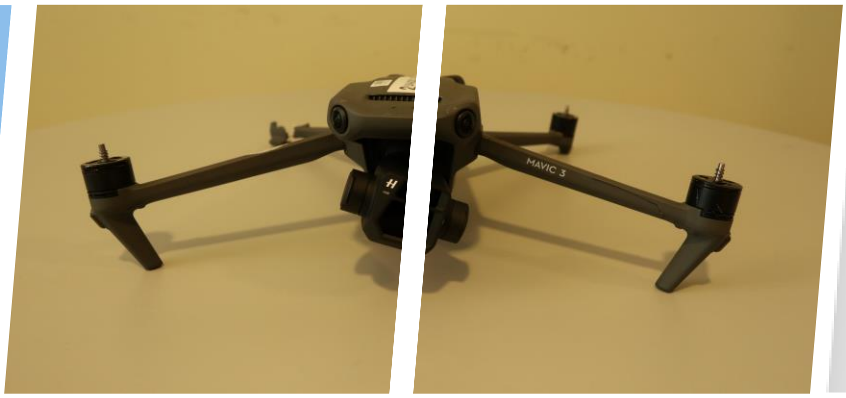
Norwegian Safety Investigation Authority



Issued May 2024

REPORT AVIATION 2024/04

Aviation incident in Bergen on 26 August 2022 involving a DJI Mavic 3 drone, LN-02023CM, operated by TV 2 Luftfoto

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving aviation safety.

The object of the NSIA's investigations is to clarify the sequence of events and causal factors, elucidate matters deemed to be important to the prevention of accidents and serious incidents, and to issue safety recommendations if relevant. It is not the NSIA's task to apportion blame or liability under criminal or civil law.

This report shall not be used for purposes other than preventive aviation safety work.

Photo: NSIA

Legal authority for the Norwegian Safety Investigation Authority's activities is enshrined in Section 12-1 of the Act of 11 June 1993 No 101 relating to aviation (Aviation Act); cf. Section 3 of the Regulations of 7 July 2016 No 906 on public investigations of accidents and incidents in civil aviation.

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report for reference.

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Report on aviation incident

Table 1: Data relating to the incident.

Type of aircraft:	DJI Mavic 3 drone
Nationality and registration:	Norwegian, LN-0203CM
Owner:	TV 2 Luftfoto
Operator:	TV 2 Luftfoto
Personal injuries:	One person sustained minor injuries
Material damage:	Broken window in building and broken drone
Location:	Bryggen in Bergen
Time of incident:	26 August 2022 at 1143 hrs

All times given in this report are local times (UTC + 2 hours) unless otherwise stated.

Notification

At 1220 hrs on 26 August 2022 the NSIA on-duty inspector was notified of the incident by the TV 2 Luftfoto manager in charge, and informed that a drone had crashed through a window of a building at Bryggen in Bergen after the drone pilot lost control of the drone.

Summary

The incident took place while TV 2 Luftfoto was practising drone flying in preparation for covering a triathlon competition starting from Bryggen in Bergen. Shortly after take-off on Friday 26 August 2022, the pilot lost control of the DJI Mavic 3 drone. The drone with registration LN-0203CM stopped responding to stick commands from the drone pilot. It flew at high speed towards a building and crashed through a third-floor window. A person who was in the room at the time suffered minor injuries. It has not been possible to determine the reason why the pilot lost control of the drone, but it appears to be associated with the transition between *ATTI mode* and *Tripod mode* under inadequate GPS levels.

The drone was operated in open category and should thus be flown in an environment where there is low risk of harming people at the ground or other aircrafts. A pre-flight risk assessment is not necessarily valid when the pilot loses control of the drone. Based on incident reporting to the NSIA, loss of control appears to be a likely event when operating a drone in this category. As this incident had clear indications of being caused by a technical malfunction and the operator was professional with long experience from operating drones, the NSIA chose to investigate the incident even if it is not mandatory according to EU directives. The flight was not performed in compliance with the requirements for open category A2.

The NSIA has discussed a few possible scenarios, including signal blockage, that can cause a drone to stop responding to stick commands from the drone pilot. The most likely scenario is that the incident occurred because a function of the drone unintentionally took control of the flight.

After the accident, the NSIA has found it challenging to obtain assistance from the drone manufacturer DJI to decrypt and analyse the flight record and to answer our technical questions. It took ten months for the NSIA to receive the manufacturer's analysis of the sequence of events. Although DJI have answered questions during the investigation some questions remain unanswered. The NSIA is also aware of two other investigations, in Great Britain and in the Netherlands, where the investigating authorities have found it difficult to obtain information from the manufacturer. After these investigations DJI received two safety recommendations to improve their process for cooperation with safety investigators.

The investigation has shown that there is no authority with a mandate to force a manufacturer of drones placed onto the European marked with a CE-declaration to support safety investigations. Given that the Safety Investigation Authorities is not supported the investigation has shown that there is no other body capable of performing detailed technical review of DJI unmanned aircraft systems.

The NSIA submits three safety recommendations following the investigation. The NSIA recommends that the European Commission implement legislation where a manufacturer of all unmanned aircraft systems can face sanction for failing to support safety investigations. The NSIA also recommends the European Commission to mandate an authority to review DJI's drones to determine whether they maintain the necessary level of safety.

One safety recommendation is also addressed to the Civil Aviation Authority (CAA) Norway in which they are asked to provide information to the national drone operators of the possible design flaw that affects DJI Mavic 3 when exiting ATTI[1] mode.

[1] 'ATTI mode' is an abbreviation for 'Attitude' mode, which means that the drone will maintain its orientation, but the stabilisation algorithm will not keep the drone hovering in place. The drone will thus 'float' on the wind in both the vertical and the horizontal plane.

About the investigation

Purpose and method

The purpose of the investigation has been to determine what caused the pilot to lose control of the drone. The NSIA has also considered what can be done to improve safety and prevent the recurrence of similar incidents and damage and injury in future.

The incident has been investigated and analysed in line with the NSIA's framework for systematic safety investigations (the NSIA method[2]).

Sources of information

- Data from the drone in question and from other drones.
- Interviews with the drone pilot and TV 2 Luftfoto's operational manager.
- TV 2 Luftfoto's operations manual (OM).
- Information and analysis of the flight record log from DJI.

The investigation report

The first part of the report, 'Factual information', describes the history of the flight, related data and information gathered in connection with the incident, as well as a description of the investigation and related findings.

The second part, the 'Analysis' part, contains the NSIA's assessment of the sequence of events and contributing causes based on the factual information. Circumstances and factors found to be of little relevance to explaining and understanding the incident are not discussed.

The final part of the report contains the NSIA's conclusions and safety recommendations.

[2] *See https://www.nsia.no/About-us/Methodology*

1. Factual information

1. Factual information

1.1 History of the flight

The drone pilot was working for TV 2 as a photographer and drone pilot for TV 2 Luftfoto.

World Triathlon Cup Bergen 2022 was being held, and TV 2 had asked TV 2 Luftfoto to film the swimming segment of the event. The swimming took place from Bryggen in Bergen.

The drone pilot and TV 2 Luftfoto's operational manager were to carry out the flight with streaming live images from drones. The drone pilot accepted the assignment on the condition that he was given time to prepare properly.

Three days before the assignment, the drone pilot tested a DJI Mavic 3 drone. He flew for about an hour with no indication of malfunction. During this time he also took the opportunity to disable the drone's obstacle avoidance system to gain experience on how the drone responded.

The day before the assignment, the drone pilot, his airspace observer and TV 2 Luftfoto's operational manager met at Bryggen in Bergen to plan where the drone should hover during the competition. The operational manager would be filming using a DJI Air2S drone. The airspace observer was to stand right next to the drone pilot. They agreed not to fly higher than 30 metres.

As part of the preparations for this flight, the drone pilot checked the weather, wind and local obstacles. No obstacles were identified, and the obstacle avoidance system was disabled to avoid interference with the picture. Visibility was good, with sun and little to no wind.

The drone pilot flew out over the harbour area to check whether conditions had changed since the training flight two days earlier. He estimated that the drone was about 10–15 metres out over the harbour from his position and flying at an altitude of 10–15 metres. The operational manager then took off with the DJI Air2S and positioned it a little below and to the left of the drone pilot's Mavic 3.

The drone pilot then noticed that the drone began to move on the screen of the remote controller and therefore looked up at the drone, which was moving slowly towards a building at Bryggen. The drone pilot tried to counteract the drone's movements by means of the control sticks on the remote controller. The drone did not respond, and the pilot did not perceive to have any contact with the drone. The remote controller did not display any indication of faulty communication between the remote controller and the drone. The drone pilot has stated he saw the express boat Vingtor arrive and noted that several boats in the harbour had radar equipment.

He informed the operational manager that he had lost contact with the drone. The drone accelerated towards a building at Bryggen. The other drone pilot, the operational manager, experienced no problems with his drone.

The drone crashed through a triple-glazed window before ending up on the floor of a break room where people were having lunch. The pilot ran up to the room and asked whether anyone had been injured. One person had suffered minor cuts. He then called the police and had the room locked.

The drone pilot has later described the acceleration as reminiscent of something the drone can do in Sport mode. The drone pilot tried in vain to put the drone in Tripod mode,[3] but the drone did not slow down. He saw that there were people in the street between the drone's position and the

[3] Flight modes are described in more detail in chapter 1.6

building it was heading towards, so he did not want to cut power to the motors and risk that the drone might injure persons on the ground. The function to cut power to the motors needs to be enabled before it will work.

Following the incident, TV 2 Luftfoto grounded all drones weighing more than 250 g pending the NSIA investigation.

1.2 Injuries to persons

Table 2: Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	Not applicable	Not applicable	0
Serious	Not applicable	Not applicable	0
Minor/none	Not applicable	Not applicable	1

1.3 Damage to aircraft

The drone sustained damage to four propellers and a motor arm. The drone's gimbal came off its fastenings.

1.4 Other damage

The drone broke a window leading into a break room in a building.

1.5 Personnel information

The drone pilot had first qualified as an RO[4] operator before taking the A2 course and exam. He piloted drones as much as practicable, but found it challenging to fly the number of hours stipulated in TV 2's operations manual (OM) to retain his rights. For various reasons, he had not managed to fly for more than 5.5 hours in 2022.

Table 3: Flying experience, drone pilot

Flying experience	All types	On type
Last 24 hours	00:00:00	00:00:00
Last 3 days	01:02:52	01:02:52
Last 30 days	01:54:24	00:00:00
Last 90 days	02:52:42	00:00:00
Total	33:12:00	01:02:52

[4] *Drone operator flying under previous regulations.*

1.6 Aircraft information

1.6.1 GENERAL INFORMATION

DJI Mavic 3 is an unmanned aircraft with four motors, each of which have its own rotor. The aircraft weighs 895 g and has a maximum speed of 19 m/s (68 km/h). The drone is equipped with sensors pointing upward, backward, forward and downward, in addition to an infrared sensor at the bottom of the drone. All these sensors can detect obstacles in the drone's flight path if the obstacle avoidance system has been activated via the DJI Fly app on the remote controller. The Mavic 3 drone had a CE declaration and was known as a legacy drone. The same drone with a newer firmware version is compliant with the requirements for a C-mark.

Figure 1: DJI Mavic 3 drone. Photo: DJI / NSIA

Table 4: Drone specifications. Source: DJI/ NSIA

Registration	LN-0203CM
Model designation	DJI Mavic 3
Serial number	1581F45TB21AQ1BE00TZ
Firmware	01.00.0500

The drone can be flown in winds of up to 12 m/s (43 km/h). The drone has as camera attached to a gimbal. In accordance with the drone's specifications, the gimbal is stated to have a range of motion in relation to the drone as shown in Table 5.

Table 5: Gimbal range of motion. Source: DJI / NSIA

Axis	**Mechanical range**
Tilt	-135°, 100°
Roll	-45°, 45°
Pan	-27°, 27°

The drone is operated using a remote controller, and the drone pilot can choose between three different modes: Normal (also referred to as *P-GPS*), *Tripod* and *Sport*.

The drone is manoeuvred by differentiating power from the four motors. It can ascend or descend, rotate right or left on its own axis, fly to the left or right, and fly backward and forward.

The drone automatically switches to *ATTI mode* if it loses sufficient satellites to stabilise its flight.

1.6.2 THE REMOTE CONTROLLER

The pilot can control the drone using a remote controller with an integrated screen, known as a *smart controller*. The specifics for the remote controller make and model are shown in Table 6.

Table 6: Remote controller specifications. Source: DJI / NSIA

Type	DJI RC Pro
Model designation	RM510
Serial number	4QQZJAL0020J5J
Android	Version 11
DJI Fly app	V 1.5.9
Firmware	03.01.0500

The remote controller features a combination of control sticks, buttons and dials to control the drone's flight path and the horizontal angle of the camera head as well as to take pictures or record video, and also to initiate the *Return to home* feature. Above the screen in the centre of the remote controller, there is a sliding switch that is used to select 'C', 'N' or 'S' mode. These modes are described in sections 1.6.4 to section 1.6.7.

Figure 2: DJI Smart controller. Photo: DJI / NSIA

1.6.2.1 The control sticks

There are two control sticks above the screen on the remote controller, as shown in Figure 2. Each stick can be moved forward and aft, and left and right thus controlling two axes.

Both sticks are spring-loaded and therefore self-centring. This means that if the pilot releases a control stick, it will automatically return to the centre position.

The left stick controls the drone's ascent and descent, as well as its movements around its vertical axis. If the left control stick is moved backward or forward, the drone will descend or ascend, which is referred to as *RC throttle* in the flight record. If the left control stick is moved left or right, the drone will turn to the left or right around its vertical axis. This is referred to as *RC rudder* in the flight record.

