

National Transportation Safety Board

Office of Research and Engineering

Washington, D.C. 20594

Performance Study

Specialist Report

Marie Moler

A. ACCIDENT

Location:	Charlottesville, Virginia
Date:	August 12, 2017
Time:	1649 EDT
Airplane:	Bell 407, N31VA
NTSB Number:	ERA17FA274

B. GROUP

No vehicle performance group was formed.

C. SUMMARY

On August 12, 2017, about 1649 eastern daylight time, a Bell 407, N31VA, operated by the Virginia State Police (VSP), was destroyed after impacting trees and terrain in Charlottesville, Virginia. The airline transport rated pilot and private pilot-rated observer were fatally injured. Visual meteorological conditions prevailed, and no flight plan was filed for the public use aerial observation flight that departed Charlottesville-Albemarle Airport (CHO), Charlottesville, Virginia about 1600.

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D. PERFORMANCE STUDY

Radar data used in this study are from the ASR-9 (airport surveillance radar) three nautical miles north of Charlottesville-Albemarle Airport (CHO) which sampled at a rate of once every 4.5 seconds. These radar data have approximately a 60 nautical mile (NM) range and an inherent uncertainty of ± 2 Azimuth Change Pulses (ACP) = $\pm (2 \text{ ACP}) \times (360^\circ/4096 \text{ ACP}) = \pm 0.176^\circ$ in azimuth, ± 50 ft in altitude, and $\pm 1/16$ NM in range.

The aircraft was equipped with automatic dependent surveillance – broadcast (ADS-B) which recorded latitude and longitude from GPS and pressure and geometric altitude every one second.

The aircraft's engine control unit (ECU) was programmed so that if a fault was recorded it retained the last ten lines (12 seconds) of parameters before the fault and then the next 40 lines (48 seconds) of parameters after the fault. The ECU recorded gas generator speed, main rotor RPM, engine torque, free turbine speed, collective position, fuel flow, absolute pressure, and measured gas temperature. A fault was recorded at the end of the flight, likely when the aircraft impacted the trees. Twenty-two lines of data were captured before the recording stopped – ten from before the fault and 12 after the fault.

Data used in this report are from these three sources.

Weather Observations

The Charlottesville-Albemarle Airport had an Automated Surface Observation System (ASOS) which at 1653 recorded winds from 190° at 6 kts, 10 miles visibility, thunderstorms in the vicinity, clear skies below 12,000 ft. The temperature was 86°F (30°C) with a dew point of 71°F (22°C) and the altimeter setting was 29.87 inHg.

A wind simulation for the accident site and time was run and depicted light and variable winds of 3 kts with clear skies over the site. Winds aloft are shown in Table 1.

Table 1. Winds aloft.

Height, mean sea level (ft)	Temperature ($^\circ\text{C}$)	Wind Direction	Wind Speed (kts)
531	31.4	156	3
561	30.9	156	3
650	30.3	159	3
829	29.8	162	3
1099	28.9	171	3
1522	27.6	182	3
2073	26	198	3
2694	24	216	4
3420	22	229	6

Aircraft Ground Track, Altitudes, and Speeds

The aircraft took off from Charlottesville-Albemarle Airport (elevation 640 ft) at 1600 and flew seven miles south to downtown Charlottesville for crowd monitoring (Figure 1). The aircraft circled over Charlottesville from about 1605 until 1644. At 1644 the aircraft flew from downtown south of I-64 to the southwest and then north to intersect Rt 29 (Figure 2). The terrain the aircraft flew over varied from 300 to 600 ft of elevation.

