National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594

ERA21FA195

VEHICLE PERFORMANCE

Aircraft Performance Study

By

Marie Moler

A. ACCIDENT

Location: Eden, North Carolina
Date: April 28, 2021
Time: 13:24 EDT
17:24 UTC
Aircraft: Bell 429, N53DE

B. SUMMARY

On April 28, 2021, about 13:24 eastern standard time, a Bell 429 helicopter, N53DE, was destroyed when it was involved in an accident near Eden, North Carolina. The commercial pilot was fatally injured, and two passengers were seriously injured. The helicopter was operated as a Title 14 *Code of Federal Regulations* Part 91 aerial observation of powerlines.

C. PERFORMANCE STUDY

1.0 Aircraft

The accident aircraft was a Bell 429, also known as a GlobalRanger. It is a four-bladed, light, twin-engine helicopter. The main rotor rotated in the counter-clockwise direction when viewed from above. The helicopter was powered by two Pratt & Whitney PW207 turboshaft engines.

Figure 1. A photograph of the accident Bell 429, N53DE.

2.0 Available Data

The helicopter was equipped with a GPMS Foresight MX health and usage monitoring system (HUMS), which captured the accident flight. The HUMS device recorded position, attitude, acceleration, and engine data. There were abnormalities that led to the attitude and acceleration data being discarded.

The flight was also recorded by Automatic Dependent Surveillance-Broadcast (ADS-B) data provided by the Federal Aviation Administration (FAA). ADS-B broadcasts an airplane's Global Positioning System (GPS) position and other data to the ground where it is recorded. The GPS position has an accuracy of approximately 20 m (65 ft) in both the horizontal and vertical dimensions.

The latitude and longitude recorded by the onboard device exhibited a stepped characteristic (Figure 2) not seen in the smoother ADS-B data. It is likely that the stepped characteristic is reflective of how the position was recorded on the GPMS device. Additionally, the track angle, which is calculated, follows with the smoothed path. However, portions of the flight were missing from the ADS-B data but were recorded by the onboard recorder. Consequently, for calculations, the onboard position data was smoothed to a closer match of the ADS-B data for a more realistic flight path.

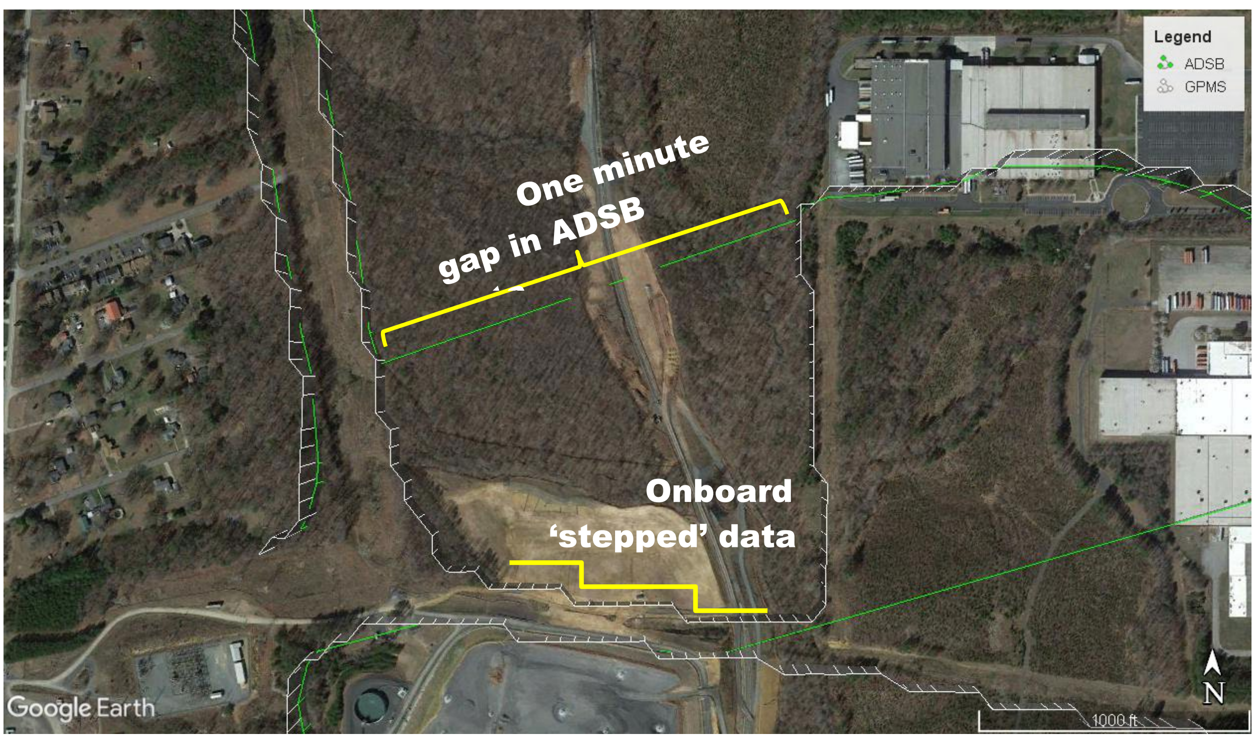

Figure 2. ADS-B flight path in green and onboard GPMS device data in white.

3.0 Weather Observations

At 13:15, the nearest weather station, seven nautical miles (NM) east of the accident site, recorded the temperature as 80°F (27°C), the dewpoint as 59°F (15°C), and the barometric pressure as 30.04 inHg. Winds were 7 kts from 220°. Skies were clear and visibility was 10 statute miles.

4.0 Flight Path

Figure 3 shows the accident flight path. Altitude above mean sea level (msl) and groundspeed are shown in Figure 4 and radar altitude, or recorded height above terrain, in Figure 5. The helicopter left Danville, Virginia about 12:33 and flew cross country south-west into North Carolina. By 12:45, the helicopter was flying powerline patrol around Eden, North Carolina. Line inspection was done at an altitude of about 100 ft above terrain with the helicopter gaining altitude during turns and when flying between line inspections.