The right control stick controls the drone's ability to move backward and forward, as well as its movements around its longitudinal axis. If the right control stick is moved backward or forward, the drone will move backward or forward. This is referred to as *RC elevator* in the flight record. If the right control stick is moved left or right, the drone will move around its longitudinal axis. This is referred to as *RC aileron* in the flight record.

1.6.2.2 Warnings

If the drones register deviations from normal flight, warning messages will be displayed on the remote controller's screen in the *DJI Fly* app. The warnings can be visual messages on the screen only or visual warning accompanied by an audible warning. The warnings are intended to inform the pilot about mode changes or action the pilot needs to take.

1.6.3 COMMUNICATION BETWEEN DRONE AND REMOTE CONTROLLER

The drone and the remote controller communicate with each other on two different frequencies. Stick commands are transmitted and received on the 2.4 GHz frequency band, while video is transmitted on 5.8 GHz. The drone's user manual contains a warning against operating other equipment on the same frequency. This warning is shown below.

> *Do not use other wireless devices operating at the same frequency as the remote controller. Otherwise, the remote controller will experience interference.*

1.6.4 NORMAL (P-GPS) MODE

The drone pilot selects the Normal (*P-GPS*) mode by sliding the flight mode switch on the remote controller to 'N', see Figure 2. The flight record designates this mode as *P-GPS*.[5] In this mode, the drone uses satellite navigation and the sensors looking forward, backward, sideways, upward and downward as well as the infrared sensing system to confirm its position and stabilise itself in a fixed position. The following specifications/limits are listed for *P-GPS* mode in the Mavic 3 User Manual:

Table 7: Limitations in P-GPS mode. Source: DJI / NSIA

Function	Limitation
Max. ascent/descent speed	6 m/s
Max. horizontal speed (no wind)	15 m/s
Max. tilt angle	30°

1.6.5 SPORT MODE

The drone pilot selects the *Sport mode* by sliding the flight mode switch on the remote controller to 'S'. The drone uses satellite navigation to confirm its position and stabilise itself while airborne. The obstacle avoidance system is disabled in this mode, and the maximum flight speed is also higher than in P-GPS mode. The following specifications/limits are listed for Sport mode in the Mavic 3 User Manual:

[5] *Position GPS.*

Table 8: Limitations in Sport mode. Source: DJI / NSIA

Function	Limitation
Max. ascent/descent speed	8/6 m/s
Max. horizontal speed (no wind)	21 m/s
Max. tilt angle	35°

1.6.6 TRIPOD MODE

The drone pilot selects the *Tripod mode* by sliding the flight mode switch on the remote controller to 'C' (Tripod mode is also called 'Cinematic', hence the letter C). In this mode, the drone uses the same sensors as in P-GPS mode, but with higher speed limitation then in *P-GPS mode*. The following specifications/limits are listed for *Tripod mode* in the Mavic 3 User Manual:

Table 9: Limitations in Tripod mode. Source: DJI / NSIA

Function	Limitation
Max. ascent/descent speed	1/5 m/s
Max. horizontal speed (no wind)	5 m/s
Max. tilt angle	25°

1.6.7 ATTI MODE

ATTI is the only mode that cannot be manually selected by the drone pilot.[6] The drone automatically enters this mode if it loses GPS signal during flight. *ATTI mode* is an abbreviation for Attitude mode, which means that the drone will maintain its orientation, but the stabilisation algorithm will not keep the drone hovering in place. The drone will thus 'float' on the wind in both the vertical and the horizontal plane. An excerpt from the user manual describing *ATTI mode* is shown below.

> *The aircraft automatically changes to Attitude (ATT) mode when the Vision systems are unavailable or disabled and when the GNSS signal is weak or the compass experiences interference. In ATTI mode, the aircraft may be more easily affected by its surroundings. Environmental factors such as wind can result in horizontal shifting, which may present hazards, especially when flying in confined spaces.*

1.6.8 SAFETY FUNCTIONS IN THE DJI FLY APP

The drone pilot can set up some safety functions in the *DJI Fly* app on the remote controller before take-off, namely the *Obstacle avoidance* and *Return to home* functions.

The obstacle avoidance system uses the drone's sensors to detect obstacles and actively prevent the drone pilot from flying the drone into them. For this flight, the function was disabled which means that the drone would not attempt to avoid obstacles.

Failsafe Return to home (RTH) is a function that controls how the drone will react if it loses contact with the remote controller. The function can be set for the drone to return to the home point, land or

[6] *Certain other DJI drones, for example the Phantom 4, can be set to ATTI mode by the drone pilot.*

hover in place. For this flight, the function was set to return to the home point at an altitude of 100 metres. The altitude set for *Return to home* must be considered in relation to local obstacles in the area where the drone will be flying. The maximum altitude of 120 meters for drone flights always applies.

1.6.9 STABILISATION ALGORITHM

The drone's stabilisation algorithm can keep the drone hovering in place in the *P-GPS*, *Tripod* and *Sport* modes. If the drone is affected by wind while hovering, the stabilisation algorithm will apply motor power to counteract the effect of the wind. The drone will compensate for as long as it has the motor power to remain in position. If the drone registers deviations that the pilot needs to know about, warning messages will be displayed on the remote controller's screen. If the drone does not have a sufficient number of satellites to calculate its GPS position with sufficient accuracy, it will switch to ATTI mode.

1.6.10 DIRECTIONAL SENSORS

The drone's camera is mounted on a gimbal, which has a degree of free movement in relation to the drone. This means that both the drone and the gimbal are equipped with sensors to determine their orientation.

1.6.11 MAVIC 3 COMPLIANCE

The European Commission publishes directives containing requirements aimed at consumer products before they can be placed onto the European marked. Compliance with requirements from all applicable EU directives for a product is required before a company can perform a self-declaration entitling them to put a CE-mark on the product.

The DJI Mavic 3 drone was placed onto the European marked with a CE declaration station compliance with the following EU directives:

- Radio Equipment Directive (RED) EU 2014/53
- Restriction of Hazardous Substances (RoHS) EU 2015/863
- Waste from Electrical and Electronic Equipment (WEEE) EU 2012/19
- Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) EC 2006/1907

A Mavic 3 with firmware 01.00.900 or later had a C1 certificate issued by Tüv Rheinland, Germany, in accordance with the requirements set out in Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems. This drone did not have C1 compliant firmware.

1.7 Meteorological information

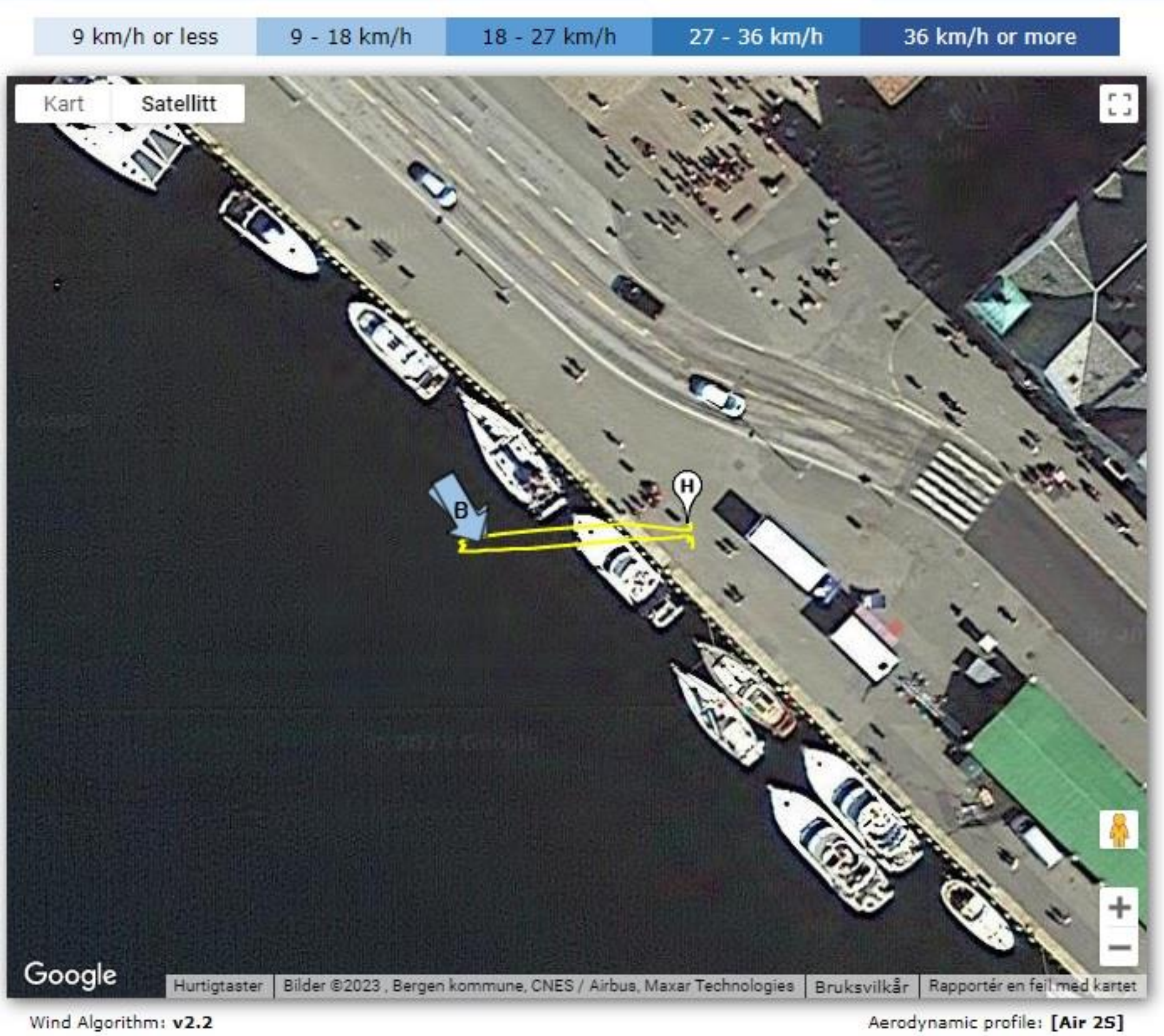
1.7.1 WEATHER REPORT FROM THE NORWEGIAN METEOROLOGICAL INSTITUTE

The NSIA has asked the Norwegian Meteorological Institute to prepare an extended weather report.

> *Observations indicate that wind conditions were fairly calm during the period in question. The wind direction was from west-northwesterly and the wind speed below 6 m/s. The wind speed at altitude (Liatårnet on Sotra island) did not exceed 6 kt.*
> *Strongest gust between 1100 and 1200 hrs: 6 m/s*
> *Direction of strongest mean wind between 1100 and 1200 hrs: 336 degrees (NW)*

1.7.2 WEATHER DATA REGISTERED BY THE DRONE

The operational manager flew his DJI Air2S drone at the same time as the drone pilot. Wind data from DJI Air2S were used in the investigation because Mavic 3 did not record a sufficient number of datapoints before it crashed.



	Flight time	Altitude	Home Distance	Wind Direction	Wind Speed
A	00m 20s	13.7 m	0.02 km	323°	12.49 km/h
B	00m 25s	13.5 m	0.02 km	319°	17.17 km/h
C	00m 30s	13.7 m	0.02 km	331°	16.63 km/h
D	00m 35s	12.7 m	0.02 km	334°	14.83 km/h

Figure 3: Wind calculation based on data from Mavic Air2S drone in the same area during the period in question. Source: TV 2 / NSIA

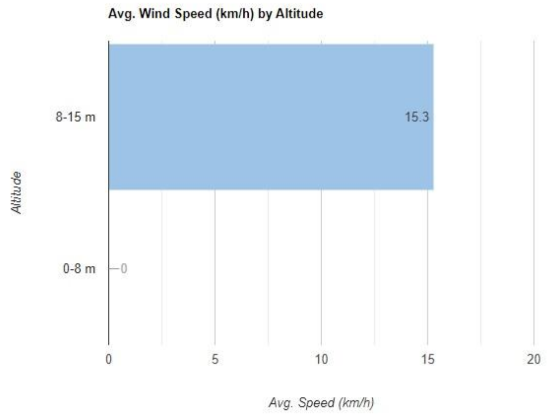


Figure 4: Wind speed at altitude registered by DJI Air2S Source: TV 2 / NSIA

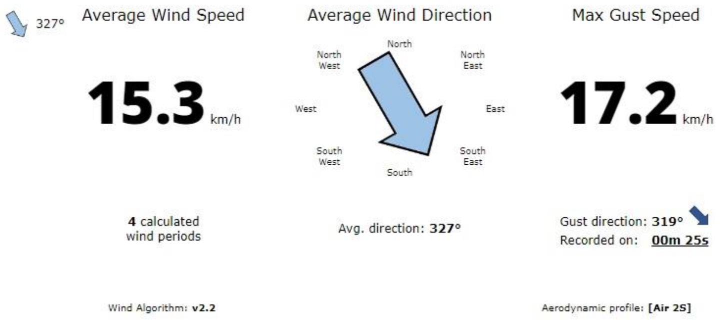


Figure 5: Wind speed and direction registered by DJI Air2S. Source: TV 2 / NSIA

1.7.3 REPORT FROM THE NORWEGIAN MAPPING AUTHORITY

The NSIA asked Norwegian Mapping Authority to assess if there were space-disturbances that could impact GPS signals. They stated that Kp index is used as an indication of GPS signal disturbance. A Kp index of 5 represents *Minor Geomagnetic Storm*. The day of the flight only values less than one was registered. There were no other indications of abnormal events.