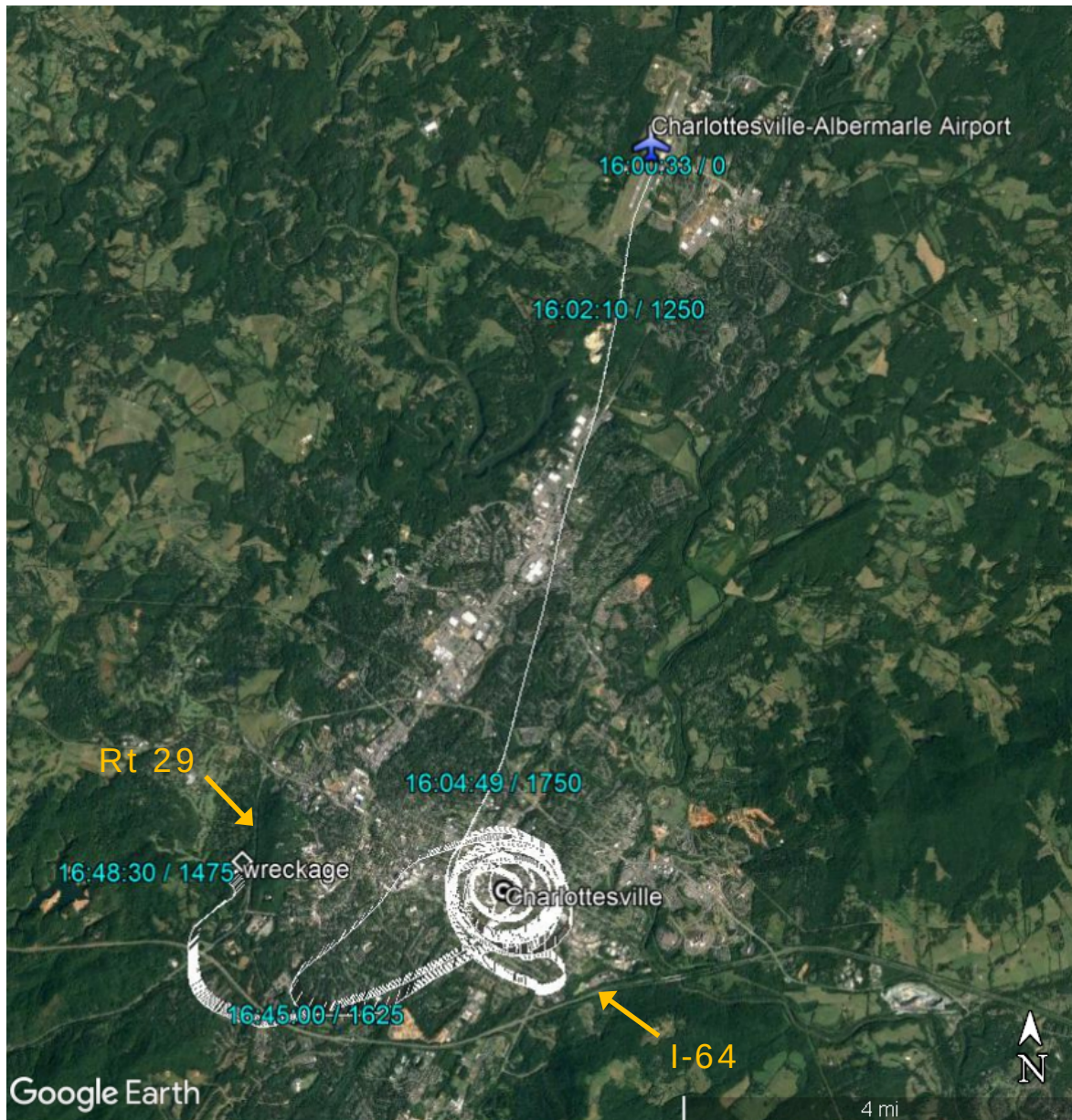


Figure 1. Aircraft flight path. Interstate 64 and Route 29 are noted.