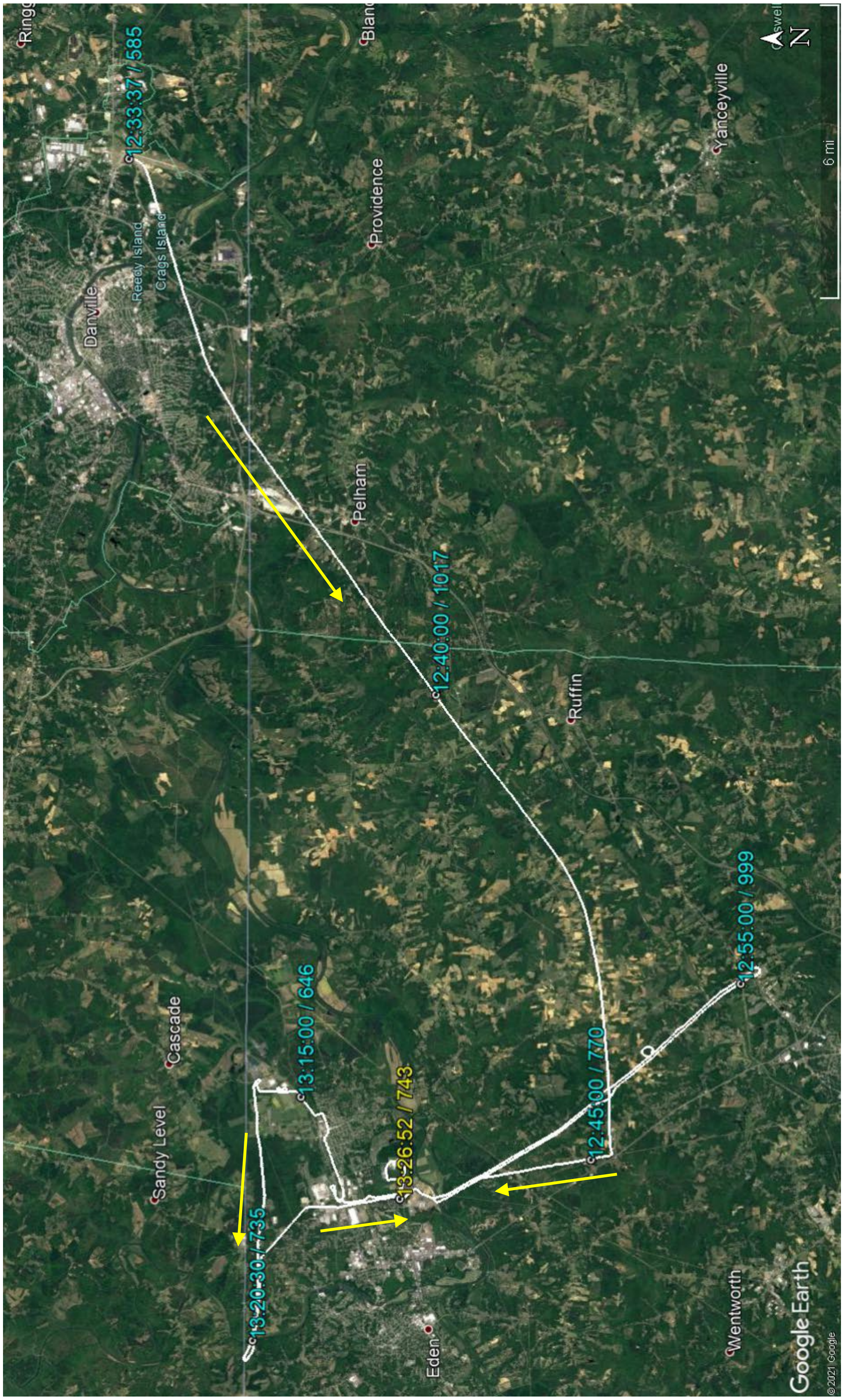

Figure 3. Accident flight path from onboard data, with time and altitude (msl) annotated for select points. The final data point is shown in yellow.

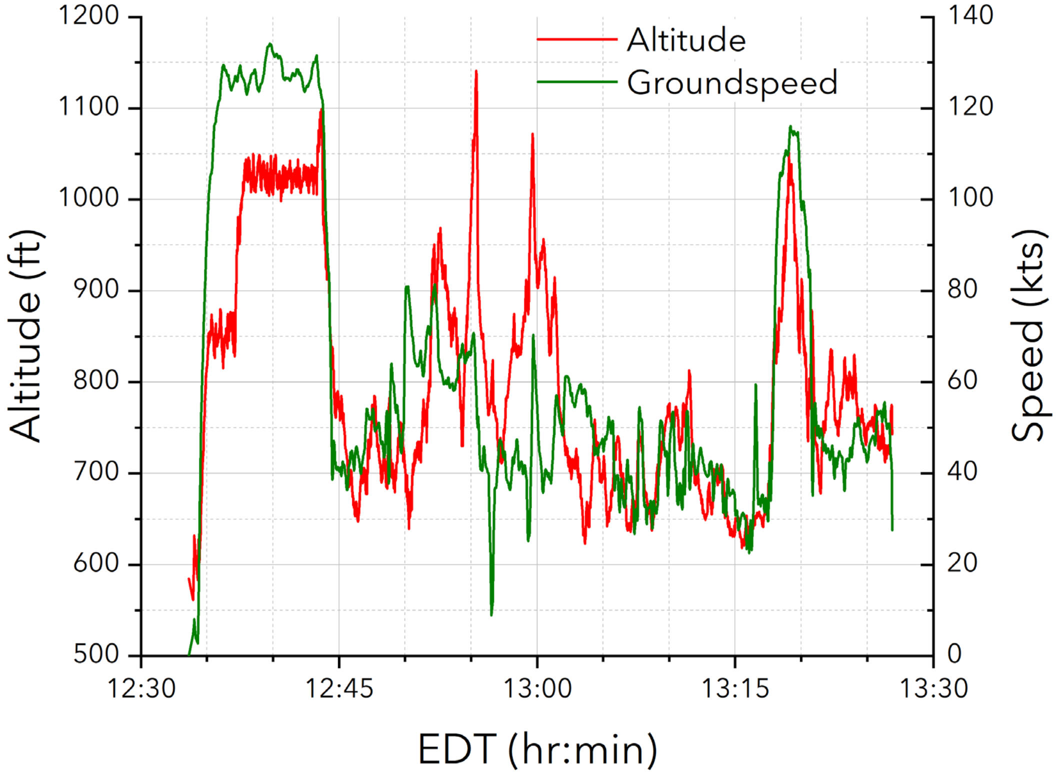

Figure 4. Accident flight altitude (msl) and groundspeed.

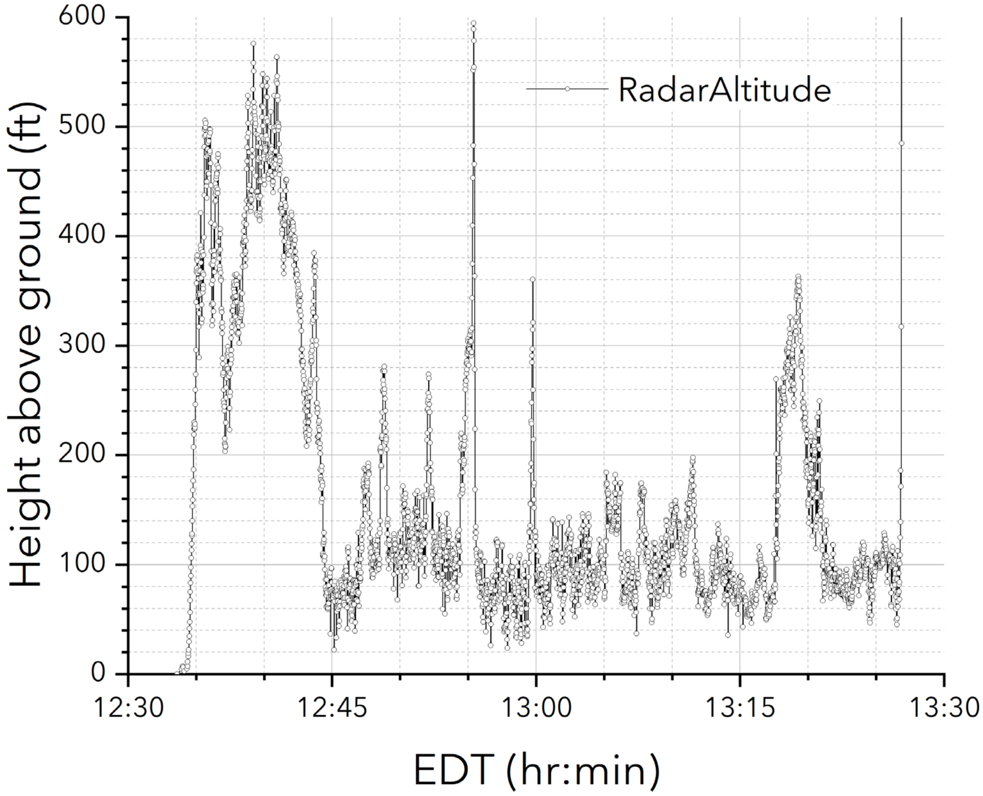

Figure 5. Accident radar altitude from onboard device.

