National Transportation Safety Board
Office of Research and Engineering
Washington, D.C. 20594

Performance Study

Specialist Report
Marie Moler

A. ACCIDENT

Location:	Zaleski, Ohio
Date:	January 29, 2019
Time:	0650 EST
Airplane:	Bell 407, N191SF
NTSB Number:	CEN19FA072

B. GROUP

The Vehicle Performance group members were:

Chairman: Marie Moler
National Transportation Safety Board
Washington, DC

Member: Albert Brand
Bell, Textron Inc.
Arlington, Texas

C. SUMMARY

On January 29, 2019, about 0650 Eastern standard time, a single-engine, turbine-powered, Bell 407 helicopter, N191SF, collided with forested, rising terrain about 4 miles northeast of Zaleski, Ohio. The helicopter was registered to and operated by Viking Aviation, LLC, doing business as Survival Flight, Inc., as a visual flight rules helicopter air ambulance flight under the provisions of 14 Code of Federal Regulations Part 135 when the accident occurred. The certificated commercial pilot, flight nurse, and flight paramedic were fatally injured, and the helicopter was destroyed. Visual meteorological conditions existed at the departure location, and company flight following procedures were in effect. The flight departed Mt. Carmel Hospital, Grove City, Ohio at 0628, destined for Holzer Meigs Hospital, Pomeroy, Ohio, about 69 miles southeast.

D. PERFORMANCE STUDY

The aircraft was equipped with an Outerlink Global Solutions IRIS flight data monitoring system. An on-board recorder stored time, pressure and radio altitude, latitude and longitude, groundspeed, vertical acceleration, lateral acceleration, pitch, roll, magnetic heading, collective, rotor speed, torque, twist grip throttle, and a variety of engine parameters. Data from the onboard Outerlink device will be referred to in this report as the onboard data. Additionally, the Outerlink device sent position and altitude data to a satellite uplink every eleven seconds. Data from the Outerlink satellite uplink will be referred to in this report as the satellite data. Altitude is reported as mean sea level (MSL), unless otherwise specified.

Also onboard was an engine control unit (ECU) which recorded gas generator turbine speed, main rotor RPM, engine torque, power turbine speed, collective position, collective pitch, and absolute pressure.

The aircraft was equipped with automatic dependent surveillance – broadcast (ADS-B) which transmitted latitude and longitude from GPS, along with pressure and geometric altitude to ground stations; the data were recorded every one second. ADS-B data from four earlier days of flights were provided to the investigation.

Weather Observations

At 0655, the nearest weather station at the Ohio University Airport (KUNI), nine miles from the end of flight, reported wind from 280° at 7 knots, 10 miles visibility or greater, overcast ceilings at 2,700 ft above ground level (AGL) or 3,100 ft MSL, temperature of -6°C (21°F), dew point temperature of -10°C (14°F), and an altimeter setting of 29.92 inHg.

The NTSB meteorology report [1] stated that the flight encountered two snow bands during the flight. The first occurred around 0638 and lasted until 0644:30. The second was from 0647 and lasted until the end of flight.

Flight Path

Figure 1 shows the accident flight path with the portions of the flight when snow was encountered annotated. The flight path was approximately 55 miles long and lasted about 22 minutes.