1.8 Aids to navigation

The flight with LN-0203CM took place under visual line of sight rules for drones. Navigational aids were therefore neither required nor used.

1.9 Communications

The drone pilot had no ground-to-air radio, nor is this required during VLOS flight.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The drone is equipped with several recording devices, both on board the drone, on the remote controller and in the DJI Fly app.

1.11.1 DATA FILE FROM THE DRONE

A data file (.DAT) is created by the drone every time the drone is started. This data file contains a number of variables. When the NSIA received the drone from TV 2 Luftfoto, there was no data file for the flight in question stored on it. The NSIA later received an export file from DJI Assistant, which TV 2 Luftfoto uses to upload flight records, but has been unable to locate the DAT file for the flight among the data.

1.11.2 RECORDING FROM THE FLIGHT

For every flight started with a drone and its remote controller, a flight record will be created and stored in the remote controller's app. The file will be named according to the following format: 'DJIFlightRecord_Year_Month_Day_[time].txt'. The file is stored in the remote controller's file system and can be exported from the remote controller. The file can be retrieved from a smart controller or from the tablet or telephone used to operate the drone. The file can then be copied onto a memory card and exported for further decryption and analysis.

The retrieved file is encrypted and must be decrypted before it can be read in plain text. The NSIA has used the Flight Reader software for the decryption but is aware that other free sources exist that could do the job as well. The file generated by Flight Reader is a csv[7] file that contains a maximum of 168 data fields for each time sample. The data fields are divided into the following categories (number of data fields in each category in brackets): custom (2), osd (52), gimbal (9), camera (5), rc (17), battery (32), mc (1), home (22), recover (7), details (15), appgps (3) and app (3). Flight Reader decrypts the flight record and presents the data. The NSIA has been in contact with the Flight Reader developer, who confirms that program only reads the data available and does not alter any values.

The data fields used in the analysis of the flight record are described in more detail in Appendix A.

The flight record shows that the drone used several modes during this flight, including Normal (P-GPS). Table 10 presents an overview of the modes used during the flight, and the corresponding time slots. The table shows both UTC time and a timeline starting at the first datapoint. Data from the flight record are presented graphically in Appendix C. This section breaks down the content of the flight record into the different modes used. This is necessary because different modes may entail different restrictions or options as described in section 1.6. It is therefore not enough to see data for the flight as a whole without information about the mode in which they arose.

Table 10: Overview of modes used during the flight. Source: TV 2 / NSIA

Mode	Start [local time]	Start timeline	End [local time]	End timeline
Starting motors	9:43:12.69 AM	0 m 0.1 s	09:43:14.11 AM	0 m 1.5 s
Manual takeoff	09:43:14.21 AM	0 m 1.7 s	09:43:23.54 AM	0 m 11.1 s
P-GPS	09:43:23.74 AM	0 m 11.3 s	09:43:34.85 AM	0 m 22.3 s
ATTI	09:43:35.05 AM	0 m 22.5 s	09:44:00.17 AM	0 m 47.7 s
Tripod	09:44:00.46 AM	0 m 47.9 s	10:42:13.72 AM	0 m 53.7 s

Data from the flight record are provided in their entirety in Appendix B and graphically in Appendix C. A timeline will be established where each mode with datapoints for GPS, compass errors, stick movements registered, the altitude at which the drone was flying and the power consumption recorded, will be shown.

1.11.3 REGISTERED DATA FROM PREVIOUS FLIGHTS

The NSIA has been given access to flight records from 28 previous flights made by the drone. These records have been reviewed to uncover incidents where the drone had previously switched into *ATTI mode*. During one of the 28 flights the record indicated that the drone had switched to *ATTI mode* while connected to seven satellites and with a GPS level indicating 0. The drone remained in *ATTI mode* for 28.6 seconds. In the following datapoint after 28.8 seconds the drone switched back to Sport mode. The GPS level was still 0.

[7] *Comma separated values*

1.11.4 DATA FROM AIRDATA

The drone operator TV 2 Luftfoto used Airdata[8] to store flight data records for all drone flights. The NSIA has been given access to Airdata links for the incident flight and other relevant flights with the same drone, and screenshots showing relevant data from the program are included in the present report. In addition to showing telemetry data from the drone, Airdata can calculate wind directions and wind speeds.

Figure 6 shows the flight path for the incident as registered in Airdata. Note that a flight path is illustrated by a line, in this case yellow, only in cases where the drone had access to a sufficient number of satellites to be able to calculate its GPS position.

Figure 6: Flight path for the flight in question. Source: TV 2 / NSIA

[8] *Web-based solution to upload records after completing a drone flight.*

	Flight time	Altitude	Home Dist	Type	Notification
	00m 00s	0.0 m	0 km	Mode	Mode changed to Motors Started
	00m 00s	0.0 m	0 km	Low Risk	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30014). Check whether the propellers are attached to the correct motors based on their markings. Incorrect installation will cause the aircraft to roll over
	00m 00s	0.0 m	0 km	Tip	Setting new Return-To-Home altitude to 100m (328 ft). Data Recorder File Index is 53. Setting new Maximum Flight Altitude to 30m (98 ft)
	00m 01s	0.0 m	0 km	Low Risk	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30014)
	00m 01s	0.0 m	0 km	Mode	Mode changed to Assisted Takeoff
	00m 11s	0.0 m	0 km	Mode	Mode changed to P-GPS
	00m 22s	25.0 m	0 km	Mode	Mode changed to Atti
	00m 22s	25.0 m	0 km	Tip	Attitude mode (Max altitude 30m)
	00m 22s	25.0 m	0 km	Low Risk	Aircraft in Attitude mode. Unable to hover. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30016). GPS signal weak. Switched to Attitude mode. Aircraft unable to hover. Fly with caution (Code: 30022)
	00m 22s	25.7 m	0 km	Low Risk	Compass or GPS signal weak. Changed to Attitude mode (Code: 30020). Aircraft in Attitude mode. Unable to hover. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30016)
	00m 47s	26.8 m	0 km	Low Risk	Aircraft in Attitude mode. Unable to hover. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30016)
	00m 47s	26.8 m	0 km	Mode	Mode changed to Tripod
	00m 47s	26.8 m	0 km	Low Risk	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30014)
A	00m 48s	26.9 m	0 km	Mode	Mode changed to Tripod
B	00m 50s	27.3 m	0.00 km	Tip	GPS signal weak (Max altitude 30m)
C	00m 50s	27.3 m	0.00 km	Low Risk	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30014)
D	00m 53s	24.3 m	0.06 km	Tip	No image transmission signal. Aircraft not connected to RC
E	00m 53s	24.3 m	0.06 km	Medium Risk	Image transmission signal lost (Code: 80001). GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30m (Code: 30014)
	00m 53s	24.3 m	0.06 km		86% Battery at maximum distance

Figure 7: Flight record as shown in Airdata. Source: TV 2 / NSIA

Figure 8 shows how the Kp index, which is an index for geomagnetic disruption of the signal between the drone and remote controller, is calculated.

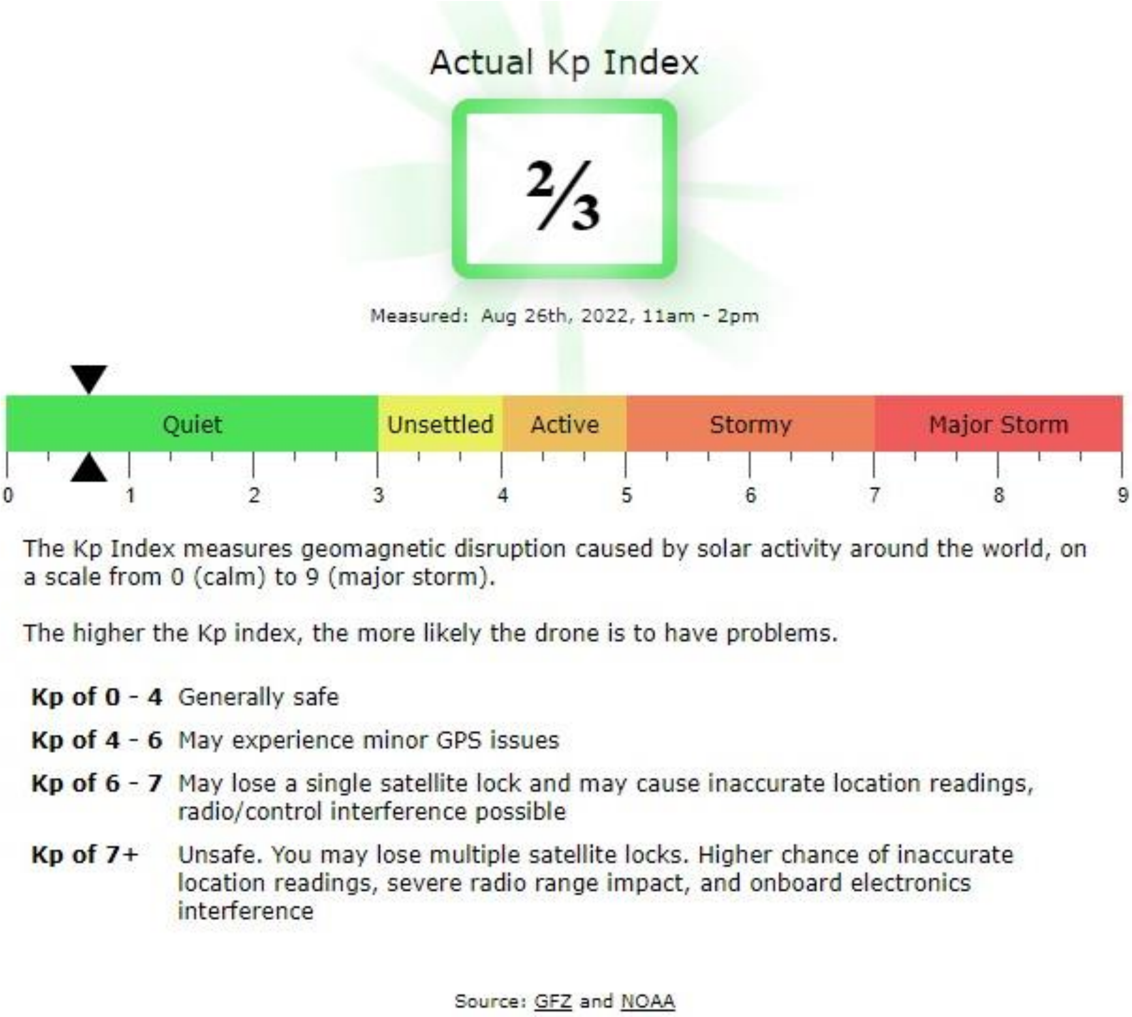


Figure 8: Kp index from Airdata. Source: TV 2 / NSIA

1.12 Wreckage and impact information

The drone flew through a triple-glazed window on the third floor of a building at Bryggen in Bergen. The drone was found lying on its back about one metre into the room. One of the persons having lunch inside the room suffered minor cuts to the head. Figure 9 is a photo taken from inside the room where the drone crashed through the window.

Figure 9: Damage to the window the drone crashed through. Source: Police / NSIA

Figure 10: Damage to the drone. Source: The police / NSIA

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 TEST FLIGHTS WITH DJI MAVIC 3 DRONE

The NSIA has conducted test flights with a DJI Mavic 3 drone to see how long it takes the drone to find enough satellites to be able to fly safely. The tests showed that it could take anything from 0.2 up to 14 seconds in the same geographical location. The drone may take longer time to obtain the required number of satellites if operated on new geographical locations.

1.16.2 FLIGHT RECORD ANALYSIS

The NSIA has been in contact with the drone's manufacturer, DJI, on several occasions during the investigation. DJI has been asked to help to decrypt the flight record and analyse its content. At the insistence of the NSIA, DJI analysed the sequence of events and produced a report. The conclusion from the report is shown in Figure 11 and the graphic representation in Figure 12.

Product Model: DJI Mavic 3 **SN:** 1581F45TB21AQ1BE00TZ

Additional Information:

Time: 2022-08-26 17:42:39 UTC+8 **Data:** FLY053

1. The aircraft worked under OPTI mode after it took off due to the weak GPS signal;

2. Flight Time T=67.4 s, Relative Height H= 24.7 m, the aircraft switched into ATTI mode;

3. T=93.8 s, H=26.9 m, the aircraft obtained the GPS signal and switched into Tripod mode, but the GPS signal was still too weak;

4. T=98.7 s, H=24.3 m, due to the weak GPS signal, the aircraft could not hover in place, then it drifted away and crashed with the obstacle;

5. The aircraft could not hover in place, brake, and avoid obstacles automatically if the GPS signal is weak. Please fly with caution.

Conclusion: The incident was caused by the operation error of the pilot.