During the final minutes of flight, the helicopter was traveling at an airspeed between 50 and 60 kts along powerlines at an altitude between 700 and 775 ft msl (Figure 6 and Figure 7). Main rotor speed was near 100%, torque varied between 15% and 25%, and the engine N1 speeds[1] were between 84 and 88%.

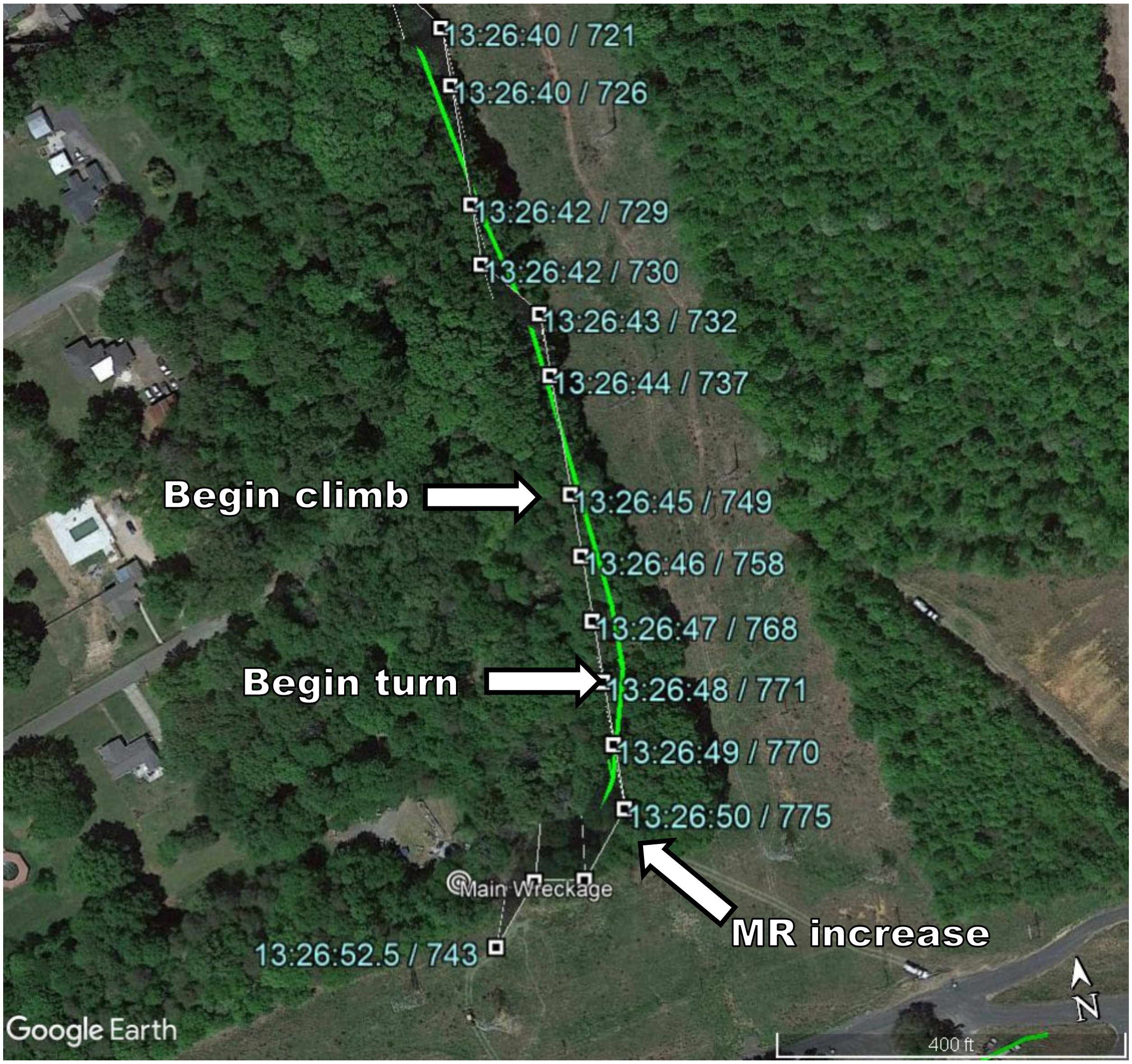

Figure 6. End of flight. Onboard data is shown in blue and white, the ADSB path is shown in green.

[1] N1 is the rotational speed of the low-pressure turbine. It is expressed as a percentage of the normal operating RPM.

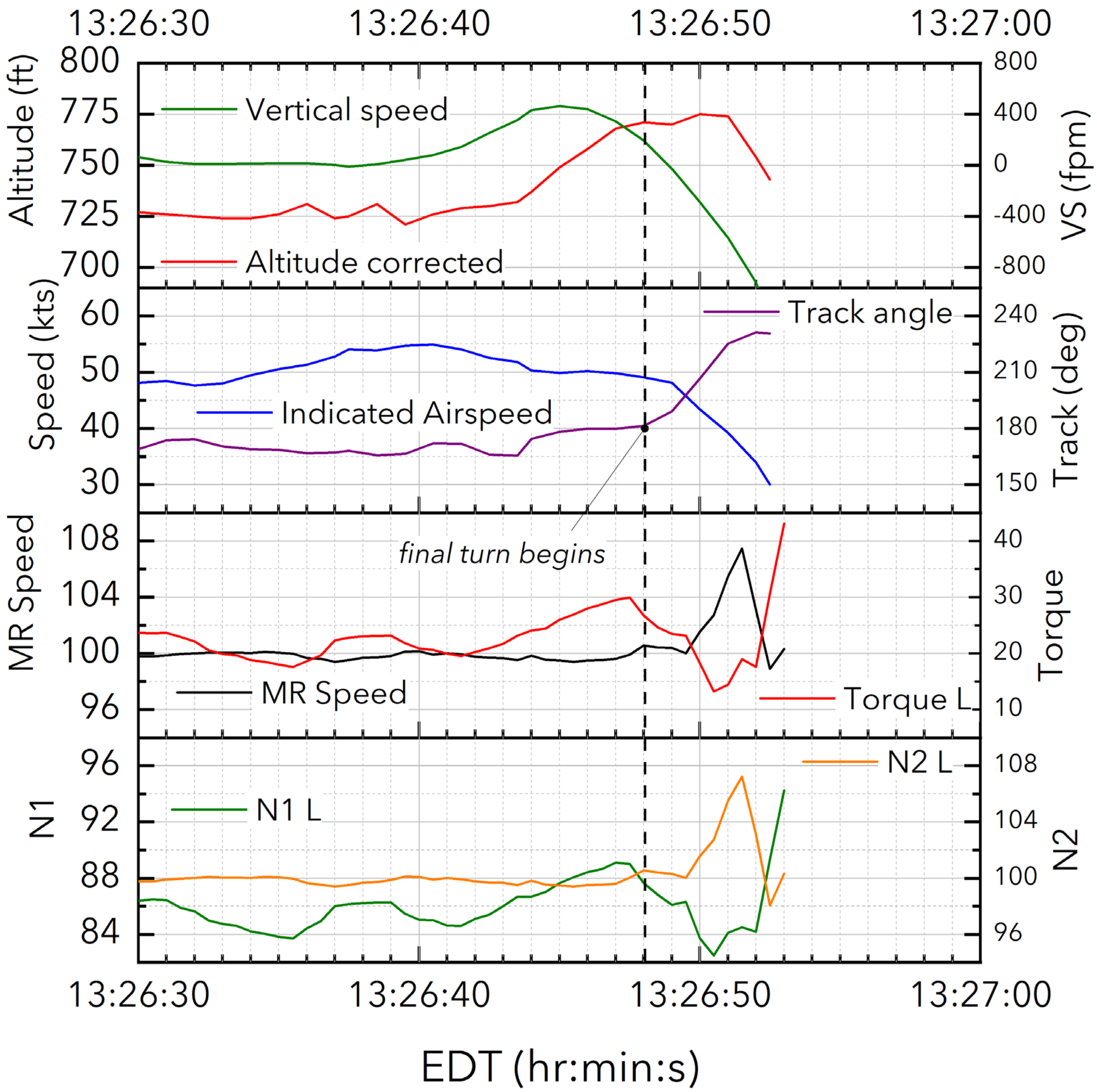

Figure 7. Altitude (msl), speeds, track, and engine parameters for the final two minutes of flight.