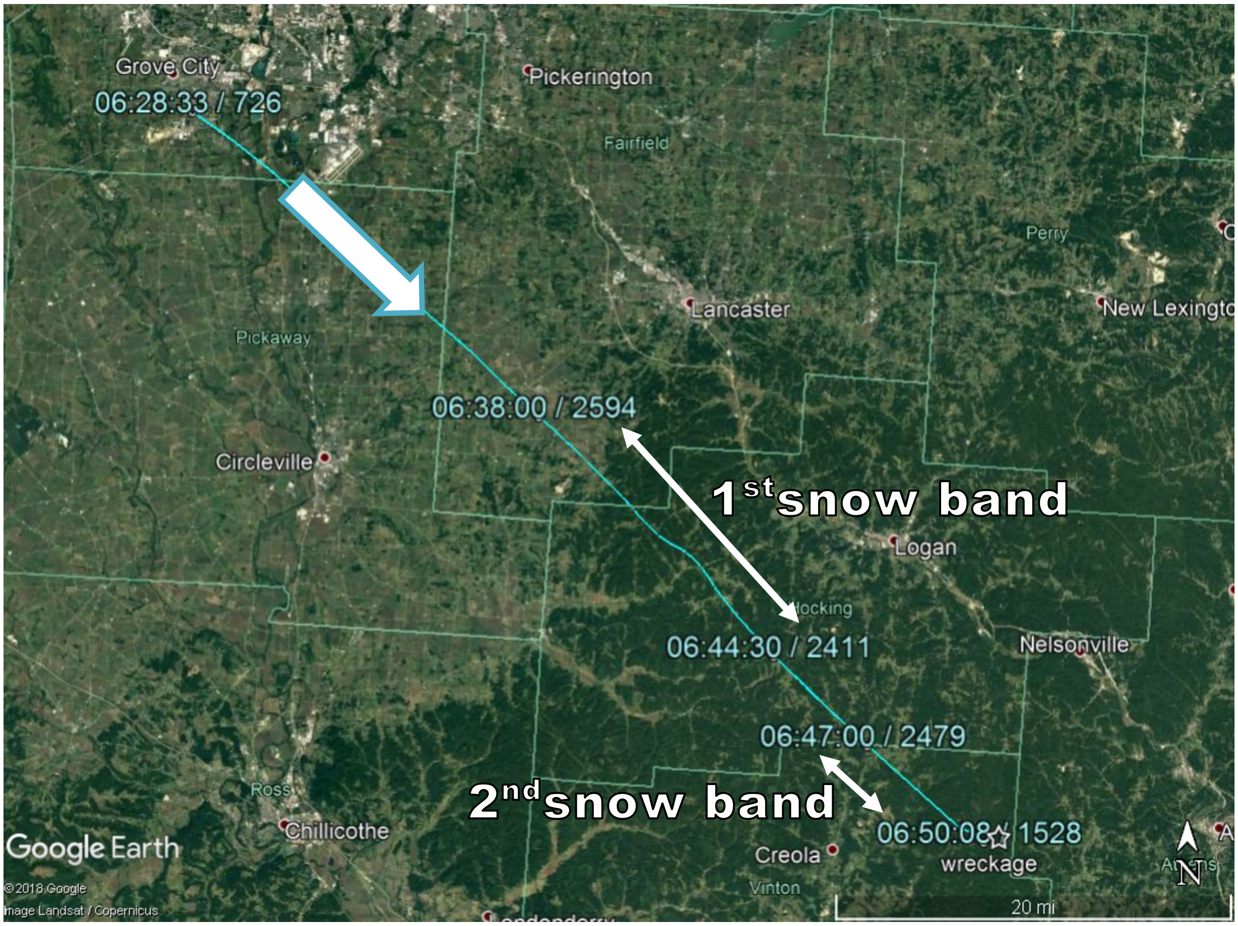

Figure 1. Accident flight path. The annotations indicate the time and the altitude (MSL).

The onboard device recorded all parameters as expected from take-off until 0647:09, when no data was recorded for two minutes. From 0649:09 to 0650:08, an additional minute of data was recorded, and then the data ended. The NTSB Flight Data Monitoring Device factual report [2] discusses the loss of data. The location of the last data point was 4,400 ft from the wreckage location. The ADS-B data from the accident flight ended about 40 seconds before the Outerlink data, so only the Outerlink data will be used in describing the accident flight. The Outerlink device also sent position and altitude data to a satellite every eleven seconds. Two satellite altitude and location points were sent after the end of the onboard data. Figure 2 shows the end of flight, loss of data, additional satellite points, and wreckage location. However, Figure 3 shows a comparison of the flight path recorded by the satellite uplink versus the onboard position recorded. The satellite data tracked a saw-toothed approximate path compared to the onboard position data, so satellite position data must be considered as having a larger uncertainty.

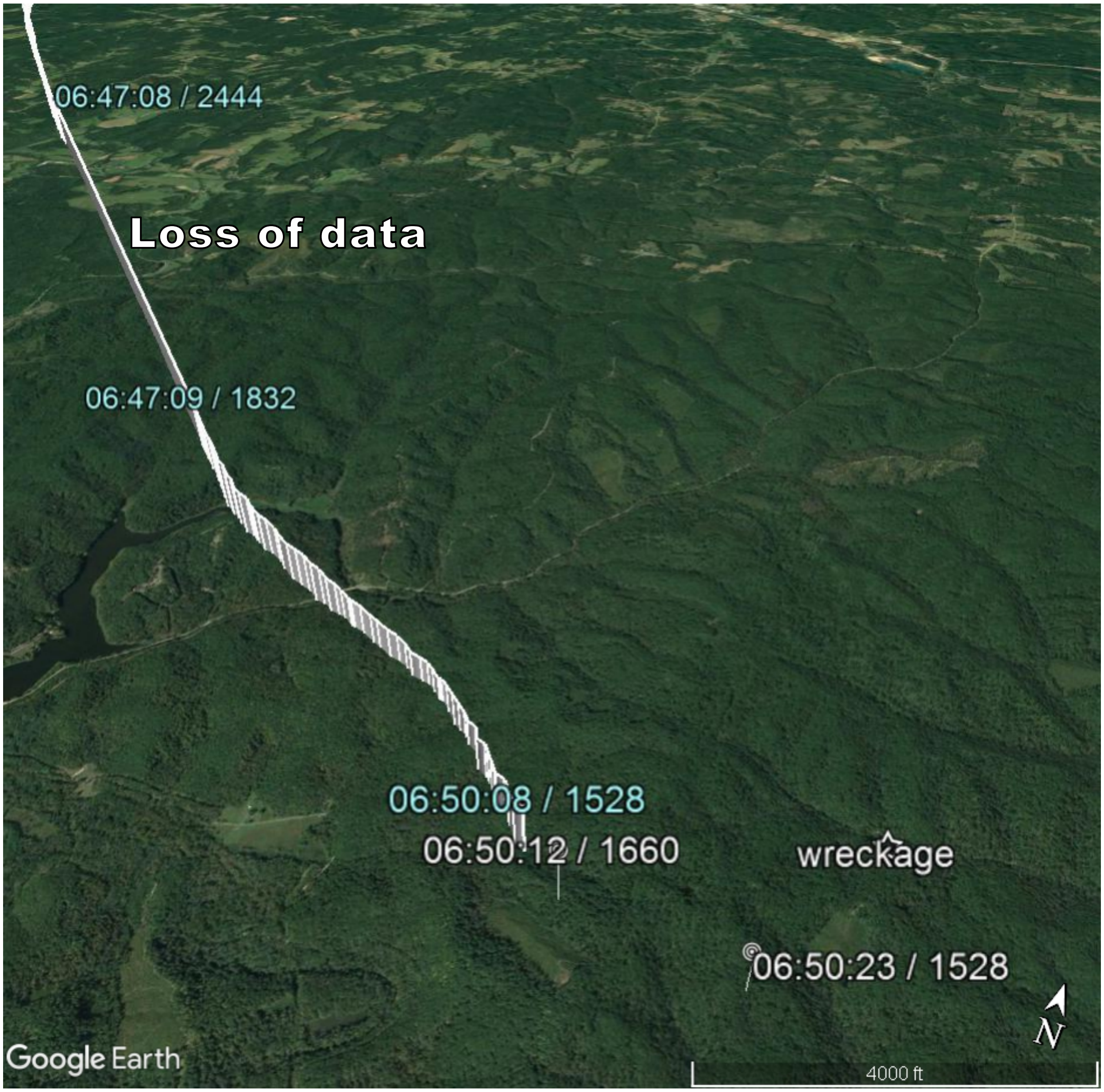

Figure 2. End of accident flight. The blue data record is from the onboard data recorder. The two circular points are from the satellite record. Annotations indicate the time and the altitude (MSL).