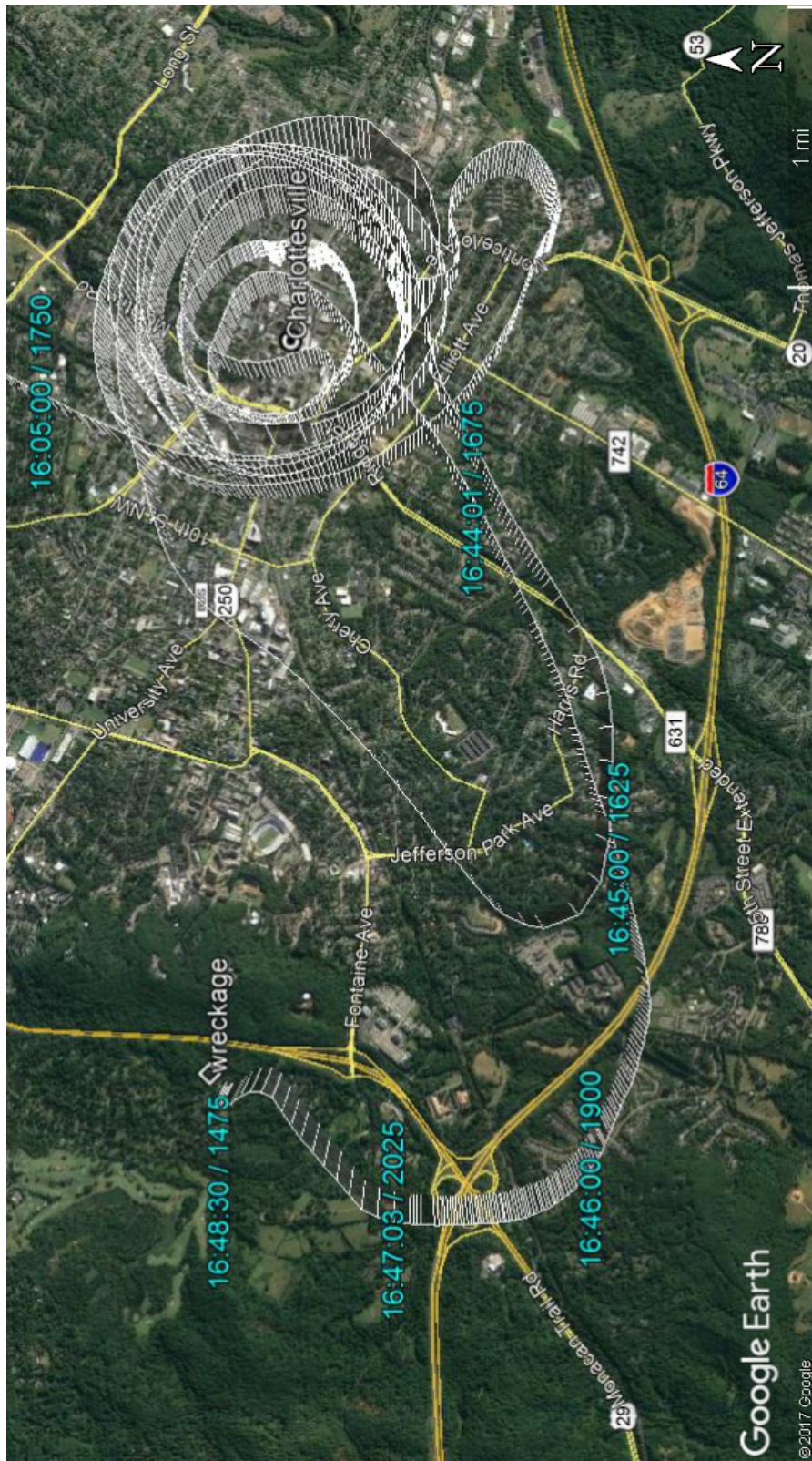


Figure 2. Aircraft flight path from Charlottesville to wreckage location.

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The aircraft's groundspeed for the flight was calculated from the radar path and is shown in Figure 3. The aircraft's maximum groundspeed was above 100 kts early in the flight and then varied from 5 kts to 80 kts during the rest of the flight. The portion shaded in orange is the monitoring flight over downtown Charlottesville.

