly flown using automated flight modes. Neither the pilot nor observer had practised for emergencies since completing their PfCO training in 2018 although, in a previous incident, the pilot had successfully recovered control of the UAS when it lost GPS and reverted to ATTI mode.

Risk of injury due to falling objects

The AAIB is not aware of any research relating to the potential for injury from a falling UAS. However, in the 1990's a dropped object prevention scheme (DROPS)[7] was introduced as part of a safety initiative by the UK Oil and Gas industry. The program has since expanded to include about 200 organisations, with the development of a DROPS analysis calculator[8]. This provides an indication as to the possible outcome[9] of a blunt object in free fall striking a person wearing personal protective equipment (ie hard hat, eye protection).

Analysis using the DROPS calculator indicated that a blunt object with a mass of more than 2 kg (the mass of the accident aircraft was 12.8 kg) falling from a height of 6 m (~20 ft) agl (the approximate height that the aircraft fell from the roof of the house) could result in a fatal injury to someone wearing a hard hat.

Footnote

7 https://www.dropsonline.org [accessed 16 September 2019]

8 https://www.dropsonline.org/resources-and-guidance/drops-calculator/e-drops-calculator/. This calculates the potential energy of an object (Mass(m) x Height(h) x Gravitational Acceleration). The DROPS Calculator is a guide only and is intended to give a general idea of the potential severity of a dropped object. [accessed 16 September 2019]

9 It is not possible to be definitive due to varying factors such as where an object strikes a person or if it penetrates the body.

Analysis

Following the GPS-compass error, the aircraft had reverted to ATTI mode. This required the pilot to take manual control of the aircraft to control its flightpath. However, the pilot and observer focused their attention on selecting the automated RTH function, but this mode was not available due to the GPS-compass error. The controller was in radio contact with the aircraft, which would have responded to manual flight control inputs had they been made.

Within about ten seconds of the error occurring, the pilot and observer lost VLOS with the aircraft when it drifted with the wind beyond a line of trees. After this, a safe landing was unlikely due to the built-up nature of the surrounding area and the lack of references available to the pilot of the aircraft's relative position, heading or height.

The aircraft manufacturer attributed the GPS-compass error to signal interference that affected the aircraft's compass. This interference had remained present for the duration of the short flight. The evidence indicates that this interference also affected the aircraft that was to be used to search for the accident aircraft. The source of the interference was not established.

The DROPS analysis indicated that a mass of more than 2 kg falling from the roof of the house could have resulted in a serious or even fatal injury to people if they had been struck. The aircraft mass, at 12.8 kg, was well in excess of this figure and therefore it is very likely that serious injuries would have occurred even if the person struck was wearing a hard hat for protection.

The aircraft operator's operations manual provided actions to take in the event of an emergency, which included the need to take manual control if an error resulted in the aircraft reverting to ATTI mode. However, the last time that the pilot and observer had practised for emergencies was when they had completed their training in 2018. This training had included an additional voluntary day that involved flying a UAS in ATTI mode but, since then, their day-to-day operations had meant that the ATTI mode was not used routinely and therefore pilots were not well-practised using this mode.

There is currently no requirement for operators to routinely practise for emergencies, such as an uncommanded fly-away. However, manual flying is a perishable skill that UAS operators may need to rely on in the event of an emergency. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2020-017

It is recommended that the Civil Aviation Authority require that operators issued with a Permissions for Commercial Operations (PfCO) include in their operations manuals the need to practise routinely the actions to take in the event of emergencies, and specify how pilots will remain competent at maintaining manual control of their aircraft in the event that automated flight modes are lost.

Conclusion

The pilot was required to take manual control of the aircraft following the loss of its automated flight modes due to signal interference. However, no manual control inputs were made, and the aircraft subsequently drifted with the wind until it collided with a house roof and fell to the ground. No persons were injured.

Operators holding a PfCO issued by the CAA are not currently required to practise routinely for emergencies or demonstrate the ability to fly their aircraft in a degraded flight mode. These skills are perishable but, as this accident shows, they may be needed at any time; it is important that they are maintained to prevent a risk of injury to people or damage to property. To address this, one Safety Recommendation has been made to the CAA.

Safety action taken

The operator of the accident aircraft stated that it had taken the following safety action:

> The operator's pilots have undergone refresher training on responding to emergency situations and operating their multi-rotor UASs in the ATTI flight mode.

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