Figure 3. Satellite received flight track (yellow) versus onboard flight track (white).

Figure 4 shows the altitude and groundspeed of the helicopter from the onboard device and the altitude data from the satellite. Above 2,000 ft MSL, the satellite altitude shows good agreement with the onboard altitude record. Below 2,000 ft, they diverge so that during that last minute of the record, the satellite recorded altitude was about 120 ft higher than the onboard recorded altitude. Figure 5 shows the altitude with the terrain elevation beneath the flight path. The helicopter gained altitude from the beginning of flight, 0628, to 0635, reaching a maximum altitude just below 3,000 ft, about 2,000 ft AGL (an overcast cloud ceiling was reported at 3,100 ft, MSL). The aircraft's speed throughout the flight was between 120 and 140 kts. From 0635 to 0643 the aircraft descended about 1,000 ft, before climbing again to an altitude of 2,600 ft at 0643:30. The terrain below the helicopter during the flight varied between 700 ft and 1,100 ft of elevation. By 0647 the helicopter was descending and at an altitude of 2,400 ft. No data was recorded onboard for the following two minutes but satellite altitude data is shown. At the same time the helicopter entered the second band of snow.

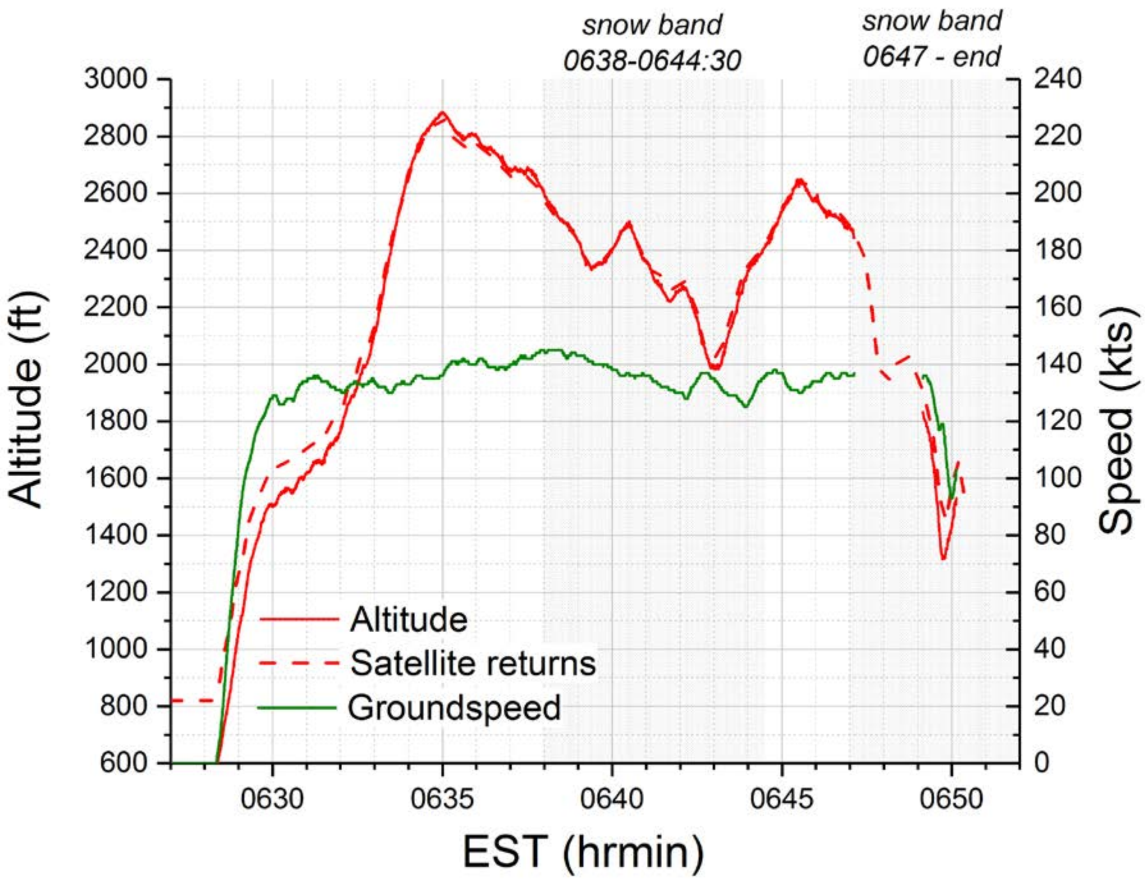

Figure 4. Altitude (MSL) and groundspeed versus time.