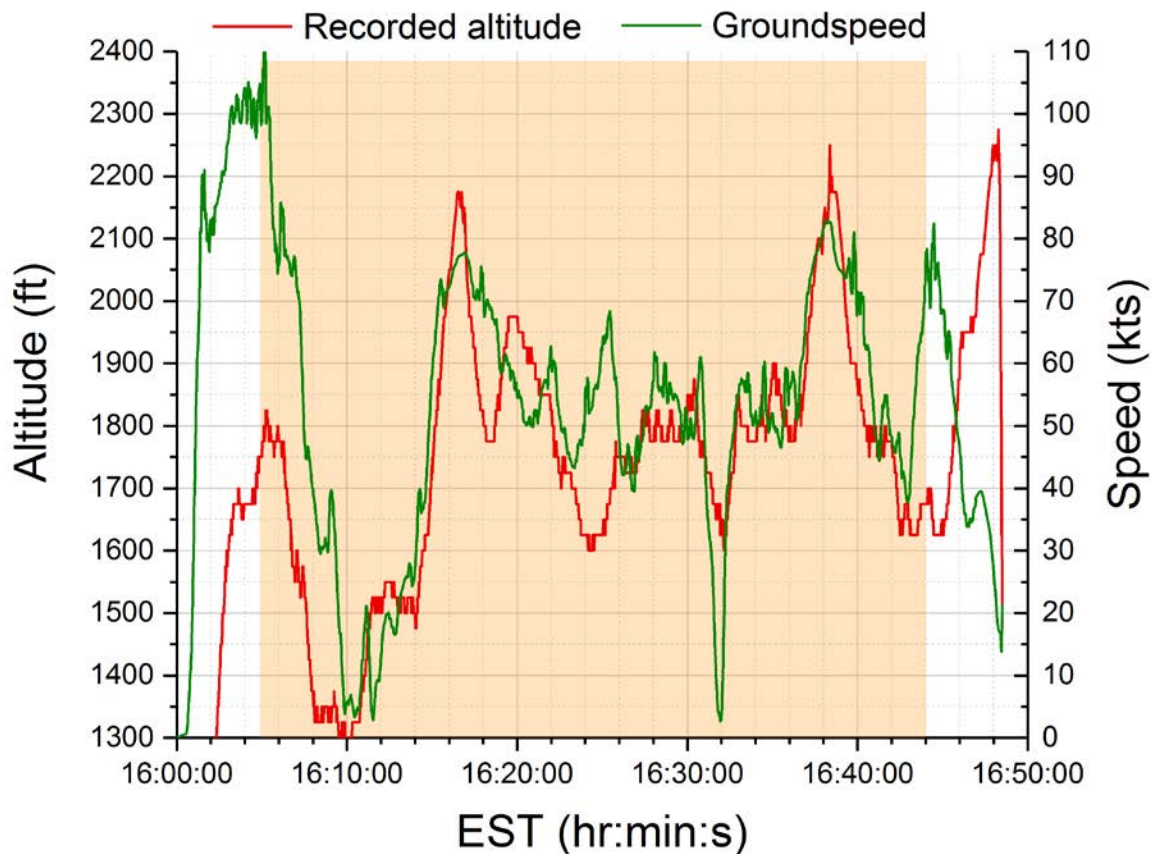


Figure 3. Aircraft altitude from radar and calculated groundspeed for whole flight.

ADS-B data was used for speed calculations for the end of flight portion. Figure 4 shows the last four minutes of flight with the calculated groundspeed and calibrated airspeed using the wind and temperature data from Table 1. Figure 5 shows the flight track of the same period of time with the approximate paths of I-64 and Rt 29 sketched in. The aircraft was climbing and slowing until 16:46 when it leveled off at 1950 ft for about a minute. It then continued to climb to an altitude of 2250 ft where it slowed from 30 kts of airspeed to about 20 kts.