Figure 11: Analysis and conclusion from DJI. Source: DJI / NSIA

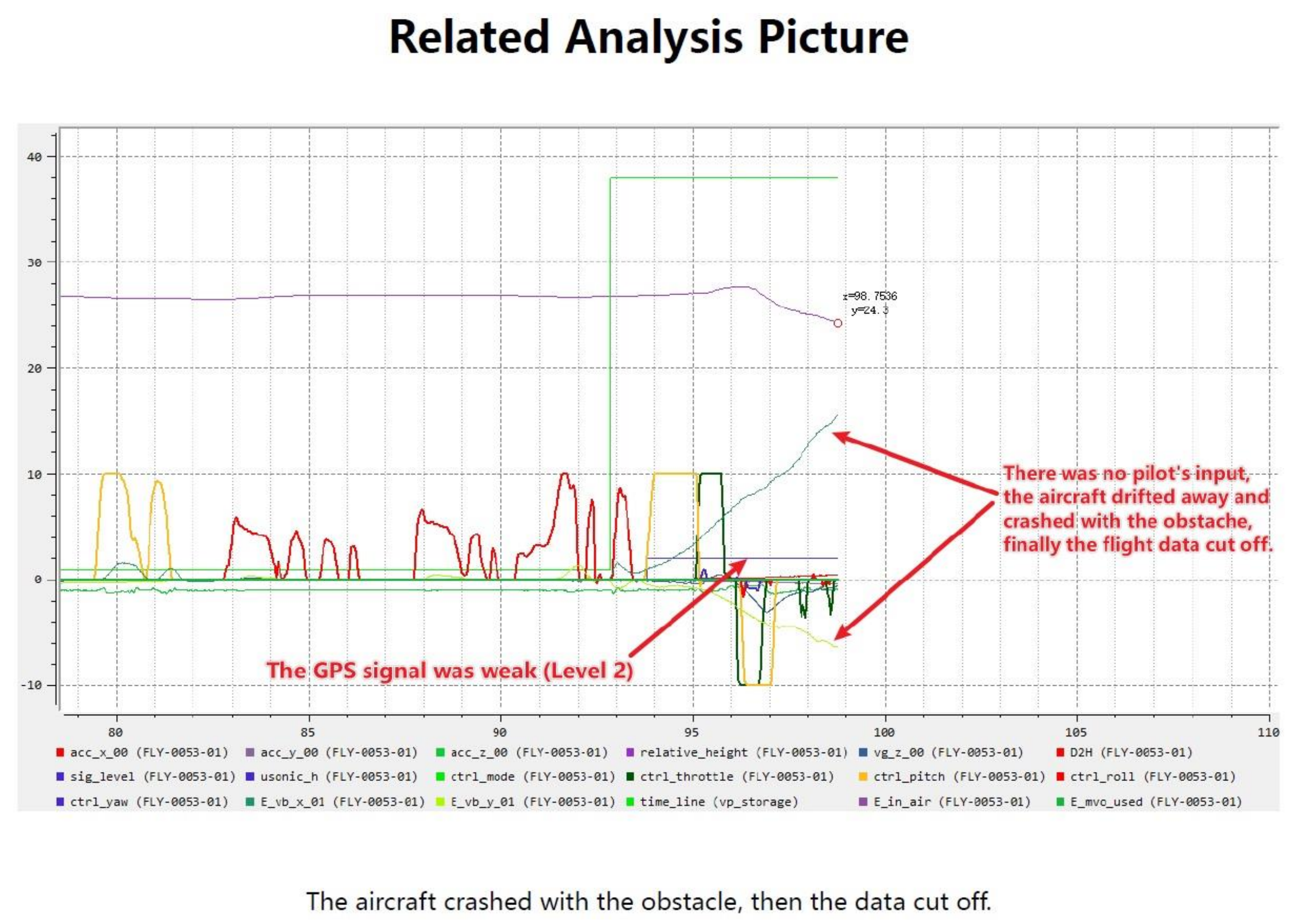


Figure 12: Graphic illustration of the analysis. Source: DJI / NSIA

The NSIA has also sent questions to DJI and received the following answers:

1. The drone enforces the mode-based speed restrictions (see section 1.6).
2. In the event of a sudden loss of battery power, data will be saved to the flight record as long as the drone is connected to the battery.
3. If the drone is started without a home point being set, a new home point will be established when the drone achieves sufficient GPS coverage.
4. A significant discrepancy between *OSD.yaw* and *GIMBLL.yaw* should give a *OSD.isCOmpassError* that is true.

1.17 Organisation and management

TV 2 Luftfoto operates in the open category,[9] and 90% of the assignments they carry out are subject to the requirements that apply to drone flight in the open category, open category A2. If TV 2 Luftfoto needs to carry out operations that exceed the limitations that apply to category A2 flights, the assignment will be carried out by an external provider that holds the necessary qualifications. TV 2 Luftfoto has operated the DJI Mavic 3 since autumn 2021 and logged around 1,130 hours divided between ten drone pilots.

TV 2 Luftfoto's drone operations in open category was based on requirements from their Operating manual.

[9] https://luftfartstilsynet.no/en/drones/veiledning/apen-kategori-oversikt/open-category/

At the time of the incident, TV 2 Luftfoto had conducted 3,700 drone flights.

The operational manager stated that they had not experienced any other episodes of unintentional movement of Mavic 3 drones, but that they had observed that take-off from steel structures could affect the drone's compass.

The drone pilot stated that when he accompanied a journalist on an assignment, he normally only flew five minutes to obtain the desired footage. When required, he uses the journalist as his airspace observer.

1.18 Additional information

1.18.1 RADIO TRANSMITTERS IN THE AREA

The NSIA has contacted the Norwegian Communications Authority (Nkom) to ask whether there are transmitters near Bryggen in Bergen, where the accident occurred. Figure 13 shows mobile phone base stations. They operate on frequencies around 700 MHz, 800 MHz, 1,800 MHz and 2,100 MHz. The transmitter indicated by the number 6 uses a frequency of around 440 MHz. The pin marked with the number 7 shows the drone's approximate location at the time of take-off. The relevant sectors for the mobile phone base stations are illustrated with a beamwidth of 120° and a distance of 100 metres from the transmitter.

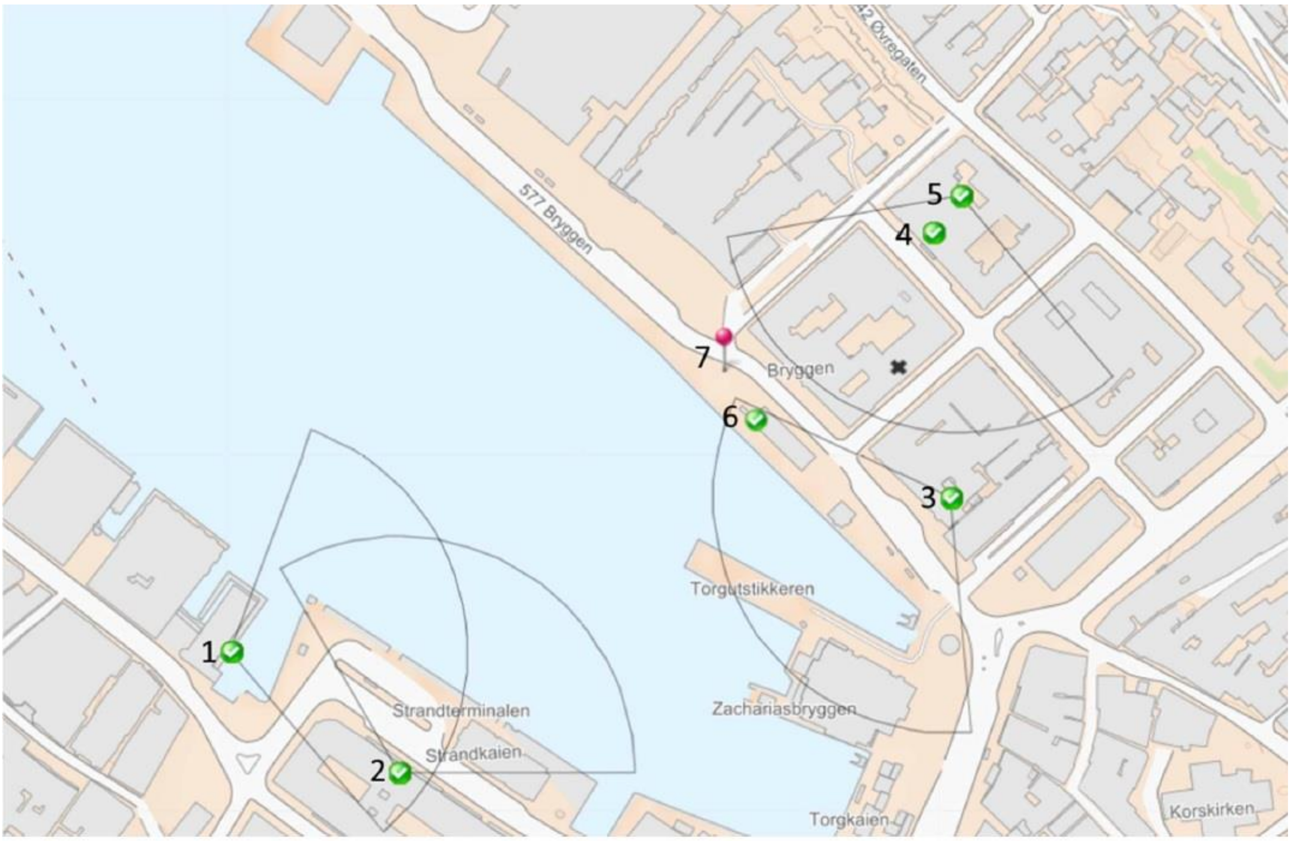


Figure 13: Overview of mobile phone base stations. The pin marked with the number 7 shows the drone's approximate take-off location. Source: NKOM / NSIA

1.18.2 PREVIOUSLY ISSUED SAFETY RECOMMENDATIONS

Safety recommendations from safety investigations are publicly available once the investigation report has been published. The recommendations can be found in the European Central Repository of Safety Recommendations.[10]

1.18.2.1 DJI Matrice 200 V1 – 21 September 2019 at Somme Crescent, Inverness

The DJI Matrice 200 Unmanned Aircraft System (UAS) was being operated on an automated flight plan to conduct an aerial survey. On the fifth flight of the day, while the aircraft was at a height of 100 m, the ballistic parachute recovery system fitted to the aircraft activated. The aircraft descended under the parachute and was subsequently found on the roof of a nearby house.

Safety Recommendation 2021-016

It is recommended that DJI introduce an effective system for providing timely technical support to State safety investigations.

1.18.2.2 Fly-away after compass malfunction SJI Inspire 2 Unmanned Aircraft System

On 11 April 2020 the crew of PH-5MV, consisting of the pilot, the payload operator and two observers, intended to perform a crowd observation and crowd control mission in the Zuiderpark, The Hague. The flight was performed with a DJI Inspire 2 Unmanned Aircraft System (UAS)with a camera payload. Shortly after take-off, during post take-off checks, the pilot lost control over the aircraft. Roughly 30 minutes later the crew was notified that witnesses had found the Unmanned Aircraft (UA) crashed on the sidewalk of a street in The Hague and reported it to the police. Following the crash, the operator initiated a safety investigation. Additionally, the Dutch Safety Board decided to conduct an investigation due to the potential for damage and injury to third parties.

To Da-Jiang Innovations Science and Technology Co., Ltd. (DJI):

2. Ensure that safety investigation authorities and operators are timely provided with technical support and relevant information for the purpose of safety investigation regarding UAS manufactured by DJI.

Deliberations with safety investigation authorities from other states have revealed that the abovementioned issue is not unique to the Netherlands. Therefore, in addition to the recommendation, the Dutch Safety Board will continue to stimulate discussion on this topic with other safety investigation authorities, emphasising the importance of manufacturer participation in safety investigations in the appropriate international bodies, in particular the International Civil Aviation Organization (ICAO).

1.18.3 OVERSIGHT OF THE DRONE MARKED

During the investigation NSIA have been in contact with authorities responsible for overseeing manned aviation.

1.18.3.6 EASA

The NSIA reached out to the European Aviation Safety Agency (EASA) to get feedback from them relating to the lack of information from DJI. The following was received from EASA.

---

[10] https://sris.aviationreporting.eu/safety-recommendations

For drones that do not require a certificate or declaration, like it seems to be the case in this event, EASA has no authority over the manufacturer's processes.' We do share the concern raised by you, and some other European Safety Investigation Authorities, regarding the lack of support from the drone manufacturers. EASA is exploring the best means and forum to raise the issue under wider discussion within the investigation community to find solutions.

1.18.3.7 European commission

The NSIA reached out to the European Commission as they are responsible for providing EASA with the rules and regulation enabling them to perform their duties. The European Commission stated that the responsibility for performing oversight of the drone products on the European marked will not fall on EASA but will fall on the national Marked Surveillance Authority. In Norway the Civil Aviation Authority (CAA) has been appointed as Marked Surveillance Authority.

1.18.3.8 Marked surveillance authority

Regulation (EU) 2019/945 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems contains technical requirements placing drones on the European marked. The requirements are aimed at the financial stakeholders such as manufacturers, authorized representatives, importers, and distributors. The regulation is part of the EU regulations for drones aimed at the civilian use of drones and will be entered into Norwegian law through and European Economic area agreement (EØS-avtalen).

The Norwegian Civil Aviation Authority (CAA) have been given the role of Marked Surveillance Authority according to regulation (EU) 2019/945 and shall surveil drones placed on the marked to be flown in open category and in standard scenarios in specific category in accordance with operational requirements in regulation (EU) 2019/947.

The Norwegian CAA will have the authority to perform an efficient marked surveillance (see sector-wide regulation in the trade-regulation as part of the European economic area agreement, also regulation (EF) 765/2008 and regulation (EU) 2918/1020). The marked surveillance authority will propose actions if a product does not comply with applicable requirements from the regulation. The marked surveillance authority will have access to a European-wide system where possible non-compliance products from all European countries are stored.

The Norwegian Marked Surveillance Authority have stated to the NSIA that they do not have the capability to perform an investigation needed to pursue and resolve the findings of this report.