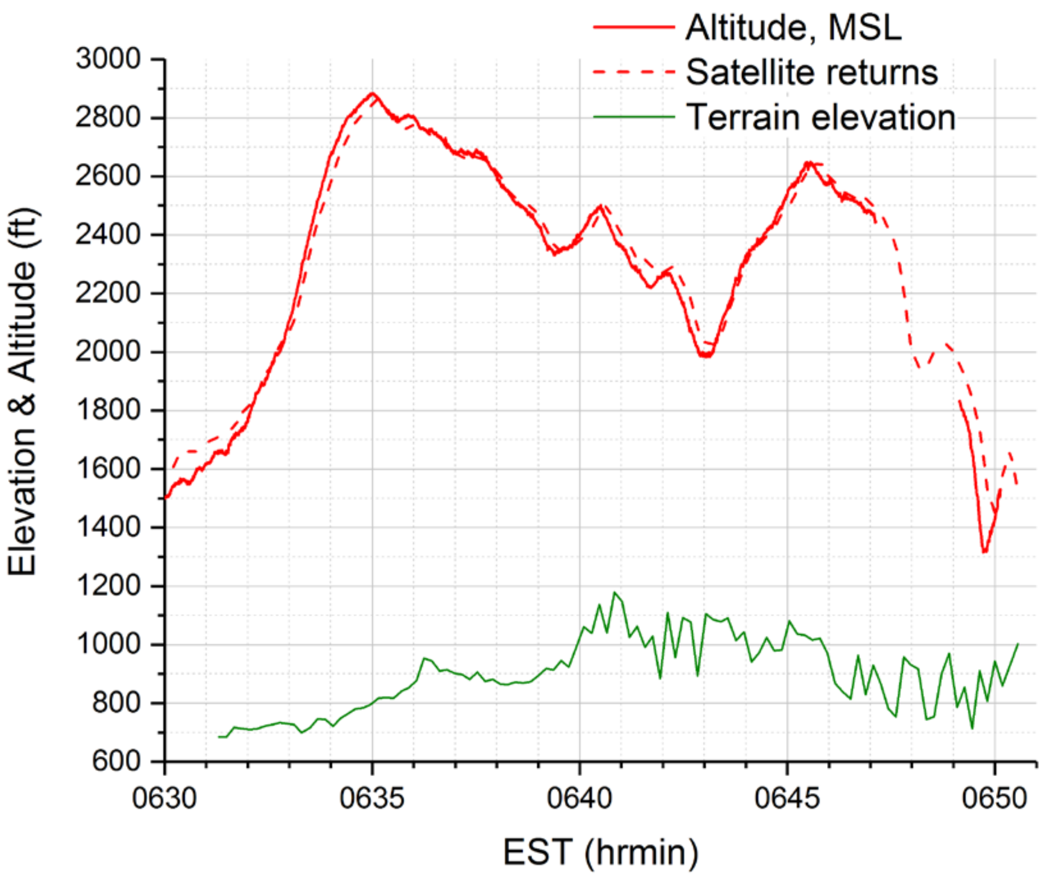

Figure 5. Altitude (MSL) and ground elevation versus time.

Satellite altitude data showed that the helicopter continued to descend until 0647:58. It briefly regained about 80 ft of altitude before descending at a rate of about 900 ft/min. At 0649:45, the aircraft had descended to 1,300 ft and then began climbing. At 0650:07.8 the helicopter was at 1,500 ft and climbing when the data ended. During the loss of onboard data, groundspeed was not recorded, but the recorded speed before and after the loss was about 135 kts. During the final recorded portion of flight the groundspeed slowed to near 100 kts.

Figure 6 and Figure 7 show the aircraft's recorded pitch and roll attitude and the collective pitch (cyclic was not recorded). Figure 6 shows the entire length of the flight. Collective was generally between 55% and 65%, aircraft pitch was ±2.5°, and roll was also ±2.5° other than a turn at 0642. During the final minute of recorded flight, collective was dropped from about 60% to 30% over the course of 20 seconds. The collective was then increased to 72% over the next 25 seconds. The aircraft was 9° left side down at 0649:25, righted itself by 0650, but then banked to 20° left side down as the data ended. Pitch went briefly 7° nose up at 0649:48 before ending 3° nose down. The recorded helicopter attitude after the data loss was more dynamic and larger control inputs were recorded than in the earlier portion of the flight, but the helicopter tracked the pilot's inputs, so the data were not indicative of a loss of control.

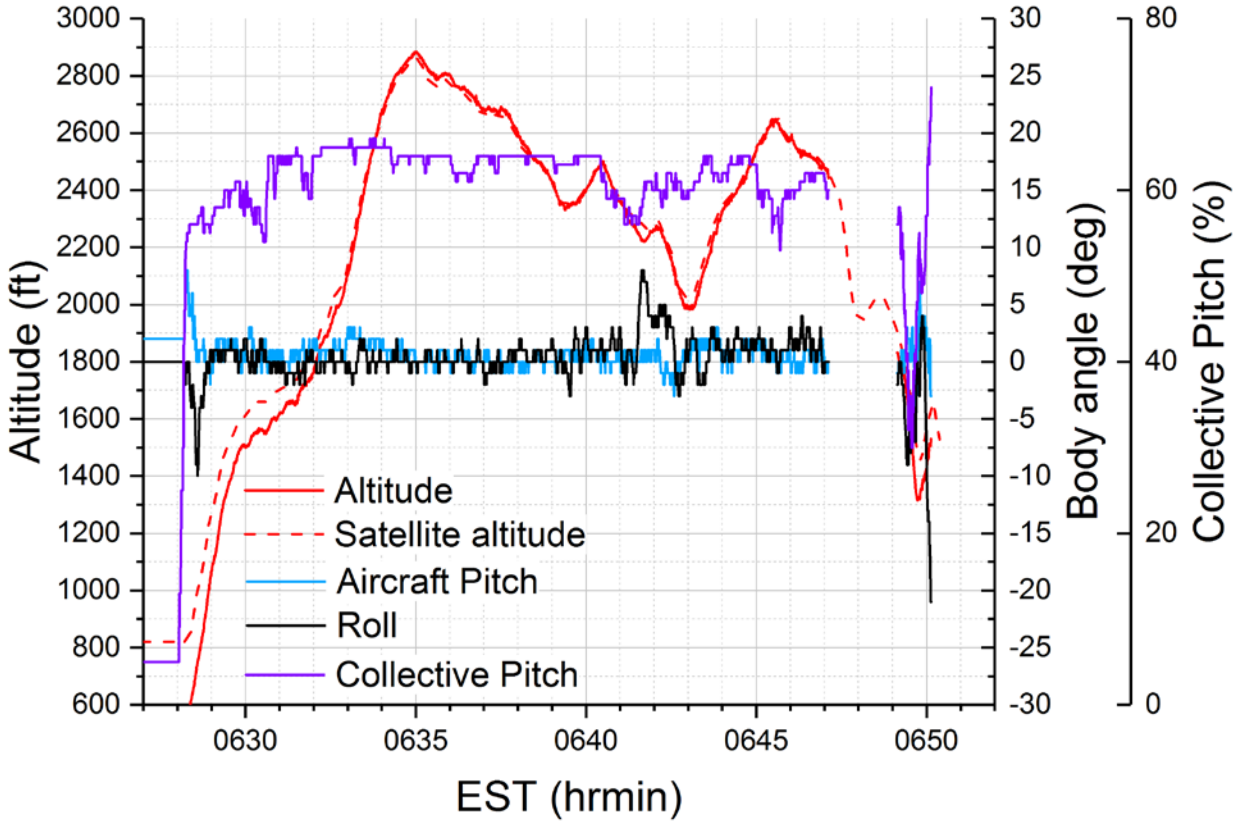

Figure 6. Altitude (MSL), aircraft pitch and roll, and collective pitch versus time.