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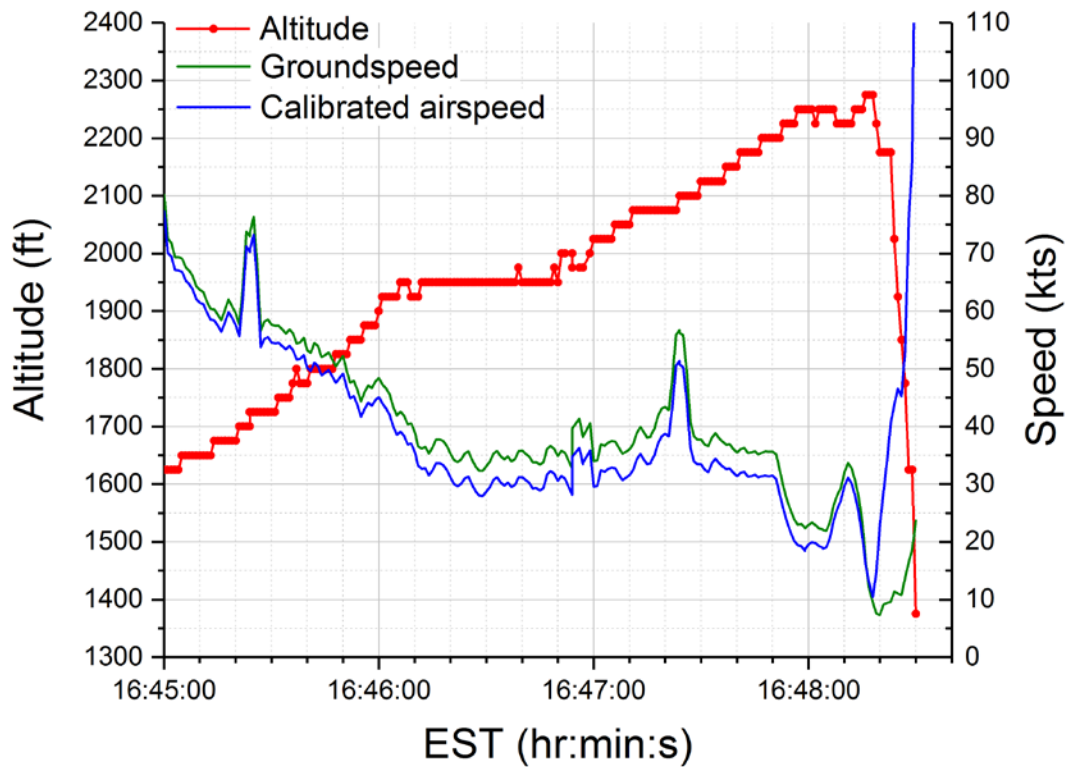


Figure 4. Aircraft altitude from ADS-B and calculated groundspeed and calibrated airspeed for end of flight.