1.18.4 COMPLIANCE ASSESSMENT

The NSIA has asked the Norwegian CAA to make an assessment of the drone flight in Bergen. The Norwegian Civil Aviation Authority conclusions have been translated to English by the NSIA below:

Based on the description and map presented by NSIA showing the operation TV 2 luftfoto flew in Bergen on 26 August 2022, this will be an operation that falls outside the limits of Open category -- A3. This is due to the proximity to buildings and uninvolved persons. At the time of the incident the only legal way to fly this close to uninvolved persons and buildings with an unmanned aircraft system weighing 895 g was "Open category – A2".

TV 2 used a Mavic 3 that was not C-marked. Thus, the flight had to be carried out according to the transition rules for A2. These can be found in regulation 2019/947 article 22. The article's letter (b) requires a minimum distance of 50 m to people. Note that this distance does not apply for buildings.

Bryggen in the city of Bergen is a busy area. Takeoff and landing was performed from a location where the CAA assesses that at the time of the flight it would not have been possible to prevent uninvolved persons from being closer than 50 meter to the unmanned aircraft system. The time when the incident occurred where would have been uninvolved persons present in the area. The Norwegian CAA cannot see that at the time of the operation it would have been possible to ensure that no persons were inside the operational area. It is our (CAA Norway) assessment that this flight at the time of the incident could not have been carried out within the framework of open category A2 with a "legacy drone" like the Mavic 3.

1.18.5 THE NORWEGIAN AVIATION ACT

The NSIA's work is regulated by Act No 101 of 11 June 1993 relating to Aviation (the Aviation Act) with pertaining regulations. The Aviation Act Section 12-6, cf. the EU Regulation on the investigation and prevention of accidents and incidents in civil aviation Article 11(2), stipulates what information an accident investigation authority is entitled to receive in connection with investigations. Article 11(2)(g) states that the NSIA shall:

have free access to any relevant information or records held by the owner, the certificate holder of the type design, the responsible maintenance organisation, the training organisation, the operator or the manufacturer of the aircraft, the authorities responsible for civil aviation, EASA and air navigation service providers or aerodrome operators.

1.18.6 NATIONAL DRONE LEGISLATION

Requirements for operating a drone in open category is given by the regulation 2019/947 which is implemented into Norwegian law through BSL A 7-2.

1.18.6.6 Requirements for operating a drone in A1

Until 31 Descember 2023 there were transitional regulation whereby an unmanned aircraft system without a C-mark could be operated in open category A1. There was a maximum weight requirement for operating in A1 of 500 grams. Flying was not permitted over uninvolved persons.

From 1 January 2024 all unmanned aircraft system needs to have a C-marking to be operated in A1.

1.18.6.7 Requirements for operating a drone in A2

Until 31 December 2023 there were transitional regulation whereby an unmanned aircraft system without a C-mark could be operated in the open category A2. There was a maximum weight requirement for operating in A2 of 2 kg.

If an unmanned aircraft system without a C-mark was operated in A2 there was a requirement to establish a safety distance of 50 meter horizontally and the distance needed to be increased by the same distance in meters as the flight height of the drone.

From 1 January 2024 all unmanned aircraft system needs to have a C-marking to be operated in A2.

1.18.6.8 Requirements for operating a drone in A3

An unmanned aircraft system without a C-mark could be operated in the open category A3 but with a requirement to maintain a minimum distance of 150 meter from both uninvolved persons and buildings.

From 1 January 2024 all unmanned aircraft system needs to have a C-marking to be operated in A1 and A2. Other unmanned aircraft systems need to be operated in A3.

1.18.7 ICAO ANNEX 13

Norway has ratified the Convention on International Civil Aviation (the ICAO Convention). In Annex 13 on Aircraft Accident and Incident Investigation, the Convention stipulates requirements concerning how a safety investigation is to be conducted. Annex 13 Chapter 5 section 5.6 of the ICAO Convention entitles an investigator-in-chief to obtain any relevant material for use in the investigation.

> ***Investigator-in-charge — Access and control***
>
> *5.6 The investigator-in-charge shall have unhampered access to the wreckage and all relevant material, including flight recorders and ATS records, and shall have unrestricted control over it to ensure that a detailed examination can be made without delay by authorized personnel participating in the investigation.*

1.19 Useful or effective investigation techniques

No methods warranting special mention have been used in this investigation.

2. Analysis

2. Analysis

2.1 Introduction

The investigation has aimed to identify the factors that contributed to the drone no longer responding to the pilot's commands. Part of the analysis was to determine the technical status of the drone and how it was operated.

2.2 Wind direction and speed

The NSIA has obtained a weather report from the Norwegian Meteorological Institute. The report indicates a wind speed of less than 6 m/s. This must be characterized as a relatively low windspeed and inside what the drone can safely fly in. Airdata can calculate wind speed based on telemetry data from the flight record after a flight but it requires GPS position. The drone that crashed had insufficient datapoints. The drone that the operational manager flew while the drone pilot was flying the Mavic 3 drone had sufficient datapoints to allow Airdata to calculate windspeed and direction. Since the two drones flew at the same time and at about the same altitude, these calculations are deemed to be the most relevant data available to this investigation in terms of wind direction and speed.

As a result, the NSIA bases its analysis on the assumption that, the Mavic 3 drone was exposed to winds with a direction of between 319° and 334° and a speed of between 3.5 m/s and 4.8 m/s. It is also assumed that there was virtually no wind at an altitude of 0–8 metres, while the wind speed and direction were as described above at an altitude of 8–15 metres.

2.3 Integrity of flight record data

2.3.1 DECRYPTION OF THE FLIGHT RECORD

The NSIA has used FlightReader as a third-party program to decrypt the flight record. The NSIA is aware that other countries' accident investigation bodies have used third-party programs for decryption, and the NSIA therefore regards the data obtained from using FlightReader to decrypt the flight record to be reliable and a true representation of the data from the drone.

2.3.2 FINAL DATAPOINT

The final datapoint was recorded 53.3 seconds into the flight, at which time the drone was moving north at a speed of 8.3 m/s, east at a speed of 16.6 m/s and downward at a speed of 0.3 m/s. The resultant speed in a north-easterly direction was 18.3 m/s. The distance from the GPS position registered for the final datapoint to the building the drone crashed into is approximately 10 metres. If travelling at a constant speed from the final datapoint, the drone would hit the building 0.5 seconds later. If the flight record had been updated at the same frequency as earlier in the flight, we would expect to see two or three datapoints time-stamped after 53.3 seconds. However, this could be due to how the recorded data is processed. Computers often have a small high-speed memory, the L2 cache, and a slower main memory with greater capacity. The drone's battery was found next to the drone on the crash site. Most likely, data from the period immediately before the drone crashed into the window were not saved to the main memory when the battery separated from the drone, and it has therefore not been possible to retrieve them. The NSIA has contacted DJI with questions about how data are saved to the flight record. They answered that the drone will save data as long as it is connected to a battery, but not given a concrete answer as to whether data are cached in a cache memory and thus possible to retrieve.

2.4 Analysis of sequence of events

The sequence of events is analysed with regards to the modes the drone used during the flight.

During this flight, the drone briefly operated in the modes *Starting motor* and *Manual takeoff*. Nothing out of the ordinary happened in either mode. When the drone entered *P-GPS* mode, a compass error occurred where the *OSD.yaw* value began to deviate from the *GIMBAL.yaw* value. The discrepancy started at 45.5°. The discrepancy increased during the following period and reached 117° at one point. The drone's gimbal was in *follow yaw* mode where its compass value should correspond fairly well with the gimbal's compass value.

The drone initially had no speed in the easterly direction, but after 15.5 seconds, the drone pilot moved the right control stick slightly to the right. This means that it was not pushed as far as it would go. The speed increased from 0 m/s to 8.9 m/s after 19 seconds, and then decreased to 4.5 m/s. The drone registered a maximum pitch of -30 degrees from 16 to 18 seconds. A small movement of the remote controller's right control stick should not have resulted in the speed and pitch registered by the drone. There is reason to believe that the drone's speed and pitch angle in the easterly direction is not based solely on input from the drone pilot.

The drone switched to *ATTI mode* after 22.5 seconds. There it responded as expected under the prevailing wind conditions.

47.9 seconds into the flight the drone transitioned into *Tripod mode* and was connected to ten GPS satellites. The value of *OSD.gpsLevel* was 0 until 56.4 seconds, when the value changed to 2. Up until 48.5 seconds the flight record indicates that neither the vision system nor the GPS was used for the drone to stabilize itself. According to the User Manual the drone should automatically change to *ATTI mode* when the vision system is unavailable, and the GPS signal is weak. The drone appears to require a connection to minimum ten GPS satellites to exit *ATTI mode*, but there seems to be no requirement for a minimum GPS, as the *OSD-gpsLevel* was remaining at 0. This is supported by data from a previous flight where the drone switched to *Sport mode* from *ATTI mode* having connection with 10 GPS satellites but only having a GPS level of 0.

The mode-change from *ATTI* to *Tripod* could also be a result of the drone pilot setting the mode selector switch on the remote controller to *Tripod mode* after 47.9 seconds and the drone only being able to calculate its own position based on data from the GPS satellites after 48.7 seconds. At that point the registered data show that GPS was used as a source to stabilise the drone, and the drone's position were recorded.

2.4.1 STICK INPUT, ALTITUDE AND VERTICAL VELOCITY

From 47.9 seconds, the left control stick on the remote controller remained in the centre position while the drone flew at an altitude of 88 feet with no vertical velocity as shown in Figure 18. During the period from 48.1 to 50 seconds, the altitude increased from 88 to 89 feet without any change of vertical velocity. After 50 seconds, the left control stick was moved forward for about 0.5 seconds, and the altitude increased from 89 to 90 feet and a speed of 0.9 m/s was registered. The stick was moved directly from full stick deflection forward to full deflection backward and held there for 0.5 seconds. During this period, the altitude decreased from 90 to 86 feet at a vertical velocity of 1.8 m/s. The control stick was then moved backward from the centre position twice, and the altitude decreased from 86 to 80 feet. In *Tripod mode*, the drone's ascent and descent speed was restricted to 1 m/s.

The drone pilot initially provided upward input for 0.5 seconds and, theoretically, the drone should be able to increase its altitude by 0.5 metres. The flight record indicates that the altitude increased by 1 foot, 0.3 meter. This seems reasonable, as wind and other factors could have counteracted the drone's ability to deliver the full theoretically possible vertical velocity. When the stick was pulled back, the altitude decreased with a vertical velocity with a maximum value of 1.8 m/s. The readout from the flight record indicate that this exceeds the theoretical maximum speeds for ascent and descent in *Tripod mode*. The drone's altitude seems to have been consistent with the input provided by the drone pilot.

2.4.2 STICK INPUT AND VELOCITY IN THE NORTHERLY DIRECTION

While the drone was in Tripod mode the value for *OSD.yaw* was between 84.3 and 91 degrees. If the drone was oriented with an *OSD.yaw* of 90 degrees all sideways speed would originate from *RC.aileron*. For this drone, having the *OSD.yaw* so close to 90 degrees enables a comparison between speed in the northerly direction and stick commands from *RC.aileron*.

The drone had registered velocities corresponding to the pilots input up until 48 seconds in the northerly direction as shown in Figure 19.

The velocity then increased as the drone pilot moved the right stick forward. Shortly thereafter, the stick was put into the centre position while the velocity increased from 0.9 m/s to 3.6 m/s. The drone pilot then moved the stick backward to counteract the drone's movement. This had no effect, and the velocity of the drone continued to increase to 6.2 m/s. The stick was then put into the centre position while the velocity continued to increase to 8 m/s, which exceeds the maximum speed of 5 m/s specified by the manufacturer for *Tripod mode*. The drone was thus flying at a higher velocity than permitted in *Tripod mode*, and the velocity increased even in the absence of command input from the drone pilot.

2.4.3 STICK INPUT, TILT ANGLE AND VELOCITY IN THE EASTERLY DIRECTION

While the drone was in *Tripod mode* the value for *OSD.yaw* was between 84.3 and 91 degrees. If the drone was oriented with an *OSD.yaw* of 90 degrees all sideways speed would originate from *RC.elevator*. For this drone, having the *OSD.yaw* so close to 90 degrees enables a comparison between speed in the northerly direction and stick commands from *RC.elevator*.

After 47.9 seconds, the drone was moving in an easterly direction at a velocity of 0.9 m/s, as shown in Figure 20.

The velocity decreased as the stick was moved back towards the centre position, as one would expect from a functioning drone. From 48.2 seconds, the stick remained in the centre position while the drone's velocity increased to 16.6 m/s. This velocity was not based on input from the remote controller, nor was it in accordance with the limitations applicable in *Tripod mode*. The velocity registered in the northerly and easterly directions exceeded the maximum speed that DJI has given for *Tripod mode*.

In the NSIA's opinion, the review of the incident shows that the speed registered for the drone was not consistent with flight in *Tripod mode* as indicated by the flight record, and nor with the drone pilot's input from the remote controller. Possible causes for this are discussed in more detail in section 2.5.

2.5 Possible causes for the loss of control

This chapter describes possible causes of the discrepancies identified in the flight record and concludes on each hypothesis.

2.5.1 THE LINK BETWEEN THE DRONE AND THE REMOTE CONTROLLER

After 47.9 seconds of flight the drone's flight path appears inconsistent with the drone pilot's stick inputs. Possible explanations for loss of control includes the signal between the remote controller and the drone being jammed, or someone taking over control of the drone. According to information provided by the Norwegian Communications Authority (Nkom), the take-off site was outside what they consider to be the risk zone for the radio transmitter closest to the crash site. Possible theories included another transmitter jamming the connection between the drone and the remote controller or an unauthorised person taking control of the drone.