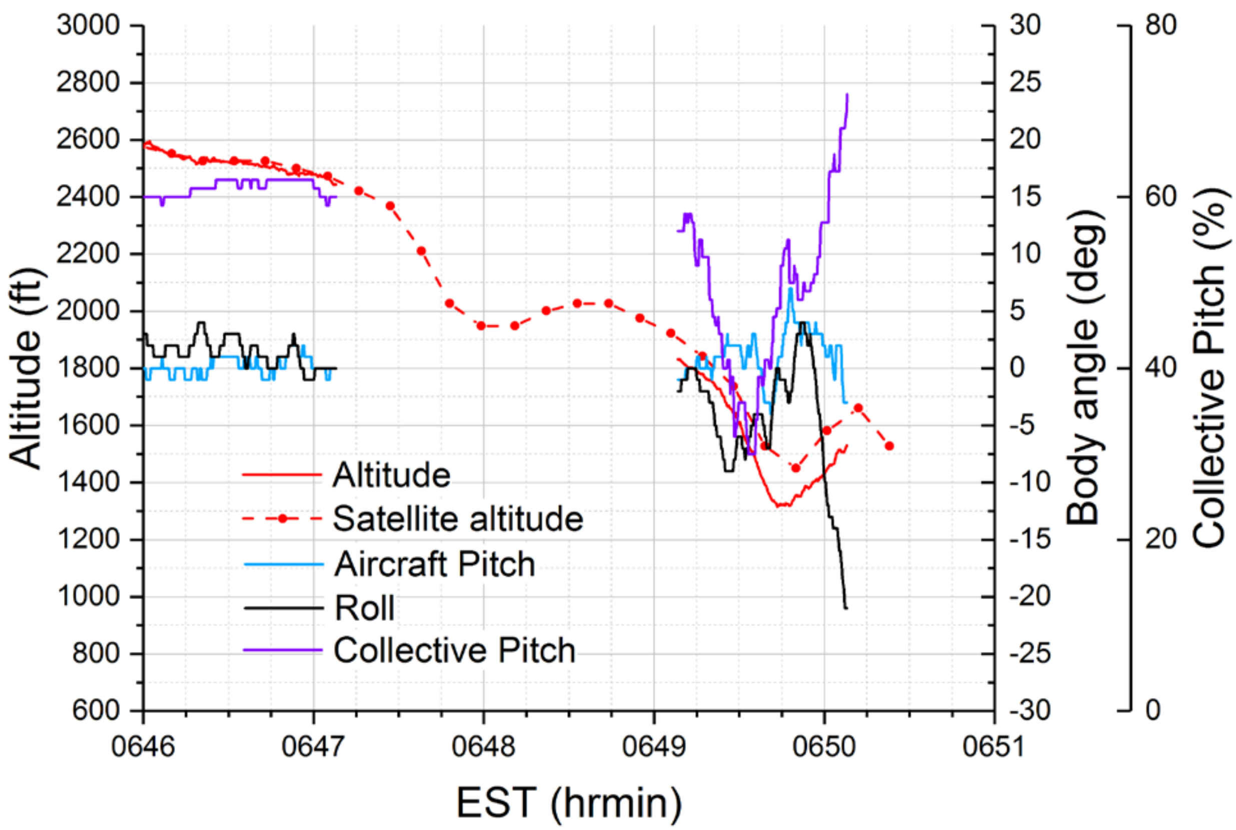

Figure 7. Altitude (MSL), aircraft pitch and roll, and collective pitch versus time for the end of flight.

Engine Control Unit Data

The aircraft's engine control unit (ECU) was programmed so that if an exceedance or fault was recorded it retained the last ten lines (12 seconds) of parameters before the event and then the next 40 lines (48 seconds) of parameters after. Two torque exceedances were recorded near the end of the flight, and fourteen seconds of data were recorded.

The ECU data does not keep universal time but does record absolute pressure. The absolute pressure was converted to altitude using a calculation that estimates ambient air pressure assuming an exponential drop in pressure at altitude with a sea-level pressure of 1 atm. This altitude estimate was compared to the rest of the flight path to determine a likely time synchronization of the data. Figure 8 shows the ECU data and the comparable onboard data versus time. The altitude data does not show direct overlap between the satellite recorded altitudes, but the trend implies that the ECU data was likely recorded starting just after the satellite data ends. If so, the impact occurred about 0650:38, 30 seconds after the end of the onboard data. This calculation is an estimate, as the final altitude record derived from the ECU pressure was 675 ft at a point where the terrain elevation was 900 ft. The earlier altitude calculations were more consistent with the terrain.