The helicopter began climbing at 13:26:45 reaching an altitude of about 775 ft msl by 13:26:48. The engine torque increased with the climb but fell off when the helicopter's altitude leveled off and it began to turn right. Two seconds later, just before 13:26:50, main rotor speed and engine N2[2] values spiked to over 107%. Torque and N1 increased from 13:26:52 until the end of the data. The aircraft lost altitude after 13:36:51.

The onboard recorder did not record control inputs, so pilot input during the final climb, turn, and upset are unknown. An onboard witness reported a loud noise

[2] N2 is the rotational speed of the high-pressure turbine. It is expressed as a percentage of the normal operating RPM.

during the final turn after which the aircraft descended into the trees. The wreckage examination found that two of the main rotor blades had impacted the tail boom and severed the tail rotor drive shaft. The sudden increase in main rotor speed likely correlates with the severing of the tail rotor drive shaft which would lead to all engine power to go to the main rotor system.

Winds were insufficient and the helicopter's forward speed too great for a loss of tail rotor effectiveness. The aircraft was not descending before the change in engine parameters, ruling out vortex ring state. Rotor speeds were normal until the last seconds of flight. The helicopter was not near the edge of its operating envelope for speed, altitude, or temperature. Weather conditions were clear and visibility was good.

5.0 LIDAR Data and Terrain

The helicopter was equipped with an onboard LIDAR ("light detection and ranging" or "laser imaging, detecting, and ranging") system which recorded the powerlines and surrounding terrain. A pulsed laser is used to determine the location of objects in relation to the system and the data is stored as a point cloud – each point representing the location of a physical object that was recorded. Duke Energy provided the LIDAR data from the accident location. Using features visible in Google Earth satellite data, the LIDAR and flightpath data were correlated as shown in Figure 8 - Figure 11.

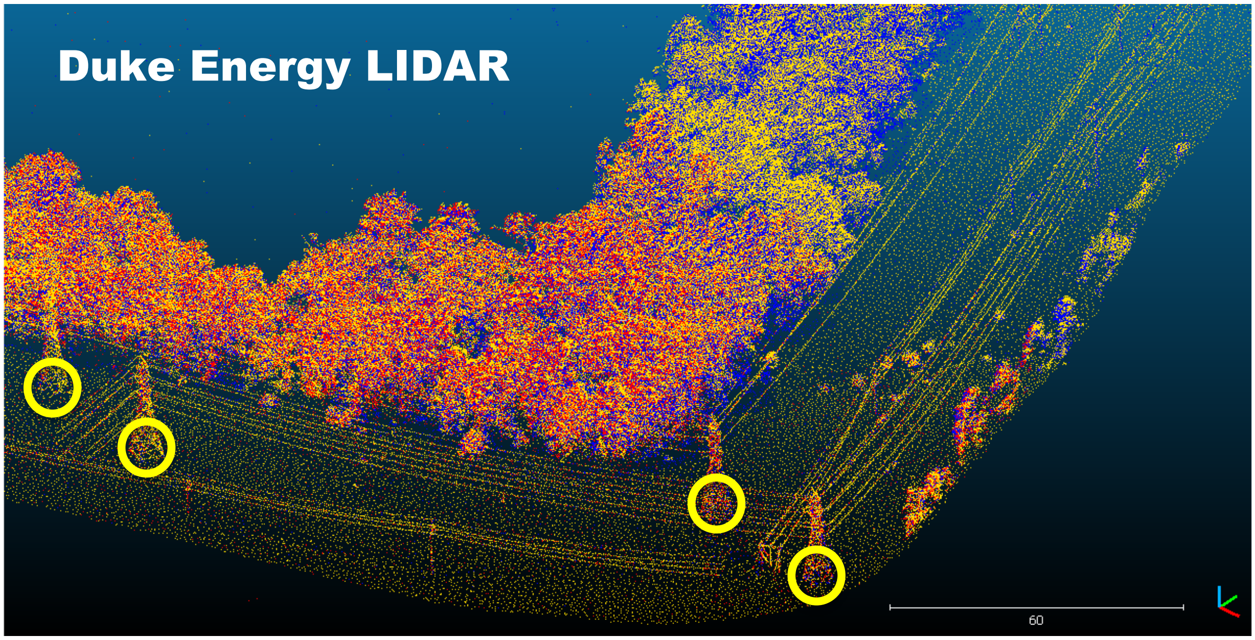

Figure 8. LIDAR data from Duke Energy corresponding to Figure 9. Yellow circles show the base of electrical towers.