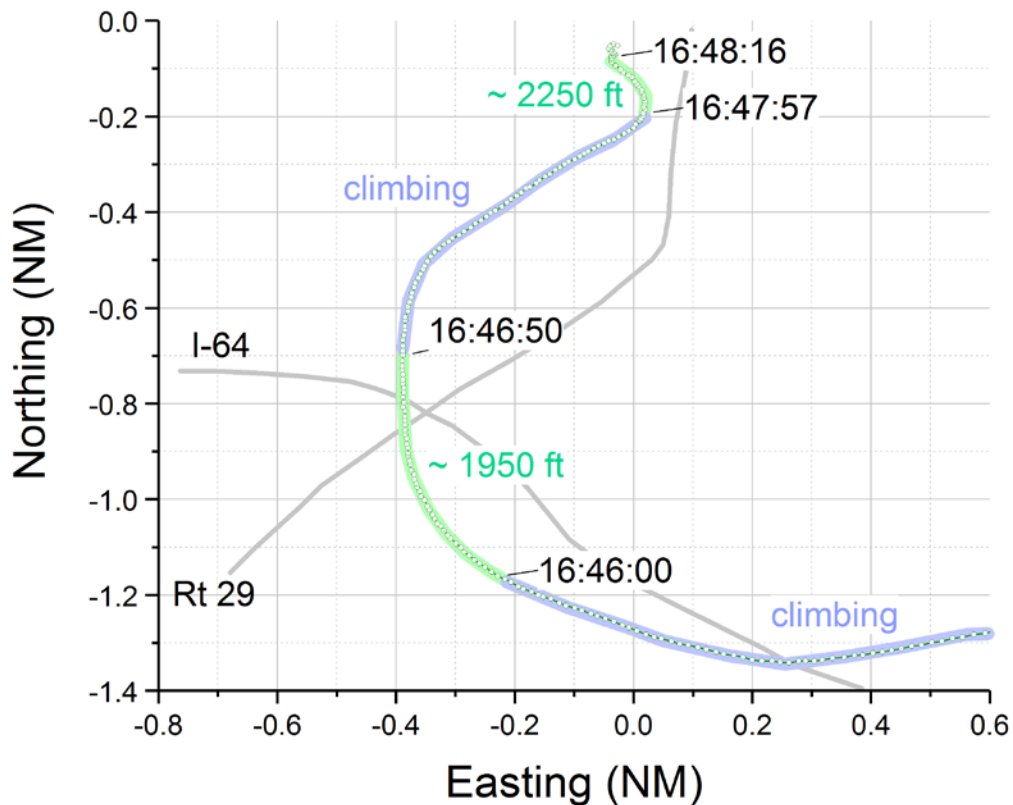


Figure 5. Aircraft flight path with selected times, events, and approximate paths of I-64 and Rt 29 marked.

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Figure 6 and Figure 7 show the last minute of flight. As the helicopter approached 2250 ft of altitude the speed slowed to about 20 kts calibrated airspeed. At 16:48:06 the aircraft's speed increased to 30 kts and at 16:48:12 it climbed from 2225 to 2275 ft while the speed again slowed to near 10 kts. The aircraft's final descent began at 16:48:18.