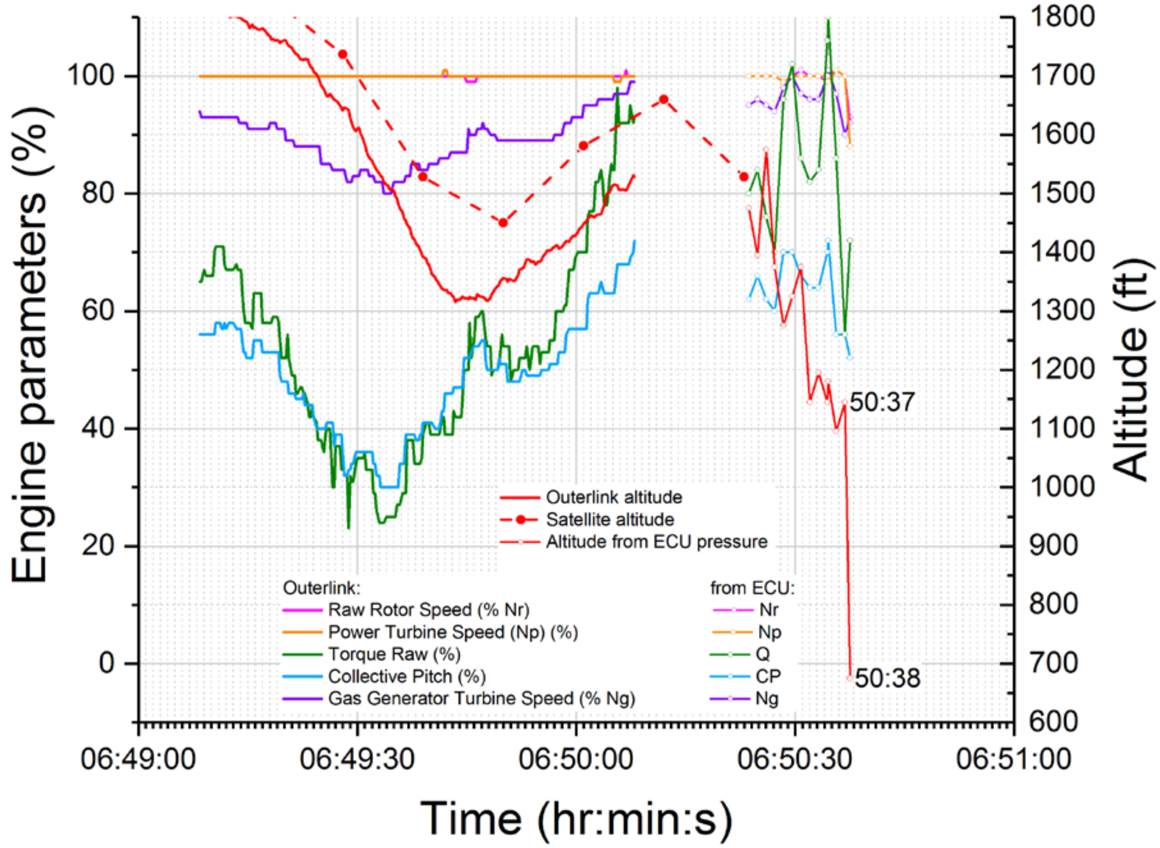

Figure 8. Engine parameters from Outerlink and ECU devices with altitude.

Collective pitch was between 60 and 70% during the final 14 seconds. The aircraft recorded two overtorques (Q greater than 100%) before the data ended. Torque exceeding 100% while the collective was about 70% indicates that the rotor was additionally loaded likely from lateral maneuvering (which was not recorded by the ECU). After each overtorque, the collective was lowered in response, while the absolute pressure reflected a decrease in altitude.

Path to Impact

The onboard data ends 4,400 ft and likely 30 s of flight time from the wreckage location. Two additional satellite points were recorded (Figure 9), but as shown in Figure 3, the ground path locations were unreliable. However, the end of onboard data, the satellite points, and the wreckage location do lie roughly along the arc of a circle 0.7NM (4,400 ft) in diameter. In the equation below, θ is the bank angle to complete a level turn of radius R at constant groundspeed V, neglecting winds (g is the gravitational constant, 32.2 ft/s^2),

$$\theta = tan^{-1}\left(\frac{V^2}{gR}\right)$$

An aircraft at a speed of 100 kts (last onboard recorded groundspeed), would need a 22° bank angle to complete a turn along the described arc. This track would be consistent with both the final roll record from the onboard device (20° left bank) and the direction of the debris field which was recorded along a heading of 345° (see Figure 9). Additionally, the distance along the arc path was about 5,900 ft and to cover it in 30 s would require an average groundspeed of 116 kts, also consistent with the above-mentioned speeds.

Figure 9. End of flight path, wreckage location, and debris field orientation (orange line).

Rotor Icing

Of interest to the investigation was the possibility of icing. The NTSB meteorology report [1] stated that the aircraft passed through two snow bands during which conditions for icing were possible. The possibility of rotor icing can be determined by comparing collective pitch to rotor torque. The relationship between collective pitch and rotor torque should remain constant and an increase in collective produces an increase in torque. If ice accretion on the rotor blades occurs, the helicopter would record higher torque values without requiring more collective pitch. Figure 10 shows collective pitch versus rotor torque, divided into timed sections. Most of the flight (red, orange, green, and blue) lay along a continuous curve of torque versus pitch. The purple section (0649-0650) represents the end of the data which coincided with the second snow band. The lowering of collective during the last minute of data differentiates that data from the rest of the flight, but the relationship between collective pitch and rotor torque does not change and does not indicate that icing affected rotor performance.