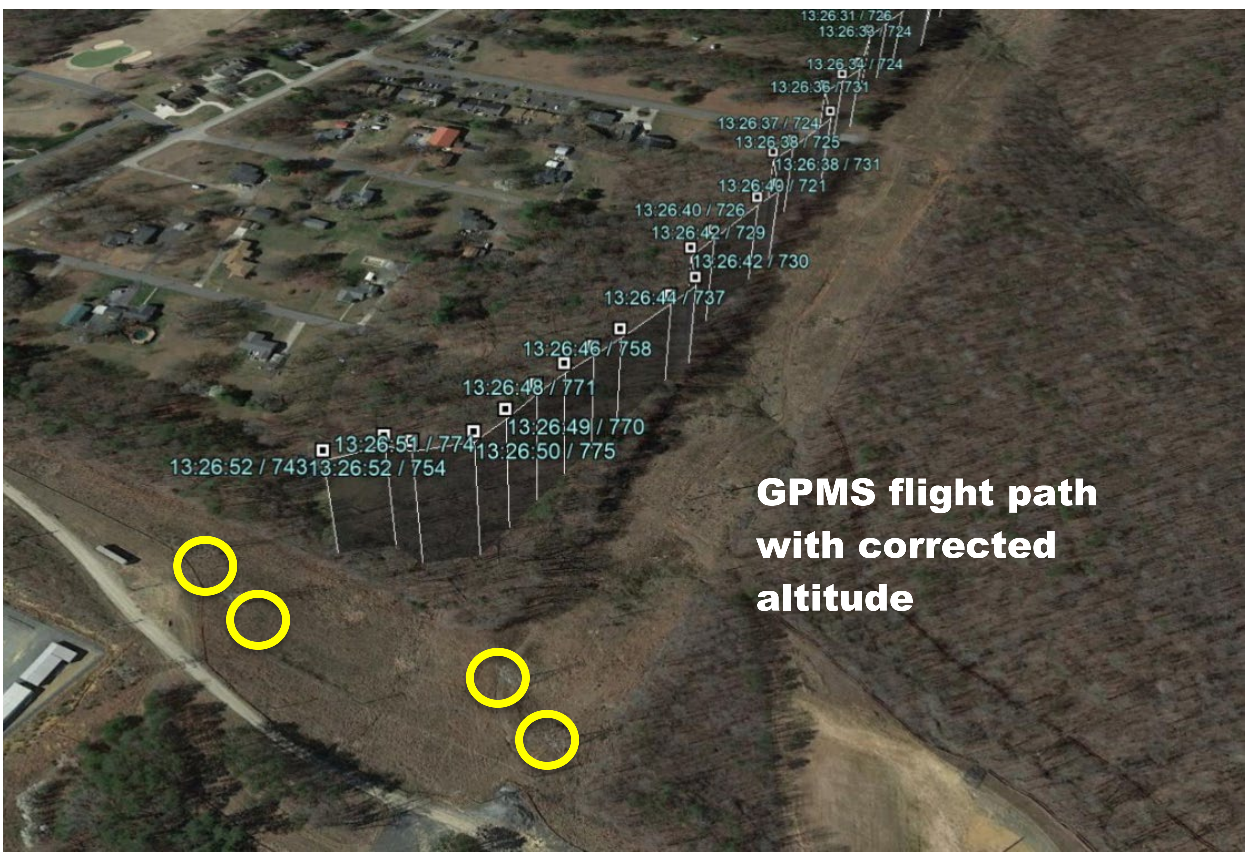

Figure 9. Google Earth satellite imagery corresponding to Figure 8. Yellow circles show the base of electrical towers.

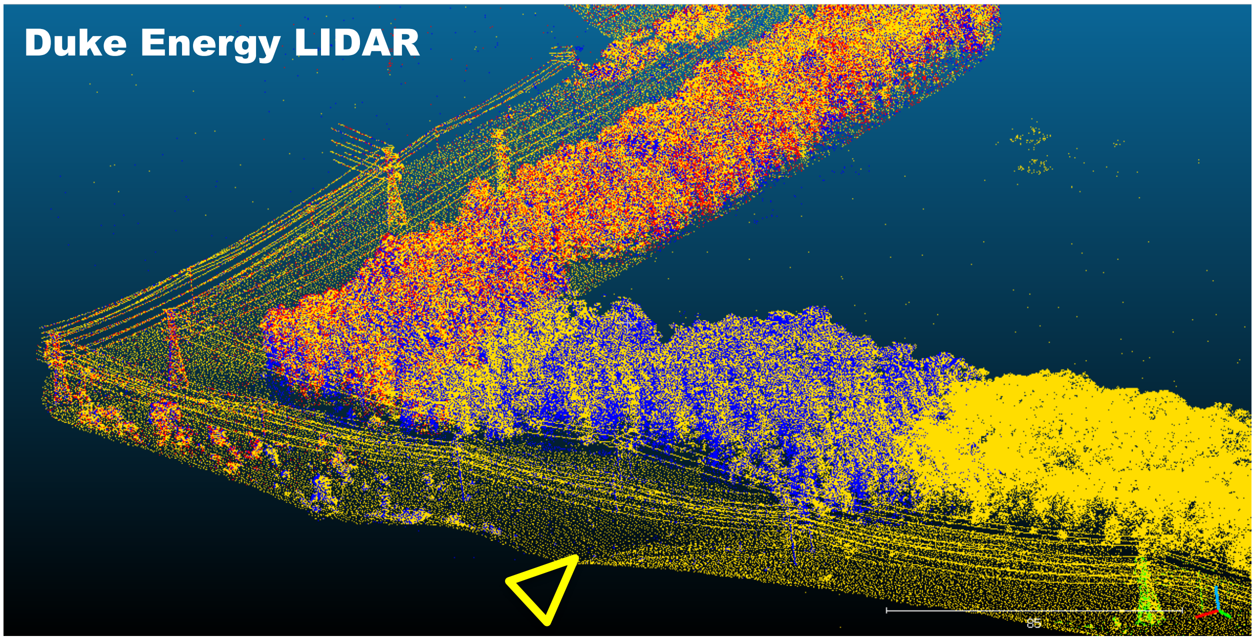

Figure 10. LIDAR data from Duke Energy corresponding to Figure 11. A yellow triangle indicates a small water course depression.

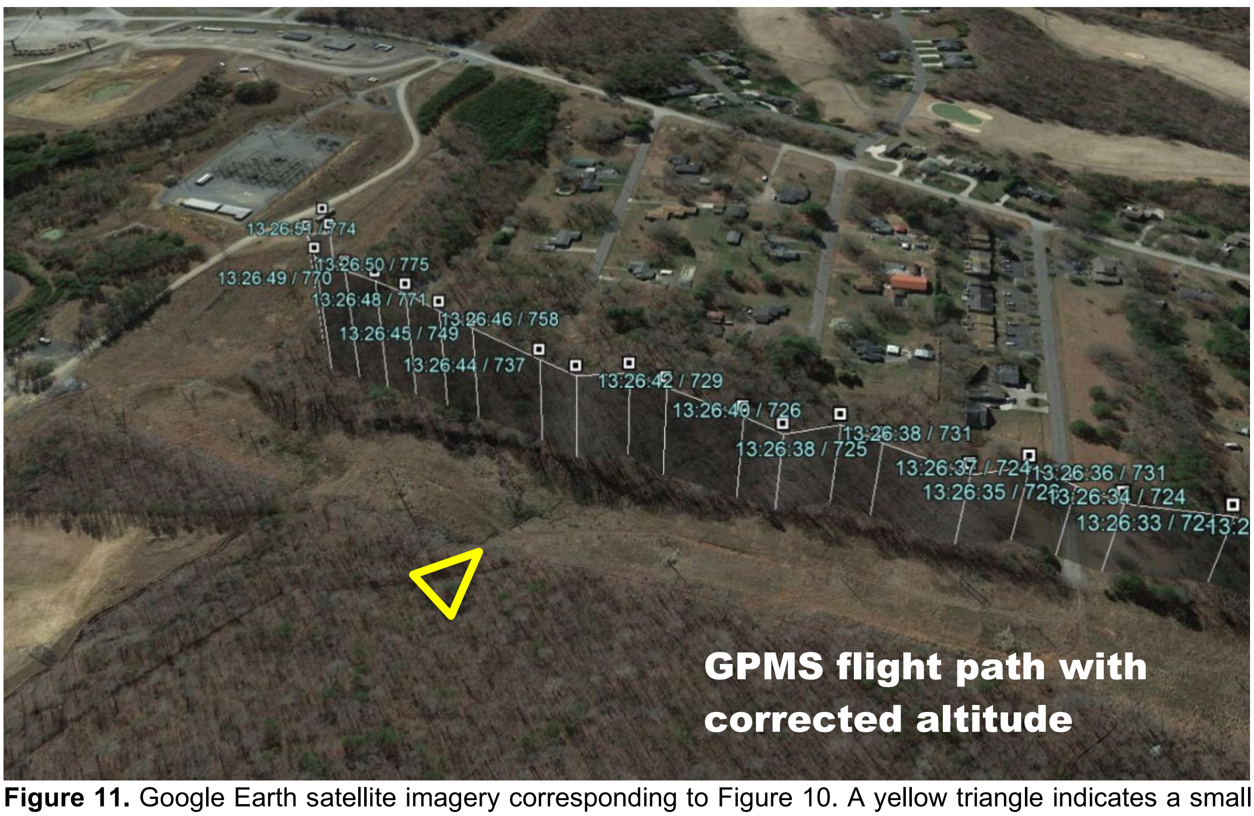

Figure 11. Google Earth satellite imagery corresponding to Figure 10. A yellow triangle indicates a small water course depression.

LIDAR data recorded that the electrical powerlines and the tops of the towers were between 90 and 100 ft above the ground. Tree heights varied from about 80 ft nearest the powerlines, to 120 ft above the local ground level at the tallest point of the canopy.