2.5.1.1 Blocked signal

The system used the 2.4 GHz frequency to transfer stick commands, a frequency band that was also used by other electronic devices, including wireless networks. If such a network transmitted a stronger signal than the remote controller, this could cause the drone to lose contact with the remote controller. In such case, the drone would react by returning to the home point as programmed by the drone pilot in the drone's application. Here, the drone took off without sufficient connection to GPS satellites to establish a home point, which makes it uncertain how the drone would behave. The NSIA asked the manufacturer DJI how the drone would behave under 'return to home' conditions if no home point had been established, and they stated that the drone would establish a new home point when sufficient GPS signals became available.

Arguments against the theory of signal jamming is that the remote controller was registered with 100% signal quality for the link from the remote controller to the drone and 100% for the link between the drone and the remote controller throughout the flight. Furthermore, the flight record does not indicate that the *Return to home* function was activated. If the signal was blocked it would also be reasonable to believe it to have jammed the signal for the Mavic Air 2S drone flown at the same time. Airdata and report from the Norwegian Mapping Authority shows a *Kp* index that says something about electromagnetic radiation. The index shown for the flight was registered as 2/3 by Airdata and less than one by the Norwegian Mapping Authority. Both are well within the range from 0 to 4 described as *generally safe*. The NSIA therefore considers the theory that the signal between the drone and the remote controller was jammed to be unlikely.

2.5.1.2 Control takeover

Anti-drone technology that would be capable of taking control of a drone exists, for example if one was illegally flying near an airport. If unauthorised persons near the crash site were in possession of such equipment and targeted the drone, it could be used to take over control. Such equipment was on the market and had been demonstrated at a number of conferences. If the remote controller was responsible for enforcing the mode-dependent speed restrictions, a party taking over control of a drone would be able to send other speed commands, as the remote controller would no longer be in control of the drone and enforce the speed restrictions. DJI has stated that the speed restrictions are managed by the drone itself, which means that the speed restrictions for the relevant mode would still apply in the event of a control takeover.

The serial number of the remote controller the drone was connected to is registered for each datapoint in the flight record. This serial number remained the same for the duration of the flight, and, in addition, a signal strength of 100% was registered for signals both to and from the drone throughout the flight. If an unauthorised person took control of the drone, the NSIA would expect the flight record to indicate a loss of signal between the remote controller and the drone, not a consistent signal strength of 100%.

2.5.2 FLIGHT MODES

Analysis of the flight record log indicated that the drone was travelling at a speed of 18.5 m/s at the final datapoint. This speed exceeded the 5 m/s that DJI stated was the maximum speed for *Tripod mode*. DJI had specified separate maximum speeds for each of the modes *P-GPS*, *Tripod* and *Sport*. The maximum wind speed the drone can safely fly in was 12 m/s, and it was stated to apply regardless of which mode the drone was operating in.

The flight record indicated that the drone switched from *ATTI* to *Tripod mode*, but a second passed before it was able to use GPS satellites to calculate its own position. This could indicate that the mode, as shown in the flight record, was initiated when the drone pilot set the remote controller's selector switch to *Tripod*, but that the drone did not switch to *Tripod* mode until it had connected to enough satellites, and that it did not check the GPS level before exiting *ATTI mode*.

The flight record indicates speed values that exceeds the speed-restriction in Tripod mode. This can be interpreted as the drone was in *Tripod* mode or that a function authorised to override speed restrictions was activated.

2.5.2.1 Compass error

The significant discrepancy between the values for *OSD.yaw* and *GIMBAL.yaw* makes it natural to consider whether this could cause a loss of control. If the drone thought it was pointing 87° (value of *OSD.Yaw*) while it was actually pointing 334° (value of *GIMBAL.yaw*), this could result in what is known as positive feedback, where the drone's efforts to hover in place would cause it to compensate in the wrong direction with steadily increasing force that could bring the drone out of control.

In this case, the drone had a virtually direct headwind with a direction of 319–324°, while *GIMBAL.yaw* shows 334°. In this situation, the drone would normally have lowered its angle of attack (pointed its nose downward) and rolled slightly to the left to compensate for the wind and remain in place. If the drone used the *OSD.yaw* value instead of *GIMBAL.yaw*, it would have thought that it was pointing 87° with the same wind direction as before. The drone would then have compensated for the wind as if it was coming from 237° and attempting to stabilise itself by lowering its nose and rolling left to compensate for a non-existent wind. This would then have caused the drone to fly to the left, away from the building it hit. The NSIA has been in contact with DJI to find out how the stabilisation algorithm works and whether there is a mechanism for handling positive feedback and how the values for *OSD.yaw* and *GIMBAL.yaw* are used. DJI has informed the NSIA that a warning message would be displayed on the remote controller if there was too much of a discrepancy between *OSD.yaw* and *GIMBAL.yaw*. Based on flight record data, the NSIA considers it unlikely that a compass error would cause loss of control.

2.5.2.2 Switching from ATTI to Tripod mode

Flight record data indicated that the drone's flight was stable in *P-GPS* and *ATTI* mode and for the first four datapoints in Tripod mode. It was not until the fifth datapoint in Tripod mode, where the drone used GPS for stabilisation (*OSD.isPGSUsed = True*), that the drone apparently did not respond properly to pilot inputs and accelerated in a northeasterly direction. At this point the log indicates GPS level 2 whereas DJI had described that GPS level 3, 4 or 5 was required for safe flight. A few datapoints later, the drone registered speeds far exceeding the limits that applied in *Tripod mode*. It appeared as if a function in the drone with the authority to override the speed restrictions for *Tripod mode* had been activated. We know that the stabilisation function had the authority to override the limits in place for the different modes, but we cannot say whether this function was active in this case. In their analysis, DJI concluded that the drone switched from *ATTI* to *Tripod mode* with inadequate GPS level to be able to maintain its position and as a result drifted into the building. In their opinion this was due to pilot error.

The NSIA is of the opinion that the first part from DJI's analysis is correct but that the conclusion cannot be correct. If the drone used the number of GPS satellites as one criterion for exiting *ATTI mode* without also considering a GPS level of 3, 4 or 5 a criterion, while also not giving the drone pilot any indication of this, it appears to be a design flaw in the drone, and not something a drone pilot is in a position to prevent nor handle. The NSIA finds it difficult to understand how a drone can drift, as DJI states, at a speed of 18.6 m/s when wind in the area was blowing at a speed of 4.2–4.8 m/s and blowing from a different direction from the direction in which the drone was flying. This design flaw in the transition from *ATTI mode* makes it clear that taking off without adequate GPS coverage is a significant risk associated with using this drone. Based on the analysis above, the NSIA recommends that all users of DJI Mavic 3 drones exercise caution when flying in areas with poor GPS coverage. This could prevent the drone from switching into *ATTI mode*. A safety recommendation to this effect is issued to CAA Norway.

The Norwegian Safety Investigation Authority recommends that CAA Norway inform users of DJI Mavic 3 drones in Norwegian airspace about this design flaw which can result in losing control of the drone after it switches out of *ATTI mode*.

2.6 Inadequate information from DJI

The NSIA has the mandate to gather all relevant information related to an aviation incident or accident. It took more than ten months and several reminders before DJI analysed the flight log. Even though they responded to questions during the investigation several questions remains unanswered. With this, DJI does not comply with the requirements set in the European regulation. Every part of European aviation is expected to comply with current regulations. Deviating from this prevents learning from accidents and incidents and opens the possibility of repetition. DJI has previously demonstrated a lack of willingness to contribute sufficiently to safety investigations of drones, both by the Dutch Safety Board and the British Air Accident Investigation Branch. DJI does not seem to have made significant changes to their willingness to participate in an investigation after receiving two safety recommendations on this matter. Based on the inadequate feedback, DJI has not provided sufficient documentation to support that the DJI Mavic 3 has an expected level of safety. Consequently, it is also not known whether the design flaw uncovered in this investigation apply to other DJI drones as well. Based on the DJI's failure to comply with previous safety recommendations, the NSIA does not consider it expedient to provide further safety recommendations to DJI.

2.7 Drone safety

The DJI Mavic 3 drone was placed on the European marked with a CE declaration. No additional aviation safety approval was sought, nor given by the European aviation safety authority (EASA). EASA have stated their lack of authority over the manufacturing process, in this case with DJI.

The European Commission stated that this type of issues relating to unmanned aircraft systems needs to be addressed by the national marked surveillance authorities. The Norwegian marked surveillance authority has stated that they will not have the capability to perform a detailed technical investigation into a DJI Mavic 3 drone to resolve the issue relating the criteria for exiting ATTI mode as identified in this report.

NSIA fears that any investigation launched by a marked surveillance authority will face similar challenges when requesting information from DJI. It will also be hollow out the NSIA mandate if the oversight authority were given the same mandate as the NSIA for obtaining relevant information. The NSIA view the marked surveillance authority as an authority of product safety and not aviation safety, which is the job of the NSIA.

The NSIA therefore issues a safety recommendation to the European Commission to mandate an authority to conduct a technical review of DJI unmanned aviation systems.

> The Norwegian Safety Investigation Authority recommends that the European Commission mandate an authority to conduct a technical review of DJI's unmanned aircraft systems in which DJI present documentation if the systems maintain the expected aviation safety standard.

NSIA have experienced difficulties receiving sufficient information from DJI. EASA have no authority to mandate DJI to support a safety investigation. There is subsequently no authority with the capability to mandate a drone manufacturer to support safety investigation authorities during safety investigations.

> The Norwegian Safety Investigation Authority recommends that the European Commission implement legislation where all manufacturer of unmanned aircraft systems can be subject to sanctions for failing to support safety investigations regardless of the category where the unmanned aircraft system was operated.

2.8 Reactions after the accident

The drone pilot quickly made himself known to the people in the break room after the drone had crashed through their window. After gaining an overview of the crash site, he called the police to report the incident. The NSIA's view is that the drone pilot acted swiftly and correctly in a stressful situation. His actions set a good example for other drone pilots encountering accidents or incidents.

2.9 Reports of technical drone malfunctions

With an increasing number of drones in the airspace, conflicts can arise between manned and unmanned aviation. This requires that aircraft can be separated in time or space. While manned aviation is subject to extensive certification processes, this does not seem to be the case for unmanned aircraft systems. This incident and its investigation indicate that there may be safety challenges that could lead to loss of control. Safe aviation also demands that drone manufacturers deliver reliable systems. To accurately assess risks in relation to regulation, it is important for CAAs to be informed about incidents. A technical failure leading to loss of control could compromise separation in time or space, making it crucial to detect and subsequently correct. With this, the NSIA encourages anyone who experiences a loss of control of a drone to report it.

2.10 Compliance with national drone legislation

The drone took off from the pier and was operated at a height of 80 feet when control was lost. The requirements for safety distance for operating a Mavic 3 drone in open category A2 would be 50 meter plus the height of the drone. Based on the assessment by Norwegian CAA this flight was not in compliance with the requirements for operating in open category A2. The challenge highlighted with this investigation show that loss of control can nullify any safety precautions established before takeoff. An investigation performed by the Dutch Safety Board involved a drone which encountered an error after takeoff and flew for 30 minutes before crashing into a street. Any establishment of a safety distance at startup would no longer be valid.

3. Conclusion

3. Conclusion

3.1 Main conclusion

During training for an assignment, the drone stopped responding to the drone pilot’s input. The drone accelerated out of control and crashed through a window. It has not been possible to determine the reason why the pilot lost control of the drone, but it appears to be associated with the transition between *ATTI mode* and *Tripod mode* under inadequate GPS levels.

3.2 Investigation results

A. The drone pilot held valid rights to fly the drone.

B. The drone flight was not in compliance with the rules for A2.

C. The drone stopped responding to input from the drone pilot.

D. One person sustained minor injuries in the incident.

E. The NSIA finds it unlikely that the drone was jammed or that someone took control over the drone.

F. The NSIA finds it probable that the drone had a flaw that caused it to switch from *ATTI* to *Tripod mode* without verifying it had a sufficient GPS level for safe flight.

4. Safety recommendations

4. Safety recommendations

The Norwegian Safety Investigation Authority submits the following safety recommendations:[11]

Safety recommendation Aviation No 2024/04T

During a flight with a DJI Mavic 3 drone from the manufacturer DJI in Bergen, Norway on 26 August 2022, the drone pilot lost control of the drone. The Norwegian Safety Investigation Authority has been unable to establish unequivocally why the loss of control occurred. The Norwegian Safety Investigation Authority has repeatedly contacted the manufacturer DJI with requests for technical support in connection with the investigation. DJI has failed to fulfil the Norwegian Safety Investigation Authority's requests and does not comply with the requirements stipulated in the Norwegian Aviation Act Chapter 12-6, cf. the EU Regulation on the investigation and prevention of accidents and incidents in civil aviation Article 11(2)g) or the ICAO Convention Annex 13 Chapter 5 section 5.6. The UK Air Accidents Investigation Branch (AAIB) and the Dutch Safety Board have both previously submitted recommendations relating to insufficient support from the DJI, with little or no effect.

The Norwegian Safety Investigation Authority recommends that the European Commission implement legislation where all manufacturer of unmanned aircraft systems can be subject to sanctions for failing to support safety investigations regardless of the category where the unmanned aircraft system was operated.

Safety recommendation Aviation No 2024/05T

While flying a DJI Mavic 3 drone from the manufacturer DJI in Bergen, Norway on 26 August 2022, the drone pilot lost control of the drone. The Norwegian Safety Investigation Authority has been unable to establish unequivocally why the loss of control occurred but considers it probable that it is related to a flaw in the drone occurring when switching from ATTI mode with low GPS levels. Due to the inadequate technical support from DJI, the Norwegian Safety Investigation Authority has not been able to verify all aspects of the issue. It is therefore uncertain whether the drone can be controlled at all times so that it does not represent a danger to persons or other aircraft. Given the lack of support it is not known if this risk is inherent in other drones produced by DJI.