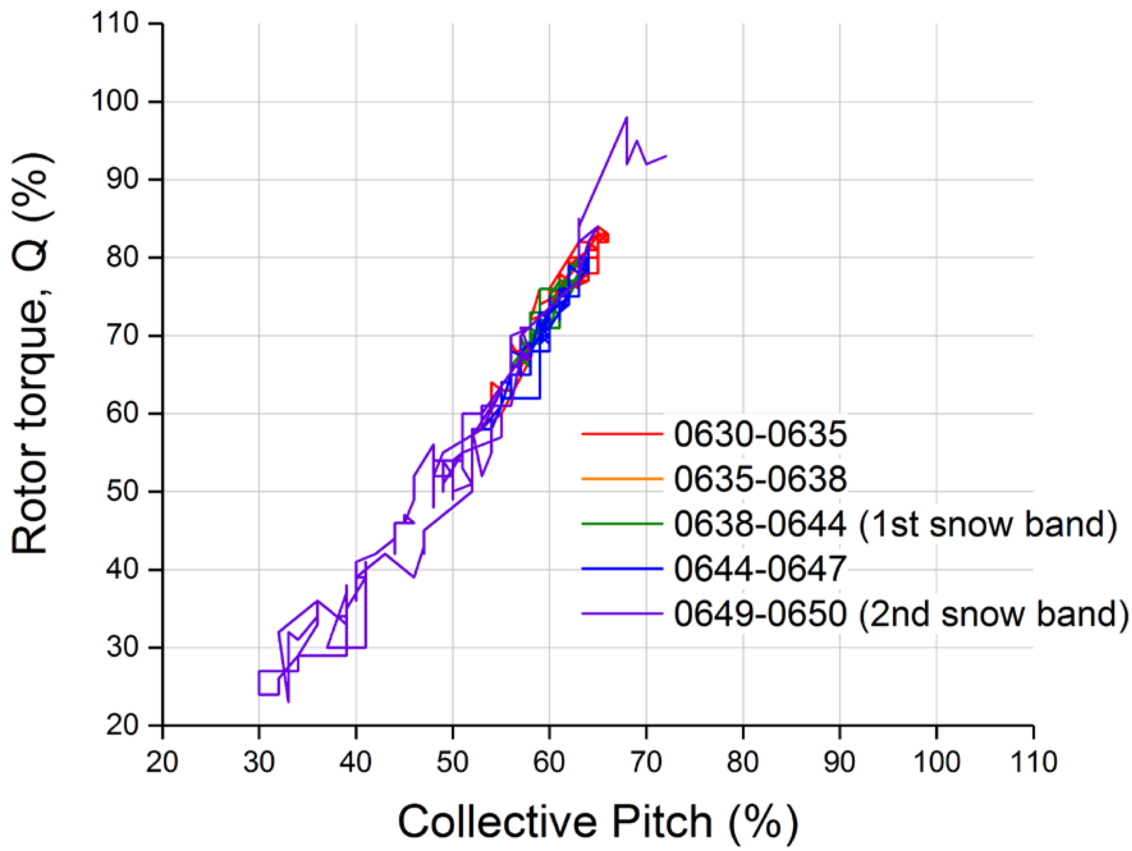

Figure 10. Rotor torque versus collective pitch at different times throughout the flight.

The onboard data ended approximately 30 seconds before the helicopter's impact with the ground. Bell reported that the development of severe rotor icing conditions would require three to four minutes of ice accretion. While there was no evidence of rotor icing, the presence of airframe icing could not be determined from the data available.

Prior Flights

ADS-B for four days of prior flights were provided to the investigation. Figure 11 shows the prior flight paths in addition to the accident flight path.

Figure 11. Four prior flights and accident flight path (white).

Figure 12 and Figure 13 show the altitudes, MSL, and height above ground of the four flights and the accident flight. Three of the flights showed flight profiles between 400 and 1,000 ft above the ground at altitudes near 1,500 ft MSL for most of the flight. The accident flight and the December flight were flown at greater heights above ground and with more variation in altitude than the other three flights.

Figure 14 shows the groundspeeds for all the flights. The accident flight was ten to 15 kts faster than some of the other flights, but not all. This data from the prior flights is discussed in additional detail in the Human Performance report [3].

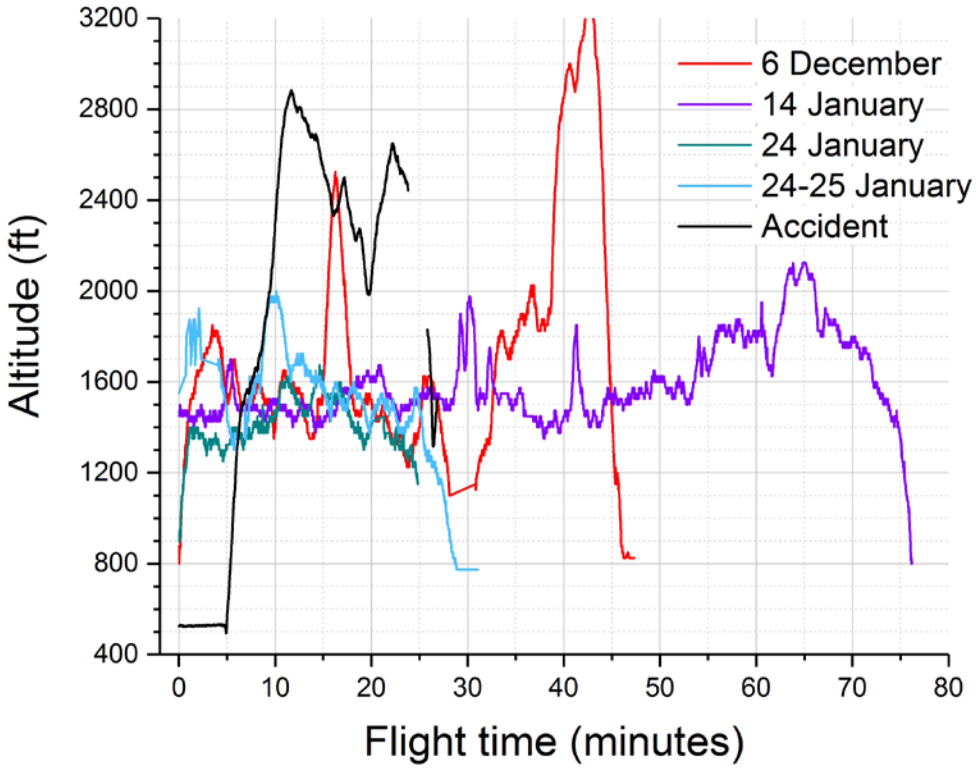

Figure 12. Altitude (MSL) versus flight time.