Figure 12 shows the corrected altitude and radar altitude from the onboard recording device, terrain elevation from Google Earth, and tree heights from Lidar for the last minute of flight. Figure 13 shows a Google Earth image of the same time frame. The water course depression is indicated with the yellow triangle. The aircraft's final climb began at 13:26:44. It climbed from about 720 ft msl to over 760 ft msl by 13:26:48 at which point the helicopter was 80 ft above the top of the tallest trees and 100 ft above local power lines. The helicopter then began to turn.

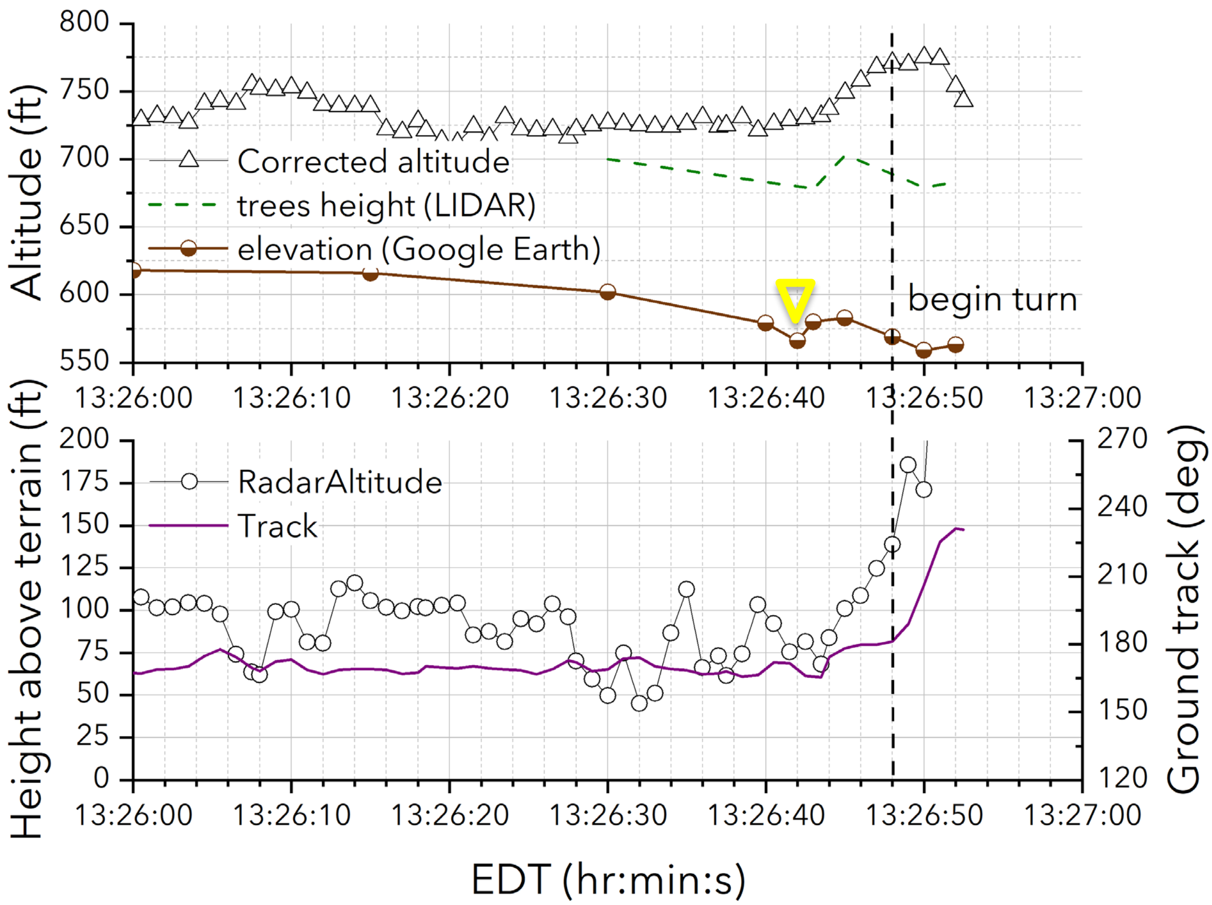

Figure 12. Altitude (msl), terrain, tree height, and track angle for last minute of flight. A yellow triangle indicates the small water course depression.

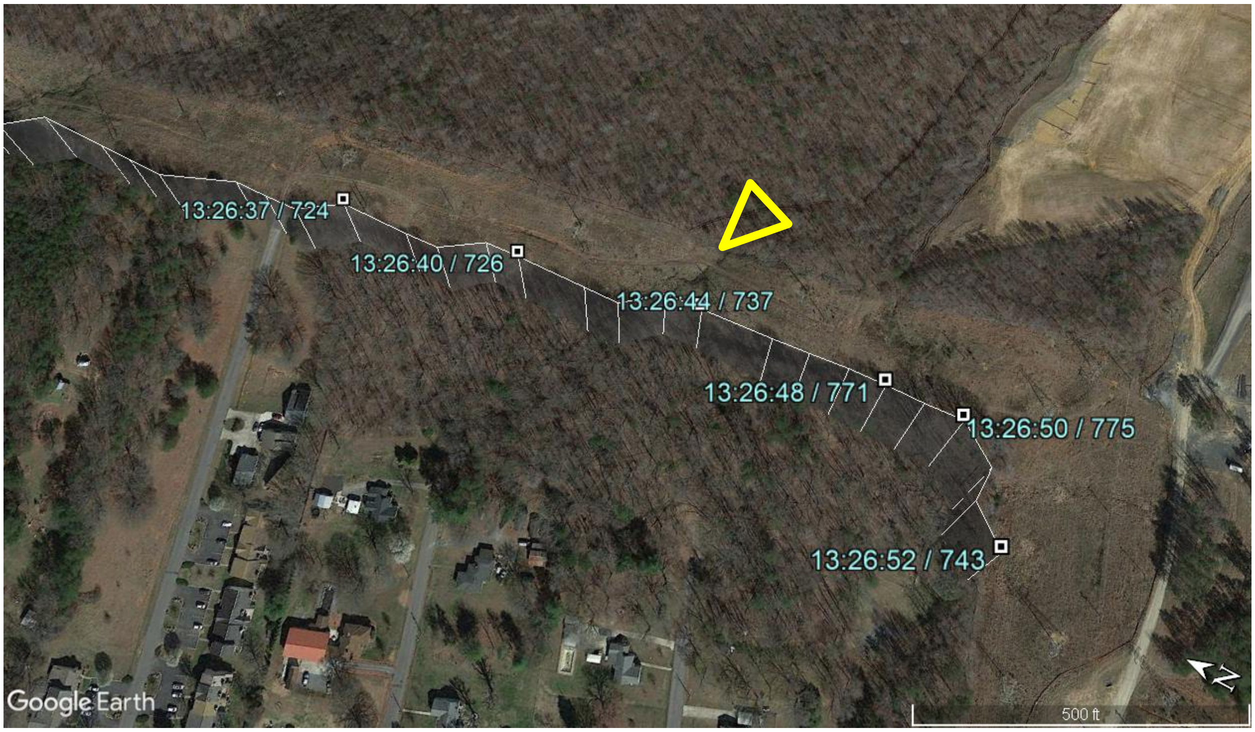

Figure 13. Flight path for last minute of flight. Selected altitudes and times are shown in blue. A yellow triangle indicates the small water course depression.