The Norwegian Safety Investigation Authority recommends that the European Commission mandate an authority to conduct a technical review of DJI's unmanned aircraft systems in which DJI present documentation if the systems maintain the expected aviation safety standard.

[11] The Ministry of Transport forwards safety recommendations to the Civil Aviation Authority and/or other involved ministries for evaluation and follow-up; see Section 8 of the Regulations on Public Investigations of Accidents and Incidents in Civil Aviation.

Safety recommendation Aviation No 2024/06T

While flying a DJI Mavic 3 drone from the manufacturer DJI in Bergen, Norway on 26 August 2022, the drone pilot lost control of the drone. The Norwegian Safety Investigation Authority has been unable to establish unequivocally why the loss of control occurred but considers it probable that it is related to a flaw in the drone when switching from *ATTI mode* at low GPS levels. Users of DJI Mavic 3 in Norwegian airspace should be informed about this flaw so that they can take steps to avoid finding themselves in a similar situation.

The Norwegian Safety Investigation Authority recommends that CAA Norway inform users of DJI Mavic 3 drones in Norwegian airspace about this design flaw which can result in losing control of the drone after it switches out of *ATTI mode*.

Norwegian Safety Investigation Authority
Lillestrøm, 14 May 2024

Abbreviations

Abbreviations

ATTI Attitude mode is manual operation without use of GPS or Optical sensors where the drone is susceptible to environmental factors such as wind

DJI Fly	Application used to control the drone
ENBR	Bergen Airport Flesland
GPS	Global Positioning System
MPH	Miles per hour (corresponds to 1.609 km/h or 0.45 m/s)
NSIA	Norwegian Safety Investigation Authority
OM	Operations manual
P-GPS	Position GPS
RTH	Return to home
Speed	Rate an object is moving along a path
UTC	Coordinated universal time
Vision	Drones hover in place based on the downward sensors
Velocity	Rate and direction an object is moving along a path

Appendices

Appendix A Flight record data fields

The NSIA has obtained descriptions of some of the data fields from the developer of Flight Reader.

OSD.flyTime [s] The accumulated flight time (in seconds) since the aircraft's motors were turned on.

OSD.latitude The aircraft's current angular distance north or south of the equator, measured in degrees, minutes, and seconds.

OSD.longitude The aircraft's current angular distance east or west of the Prime Meridian, an imaginary line passing through the Royal Observatory in Greenwich, England and running from the North Pole to the South Pole.

OSD.height [ft] The aircraft's current height (in feet) above the takeoff location.

OSD.vpsHeight [ft] The distance (in feet) between the aircraft's current location and the closest obstacle beneath it. This value is only available when the downward sensors are enabled and within range of a nearby obstacle.

OSD.altitude [ft] The aircraft's current distance above sea level (in feet).

OSD.mileage [ft] The total distance (in feet) the aircraft traveled over the entire flight.

OSD.hSpeed [MPH] The current speed (in MPH) at which the aircraft is moving parallel to the Earth's surface.

OSD.xSpeed [MPH] Current aircraft speed (in MPH) in the x direction using the North-East-Down (NED) coordinate system.

OSD.ySpeed [MPH] Current aircraft speed (in MPH) in the y direction using the North-East-Down (NED) coordinate system.

OSD.zSpeed [MPH] Current aircraft speed (in MPH) in the z direction using the North-East-Down (NED) coordinate system.

OSD.pitch The rotation of the aircraft (between -180 to 180 degrees) about the transverse axis. During a pitch, the front of the aircraft moves up or down, while the rear moves in the opposite direction.

OSD.roll The rotation of the aircraft (between -180 to 180 degrees) about the longitudinal axis. During a roll, one side of the aircraft rises while the other side lowers.

OSD.yaw The rotation of the aircraft (between -180 to 180 degrees) about the vertical axis. During a yaw, the front of the aircraft moves to the left or right, while the rear moves in the opposite direction.

OSD.yaw [360] The rotation of the aircraft (between -0 to 360 degrees) about the vertical axis. During a yaw, the front of the aircraft moves to the left or right, while the rear moves in the opposite direction.

OSD.flycState The current aircraft state or flight mode.

OSD.gpsNum The number of GPS satellites the aircraft is currently connected to.

OSD.isGPSUsed When true, the aircraft is able to use the GPS satellite data for positioning purposes.

OSD.isCompassError The aircraft's compass is in an error state and needs to be calibrated or moved away from nearby interference.

OSD.isVisionUsed When true, GPS data is unavailable and the downward sensors are being used to stabilize the aircraft.

GIMBAL.yaw The rotation of the gimbal (between -180 to 180 degrees) about the vertical axis. During a yaw, the front of the gimbal moves to the left or right, while the rear moves in the opposite direction.

GIMBAL.yaw [360] The rotation of the gimbal (between 0 to 360 degrees) about the vertical axis. During a yaw, the front of the gimbal moves to the left or right, while the rear moves in the opposite direction.

RC.downlinkSignal The signal quality (from 0 to 100%) for video and other data transferred from the aircraft to the remote controller.

RC.uplinkSignal The signal quality (from 0 to 100%) for control information and other data transferred from the remote controller to the aircraft.

RC.aileron The current remote controller stick position (between 364 to 1684) responsible for moving the aircraft left or right. When set to 1024, the remote controller stick is in the default center position.

RC.elevator The current remote controller stick position (between 364 to 1684) responsible for moving the aircraft forward or backward. When set to 1024, the remote controller stick is in the default center position.

RC.throttle The current remote controller stick position (between 364 to 1684) responsible for moving the aircraft up or down. When set to 1024, the remote controller stick is in the default center position.

RC.rudder The current remote controller stick position (between 364 to 1684) responsible for turning the aircraft to the left or right. When set to 1024, the remote controller stick is in the default center position.

BATTERY.current [A] The flow of electrical charge (in amperes) from the aircraft battery to its motors and other electronic components.

Appendix B Flight record data

The first datapoint in Tripod mode was registered at 47.9 seconds, and the final one after 53.3 seconds. The tables below show data for GPS, compass, stick movements and speed.

GPS

Table 11: GPS values in Tripod mode. Source: TV 2 / NSIA

Data	Start [s]	End [s]	Development	Min. value	Max. value
OSD.gpsNum	47.7	53.7	Variable	9	11
OSD.isGPSUsed	47.7	48.5	Stable	False	
	48.7	53.7	Stable	True	
OSD.isVisionUsed	47.7	53.7	Stable	False	
OSD.gpsLevel	47.7	48.9	Stable	0	0
OSD.gpsLevel	49.1	53.7	Stable	2	2

Compass

Table 12: Compass values in Tripod mode. Source: TV 2 / NSIA

Data	Start [s]	End [s]	Development	Min. value	Max. value
OSD.yaw	47.9	53.7	Variable	84.3°	91°
GIMBAL.yaw	47.9	53.7	Variable	334.2°	334.4°
GIMBAL.mode	47.9	53.7	Stable	Follow yaw	

Stick movements

Table 13: Stick movement values in Tripod mode. Source: TV 2 / NSIA

Data	Start [s]	End [s]	Development	Min. value	Max. value
RC.aileron	47.9	48.1	Variable	1,522	1,545
	48.3	52.9	Stable	1,024	
	53.1	53.1	Point	990	
	53.3	53.7	Stable	1,024	
RC.elevator	47.9	48.7	Stable	1,024	
	48.9	50.3	Decreasing	1,684	
	50.5	51.1	Stable	1,024	
	51.3	51.9	Stable	364	
	52.1	53.7	Stable	1,024	
RC.throttle	47.9	49.9	Stable	1,024	
	50.1	50.5	Stable	1,684	
	50.7	51.5	Stable	364	
	51.7	53.7	Variable	773	1,024
RC.rudder	47.9	49.9	Stable	1,024	
	50.1	50.1	Point	1,081	
	50.3	51.1	Stable	1,024	
	51.3	51.3	Point	950	
	51.5	51.5	Point	949	
	51.7	53.7	Stable	1,024	

Speed

Table 14: Speed values in Tripod mode. Source: TV 2 / NSIA

Data	Start [s]	End [s]	Development	Min. value [MPH]	Max. value [MPH]
OSD.xSpeed[MPH]	47.9	49.5	Variable	0.9	1.8
	49.7	53.7	Increasing	2	18.6
OSD.ySpeed[MPH]	47.9	48.5	Variable	2.9	1.3
	48.7	53.7	Increasing	1.8	37.1
OSD.zSpeed[MPH]	47.9	50.1	Stable	0	
	50.3	53.7	Variable	-1.8	4.5

Appendix C Graphic representation of values from the flight record

Downlink and uplink signal strength

The flight record contained values for *RC uplink* and *RC downlink*. These values tell us whether the drone could receive data from the remote controller (uplink) and whether it could transmit data to the remote controller (downlink). A graph of the downlink and uplink signal strength as a function of the timeline is shown in Figure 14. The graph shows that the value for *RC uplink* is 100 from the first datapoint 0.1 seconds into the flight up until the final datapoint after 53.7 seconds. *RC downlink* shows 100 at its first datapoint after 0.3 seconds continuing right up until 53.7 seconds. The final four datapoints, at 53.7, show a value of 0.

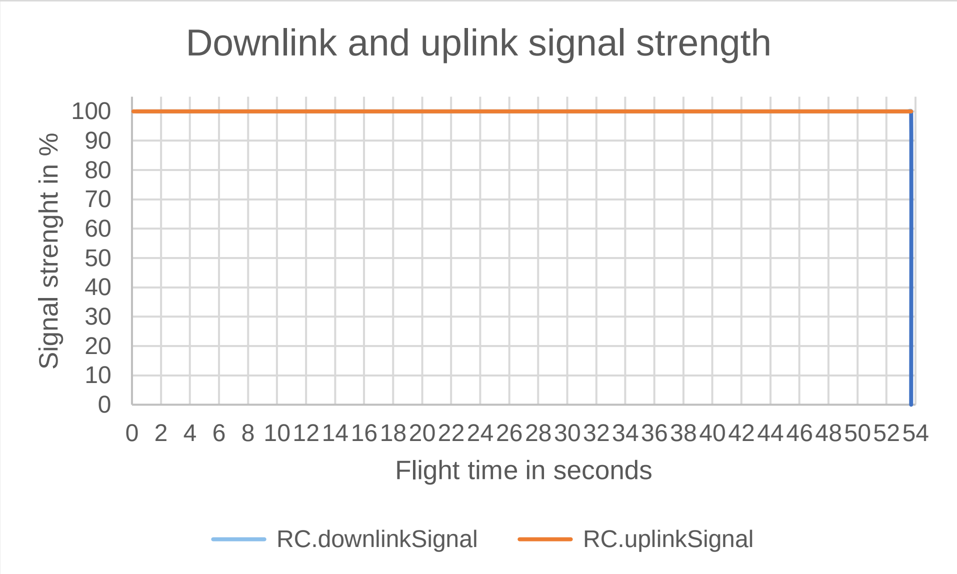


Figure 14: Downlink and uplink signal strength. The Y axis shows signal strength in per cent, while the X axis represents the timeline. Source: TV 2 / NSIA

GPS reception

The number of satellites registered by the drone was stored in the flight record and is shown in Figure 15.

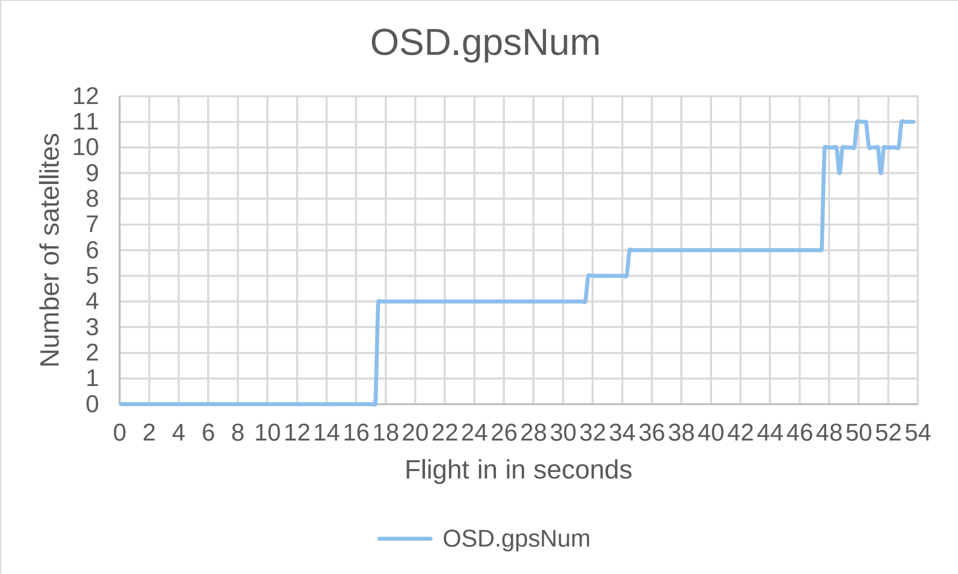


Figure 15: Number of satellites registered. The Y axis shows the number of satellites, while the X axis represents the timeline in seconds of flight. Source: TV 2 / NSIA

Direction angle in the vertical axis

The drone registered which compass bearing it was pointing in at all times. This information was recorded in the flight record as *OSD.yaw*. The drone's camera axis also registered its compass bearing in the flight record as *GIMBAL.yaw*. A graphical representation of the values for *OSD.yaw* and *GIMBAL.yaw* is shown in Figure 16. The *GIMBAL.yaw* values remained between 334.2° and 334.8° throughout the recording.