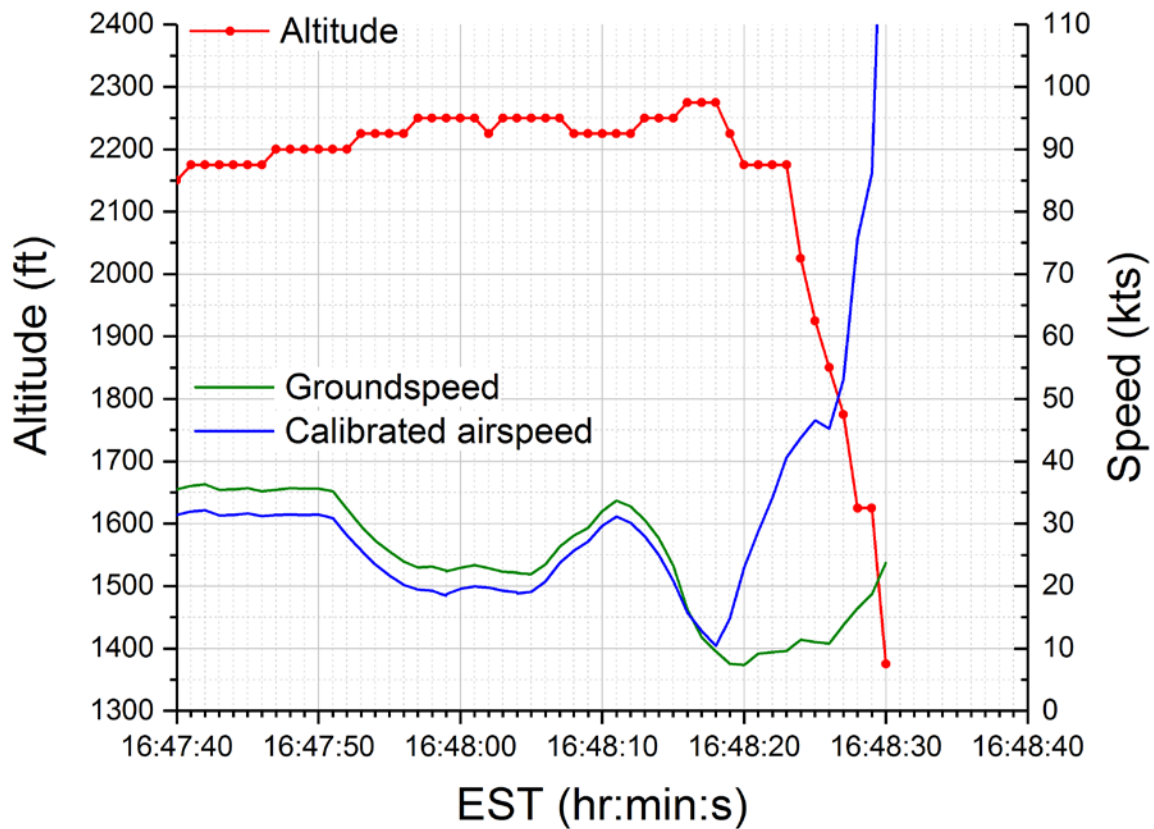


Figure 6. Aircraft altitude, calculated groundspeed, and calibrated airspeed for last minute of flight.