Radar altitude recorded slightly higher values than corrected altitude minus the tree heights. It recorded the aircraft was 80 ft above what was below it at 13:26:44 and 120 ft above what was below it at the beginning of the turn. GPS data has about 65 ft of resolution in position, both vertical and horizontal when recorded properly. Pressure altitude data is corrected using barometric information and checked against the aircraft's take-off location for reasonableness, but the calculation introduces uncertainty. The radar altimeter measures altitude above the terrain presently beneath an aircraft by timing how long it takes a beam of radio waves to travel to ground, reflect, and return to the craft. The corrected altitude and Lidar combination puts the aircraft very close to the tree height at 13:26:30, so it is unlikely any lower than calculated as that would put the aircraft into the trees earlier in the flight. Therefore, heights above terrain at the end of flight reflect the likely minimum separation.

Also of interest was the relative height of the oncoming power lines (see Figure 8). These wires were 100 ft above the terrain, the elevation of which was approximately the same as that at 13:26:50 (~570 ft). The helicopter was approximately 100 ft above these oncoming wires at the top of its climb and was 100 ft horizontally away at the end of flight.

6.0 Earlier Climbs and Turns

As discussed earlier, as the helicopter approached the oncoming power lines it needed to either climb over them or turn. By comparing earlier portions of the flight to the end of flight prior to the spike in rotor speed, it might be determined what type of maneuver the helicopter was attempting at the end of flight. Rotor speed during the earlier portions of flight did not exceed 101%.

While flying along the lines, the helicopter was on average 100 ft above the ground. Figure 14 shows three times the helicopter climbed over powerlines and one time when it overflew a building. When flying across power lines or over a building, the helicopter climbed to 150 ft or more above the ground. Groundspeed while flying along the wires was 50 to 75 kts with little noticeable change in speed while climbing to cross lines.

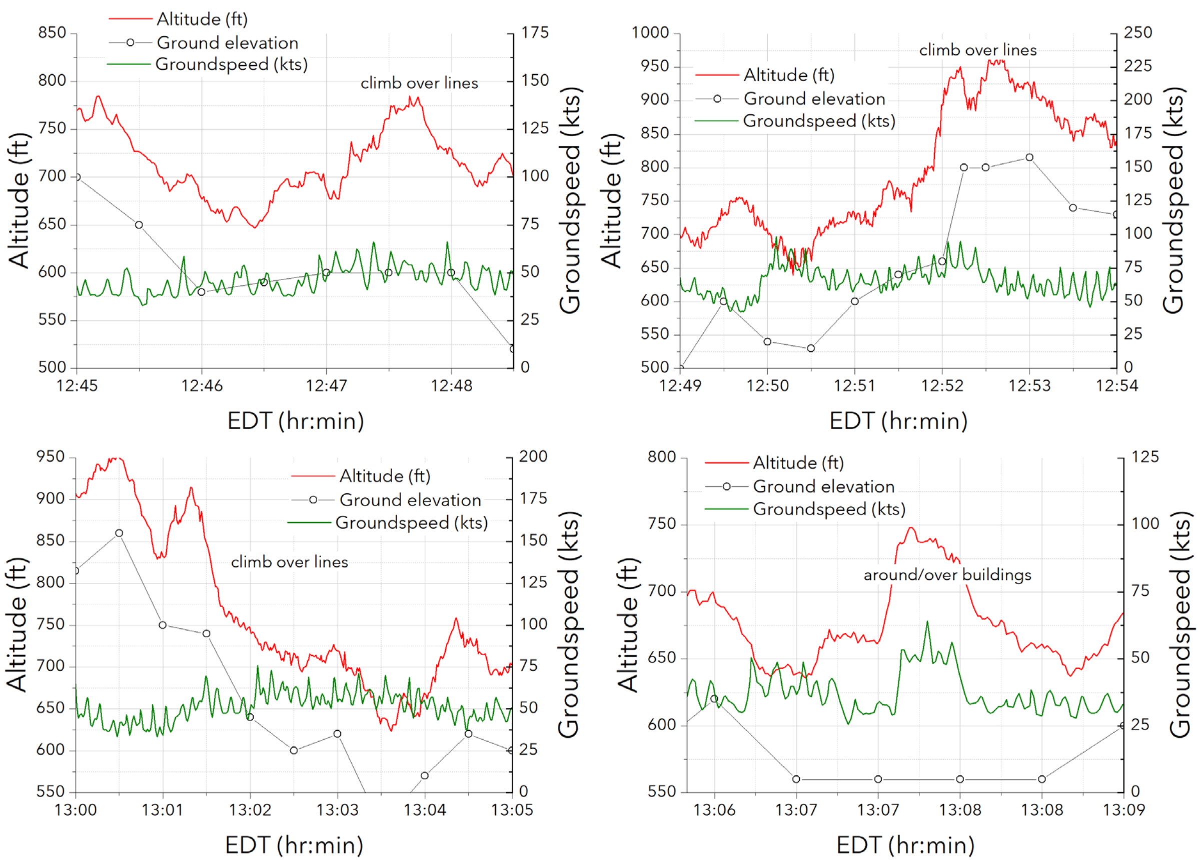

Figure 14. Altitude, ground elevation, and groundspeed for four earlier climbs over power lines or buildings.

Figure 15 shows four prior 90° turns and Figure 16 shows four 180° turns the helicopter completed. 90° turns were completed in about 5 seconds at speeds between 30 and 40 kts and about 100 ft above the terrain. Altitude remained consistent for the four turns shown. 180° turns took about 15 seconds at speeds between 40 and 80 kts. For three of these turns, the helicopter climbed 100-250 ft and descended again during the turns. These four turns showed a large variation in how much the helicopter would climb while completing 180° or greater turns.

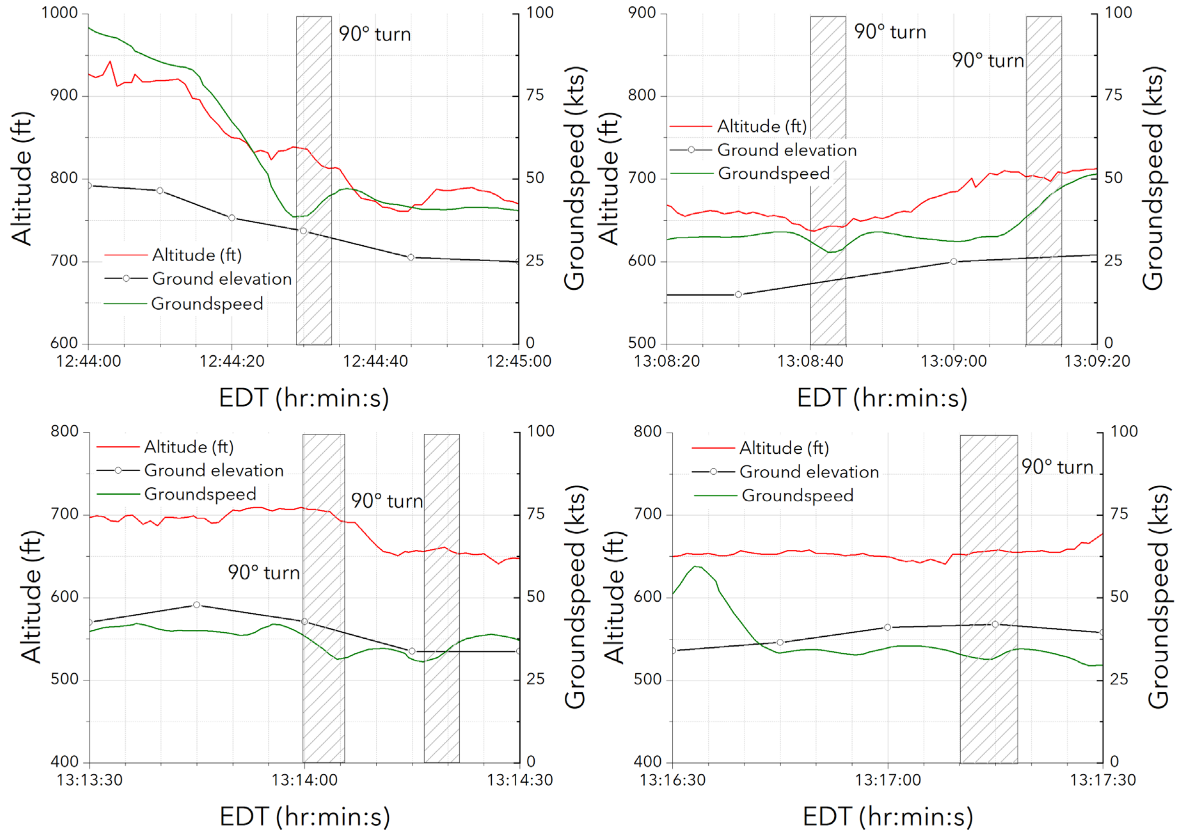

Figure 15. Altitude, ground elevation, and groundspeed for four earlier 90° turns.