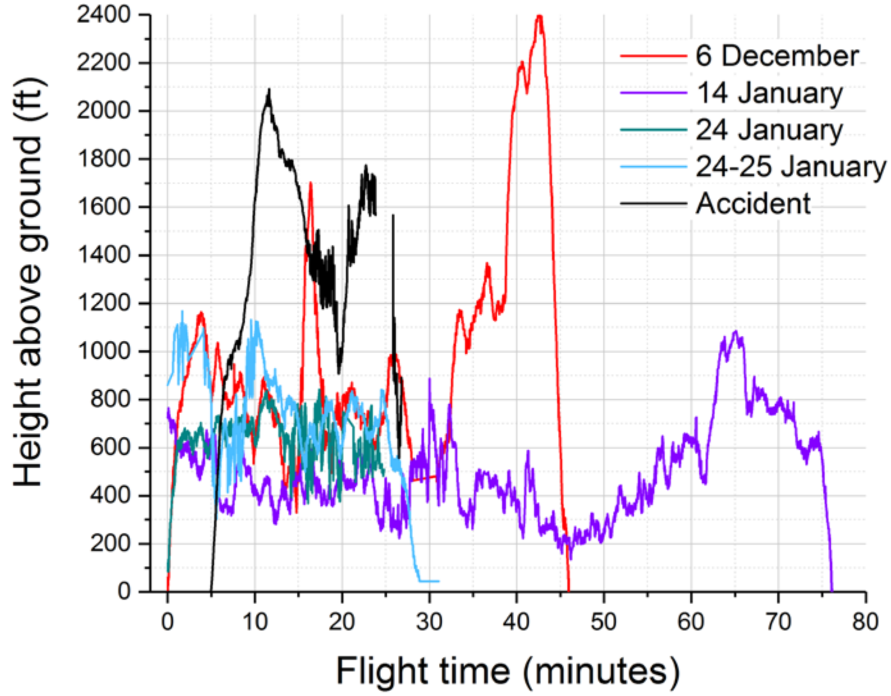

Figure 13. Height above ground versus flight time.

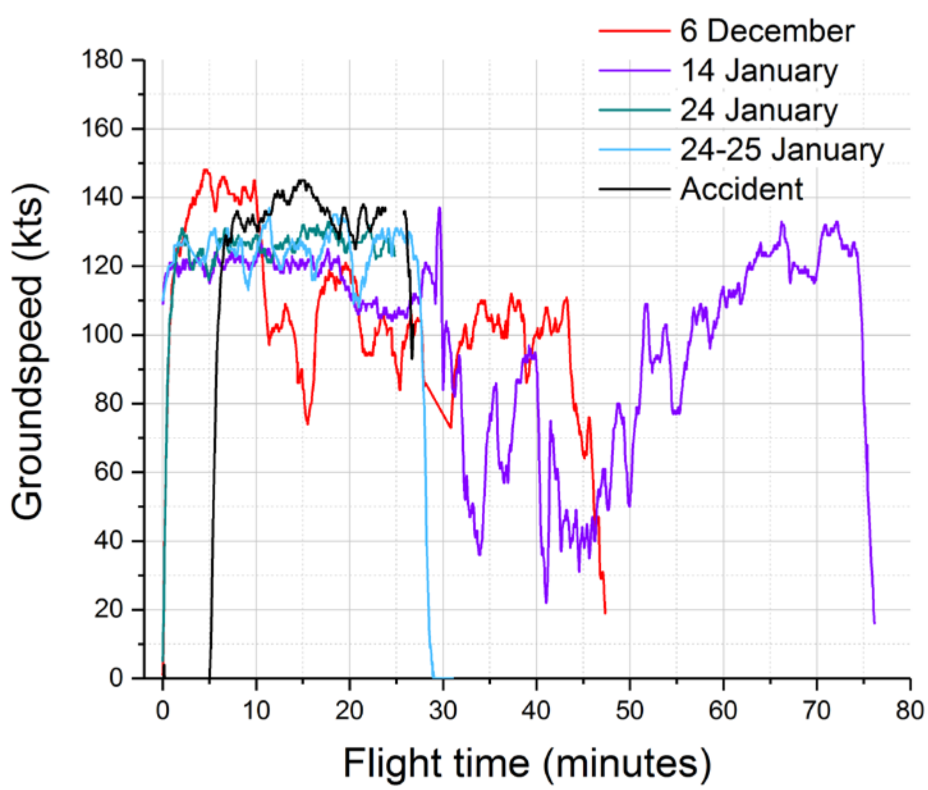

Figure 14. Groundspeed versus flight time.

E. CONCLUSIONS

The accident flight departed Mt. Carmel Hospital, Grove City, Ohio at 0628, destined for Holzer Meigs Hospital, Pomeroy, Ohio, about 69 miles southeast. Altitude varied between 2,000 and 2,900 ft (after the initial climb) and the groundspeed was between 120 and 140 kts. The helicopter passed through two snowbands during the 22-minute flight. The aircraft had begun a descent from 2,600 ft when a two-minute-long loss of data occurred, and it entered the second snowband. When data recording resumed, the aircraft was still descending and then began to slow. The helicopter attitude after the dropout was more dynamic and there were larger control inputs than during the earlier portion of the flight, but the helicopter tracked the pilot's inputs, so the data were not indicative of a loss of control. The possible flight path between the final data points and the wreckage location could be flown in a manner consistent with the recorded end of flight. There was no evidence of rotor icing during the flight, but airframe icing could not be determined from the data available.

Marie Moler
Specialist – Airplane Performance
National Transportation Safety Board

F. REFERENCES

1. Meteorological Factual Report, CEN19FA072, National Transportation Safety Board, 2019.
2. Flight Data Monitoring (FDM) Device Factual Report, CEN19FA072, National Transportation Safety Board, 2019.
3. Human Performance Factual Report, CEN19FA072, National Transportation Safety Board, 2019.