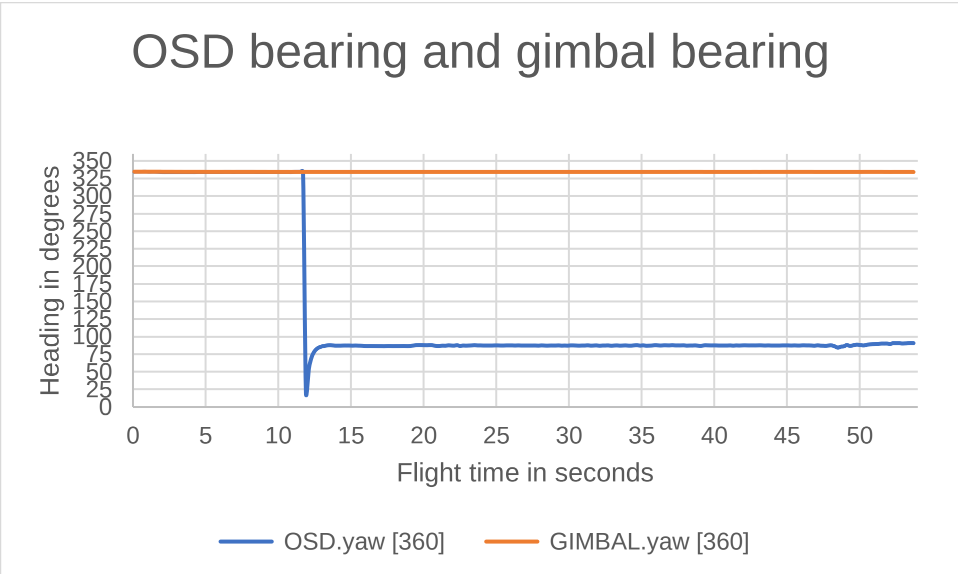


Figure 16: Values for OSD.yaw and GIMBAL.yaw. The Y axis shows heading in degrees, while the X axis represents the timeline in seconds. Source: TV 2 / NSIA

During the period from 0.1 to 11.7 seconds, the *OSD.yaw* values were between 334° and 334.8°. After 11.9 seconds, the value changed to 20.1°, and the value increased in the following datapoints until it reached a value of between 86.2° and 88° after 13 seconds. The values remained between 84.3° and 91° throughout the period from 13 to 53.7 seconds.

Notifications

Notifications to the pilot were displayed on the remote controller's screen during the flight. The notifications and the time at which each were displayed are listed in Table 15.

Table 15: Warning messages displayed on the screen. Source: TV 2 / NSIA

Time	Notification messages
0 m 0.1 s	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30014).; Check whether the propellers are attached to the correct motors based on their markings. Incorrect installation will cause the aircraft to roll over during takeoff (Code: 30251).
0 m 1.1 s	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30014).
0 m 22.5 s	Aircraft in Attitude mode. Unable to hover. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30016).; Attitude mode (Max altitude 30 m).; GPS signal weak. Switched to Attitude mode. Aircraft unable to hover. Fly with caution.
0 m 22.7 s	Compass or GPS signal weak. Changed to Attitude mode.; Aircraft in Attitude mode. Unable to hover. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30016).
0 m 47.9 s	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30014).
0 m 50.5 s	GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30014).; GPS signal weak (Max altitude 30m).
0 m 53.7 s	Image transmission signal lost (Code: 80001).; GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30014).; No image transmission signal.
0 m 53.7 s	Image transmission signal lost (Code: 80001).; GPS signal weak. Fly with caution. Aircraft in Altitude Zone. Max altitude set to 30 m (Code: 30014).; Aircraft not connected to RC.
0 m 53.7 s	Image transmission signal lost (Code: 80001).
0 m 53.7 s	Aircraft not connected to RC.

RC throttle

Moving the left control stick on the remote controller forward or backward sent a command to the drone to either ascend or descend. The flight record refers to this control stick as *RC throttle*. Input from *RC throttle* can be compared to the drone's altitude, shown in Figure 17, and its vertical speed, shown in Figure 18.

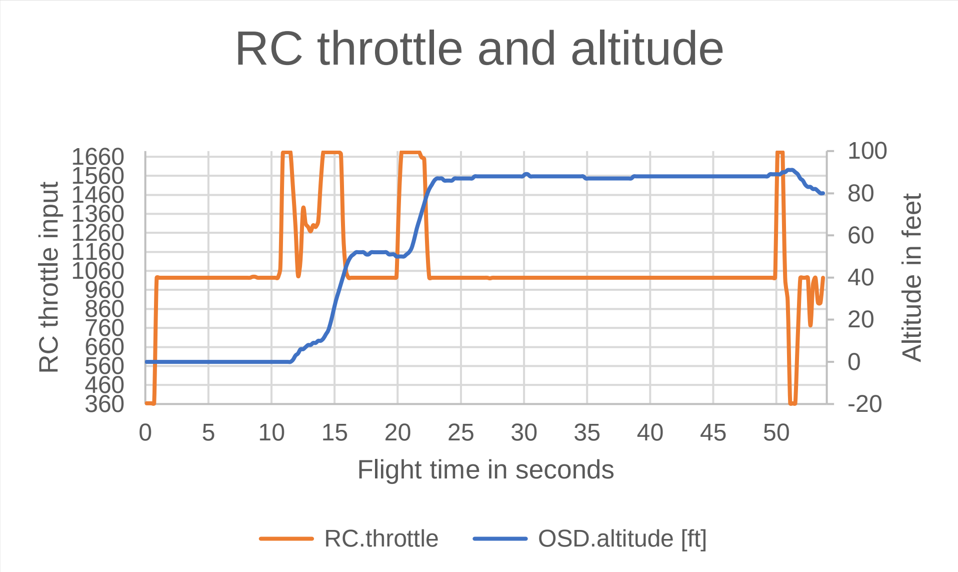


Figure 17: Altitude command input and the drone's altitude. Source: TV 2 / NSIA

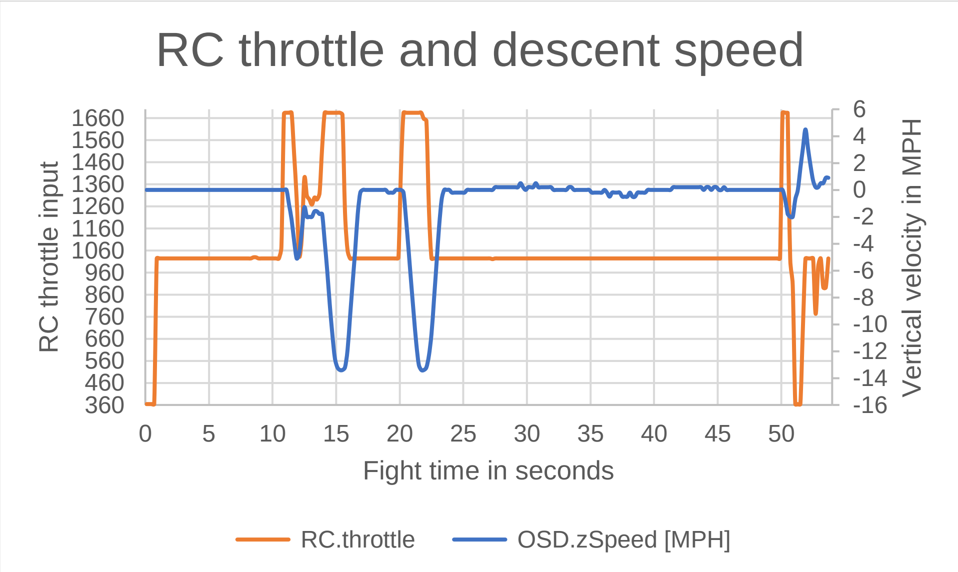


Figure 18: Altitude command input and the drone's speed on the Z axis. Source: TV 2 / NSIA

Figure 18 also shows the control stick input on the left-hand side of the graph. Value 1024 indicates a control stick in the middle position, values between 364 and 1023 indicates stick movement backwards (drone descending) and values between 1025 and 1684 indicates control stick movement forwards (drone climbing). The drone's vertical speed is indicated by the scale on the right-hand side of the graph (negative values indicate climb and positive values indicate descend). Note that the speed is shown as retrieved from the flight record, in miles per hour (MPH).

RC elevator

Moving the right control stick on the remote controller forward or backward sent a command to the drone to fly either forward or backward. The flight record refers to this control stick as *RC elevator*. Input from *RC elevator* can be compared with the drone's speed along the longitudinal axis. Value 1024 indicates a control stick in the middle position where values between 364 and 1023 indicates stick movement backwards (drone flying backward) and values between 1025 and 1684 indicates control stick movement forward (drone flying forwards).

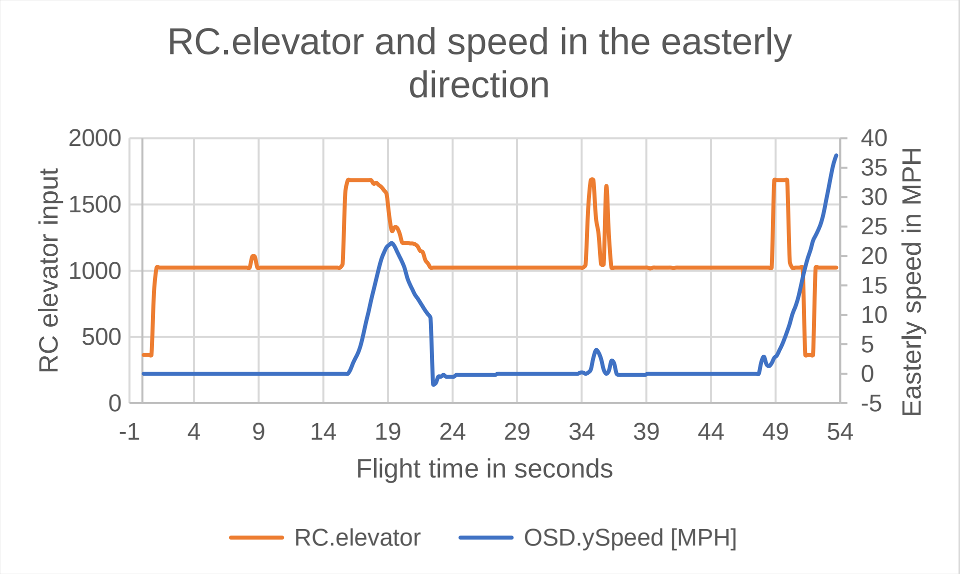


Figure 19: Stick command input and the drone's speed in the easterly direction. Source: TV 2 / NSIA

Figure 19 shows the control stick values on the left-hand side of the graph. The drone's speed in the easterly direction is indicated by the scale on the right-hand side of the graph. Note that the speed is shown as retrieved from the flight record, in miles per hour (MPH).

RC aileron

Moving the right control stick on the remote controller to the left or right sent a command to the drone to fly either left or right. The flight record refers to this control stick as *RC aileron*. Input from *RC aileron* can be compared with the drone's sideway speed. Control stick value of 1024 indicates a control stick in the middle position where values between 1023 and 364 indicates stick movement to the right (drone flying to the right) and values between 1025 and 1684 indicates control stick movement to the left (drone flying to the left).

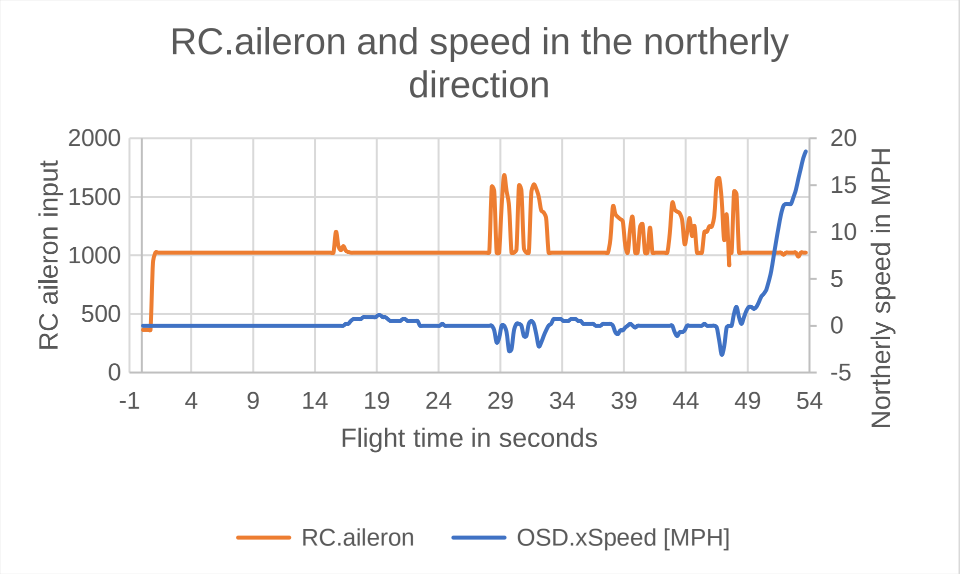


Figure 20: Command input and the drone's speed in the longitudinal axis. Source: TV 2 / NSIA

The stick movement values are shown in figure 20 on the left side while the drone's speed-component in the northerly direction is indicated by the scale on the right-hand side of the graph (left and right seen from the drone). Note that the speed is shown as retrieved from the flight record, in miles per hour (MPH).