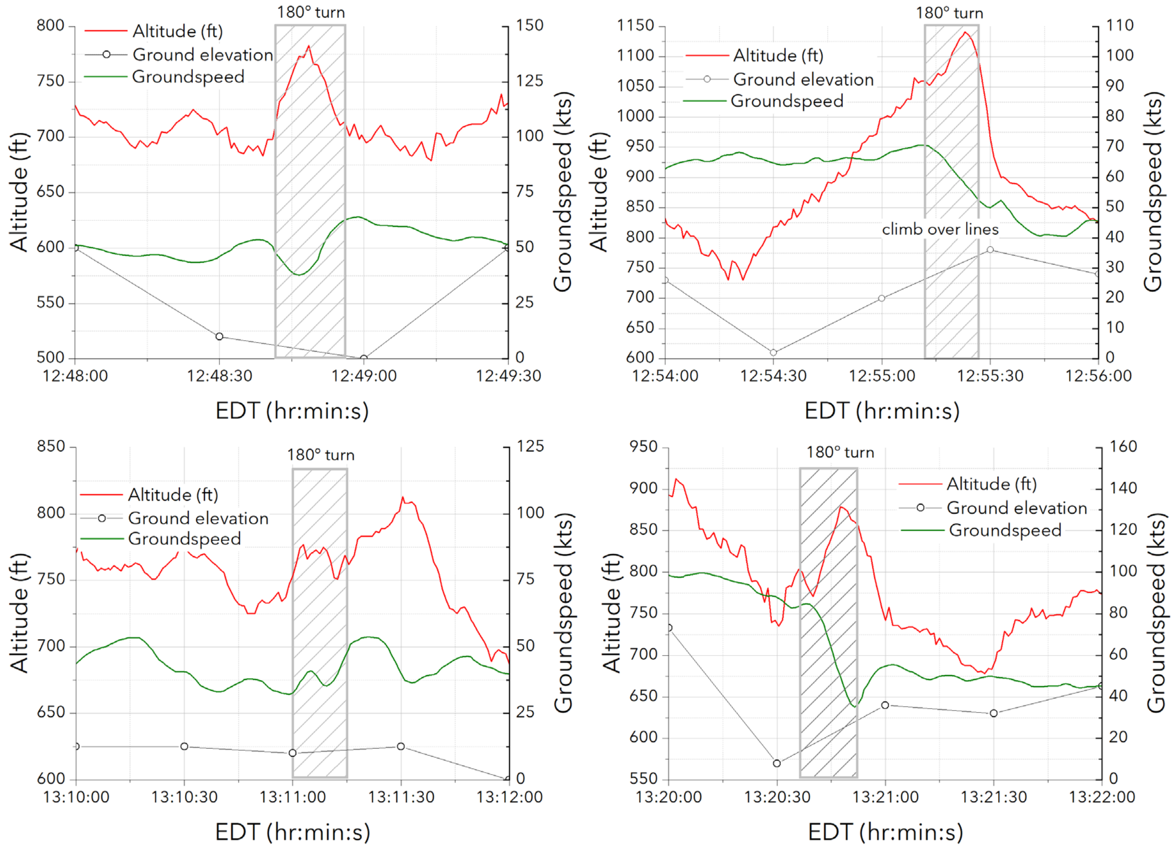

Figure 16. Altitude, ground elevation, and groundspeed for four earlier 180° turns.

At the end of flight the helicopter had climbed 50 ft and was about 200 ft above the ground and was at an airspeed of 50 kts. Based on earlier maneuvers, this flight path would have been consistent with either climbing over the powerlines or performing a 180° turn. The altitude and groundspeed were higher than previous 90°. The change in heading occurred about two seconds before the overspeed of the main rotor, so the pilot may have been attempting a 180° turn.

7.0 Flight Simulations from Bell Flight

To explore possible control inputs made during the accident sequence, Bell Flight simulated the flight of a representative Bell 429 helicopter. Three portions of the flight were simulated: two earlier 180° turns and the last minute of the accident flight. The simulations did not include flexing of the fuselage, mast bending, tail boom flexing, or centrifugal force deformation of the elastomeric bearings.

The purpose of looking at the 180° turns was to see what control inputs they required and helicopter attitudes they resulted in. The two turns that were simulated were at 13:11 and 13:20:30 (Figure 16). The turn at 13:11 was made at a relatively level altitude and a groundspeed that was increasing from 30 to 50 kts. The simulation showed that the maneuver required no more than a 5% input in collective or cyclic and resulted in a 25° bank angle to complete the turn. The second turn simulated had a 100 ft climb, then descent as the speed slowed from 80 kts to 50 kts. This maneuver required a 15% increase in collective, a 10% change in longitudinal cyclic, and a 5% change in lateral cyclic. The helicopter attitude was a 30° bank angle and a greater than 15° nose up attitude on the climb and not quite 10° nose down on the descent. Neither maneuver exceeded nor approached the performance limitations of the helicopter.

A similar simulation was done for the end of flight. Before the sudden increase in rotor speed, the flight path required less than 5% increase in collective and cyclic. The resulting bank angle at the beginning of the turn was about 20° and the helicopter was pitched somewhat nose up.

As stated earlier, the wreckage examination found that two of the main rotor blades had impacted the tail boom and severed the tail rotor drive shaft. Bell Flight's investigation found that near the end of flight, a full aft cyclic input could induce sufficient main rotor blade flapping for the rotor blades to impact the tail boom as seen in the wreckage. The simulation only considered a full aft cyclic input and did not consider any dynamic commands prior.

D. CONCLUSIONS

During the 50-minute-long flight, the helicopter flew along powerlines for inspection purposes. It performed turns and maneuvers and climbed over powerlines throughout the flight without incident. Bell Flight simulations found that these maneuvers neither exceeded nor approached the performance limitations of the helicopter.

Near the end of flight, the helicopter was at an airspeed of about 50 kts and an altitude 100 – 125 ft above the ground. The helicopter executed a climb to 775 ft msl, more than 75 ft above the tallest trees and above oncoming power lines. The helicopter began a right turn and about two seconds later there was a spike in the main rotor speed. Main rotor speed then dropped and the data ended three seconds later as the helicopter lost altitude. The wreckage showed that two main rotor blades impacted the tail boom and severed the tail rotor drive shaft, which likely caused the spike in main rotor speed.

The start of the final turn began before the increase in main rotor speed and was likely intentional. The helicopter's speed and climb were somewhat consistent with earlier 180° turns. A Bell Flight simulation found that a full aft cyclic input at that point in flight could cause the main rotor blades to impact the tail boom. Since pilot inputs were not recorded, this could not be corroborated with the flight data.