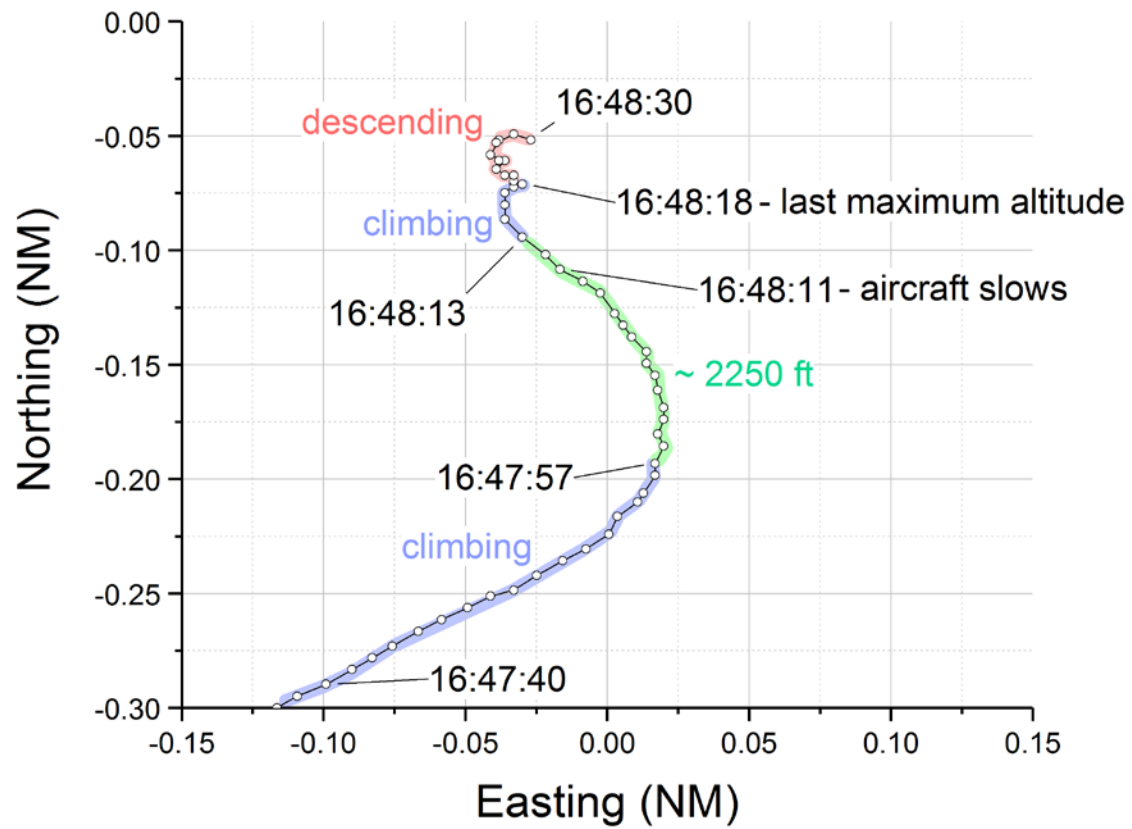


Figure 7. Aircraft flight path with selected times and events marked for the last minute of flight.

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Engine Control Unit Data

As stated earlier, the ECU recorded 22 lines of data which corresponded to twenty seconds worth of data. Comparing the ECU calculated altitude and the ADS-B reported altitude showed good agreement and allowed for the ECU data to be time correlated with the ADS-B data which is shown in Figure 8. The absolute pressure from the ECU 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.

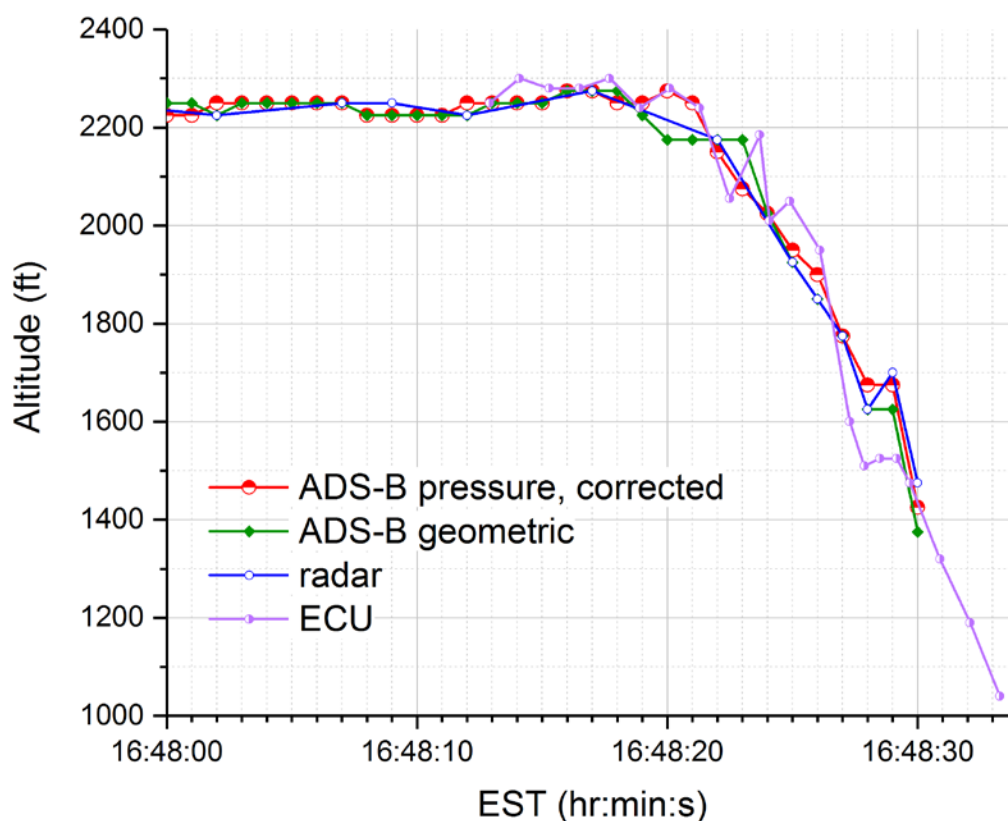


Figure 8. Aircraft altitude from ADS-B, radar, and calculated altitude from ECU data.

Figure 9 shows torque, free turbine speed, collective position, gas generator speed, and main rotor speed. Figure 10 shows fuel flow and absolute pressure.

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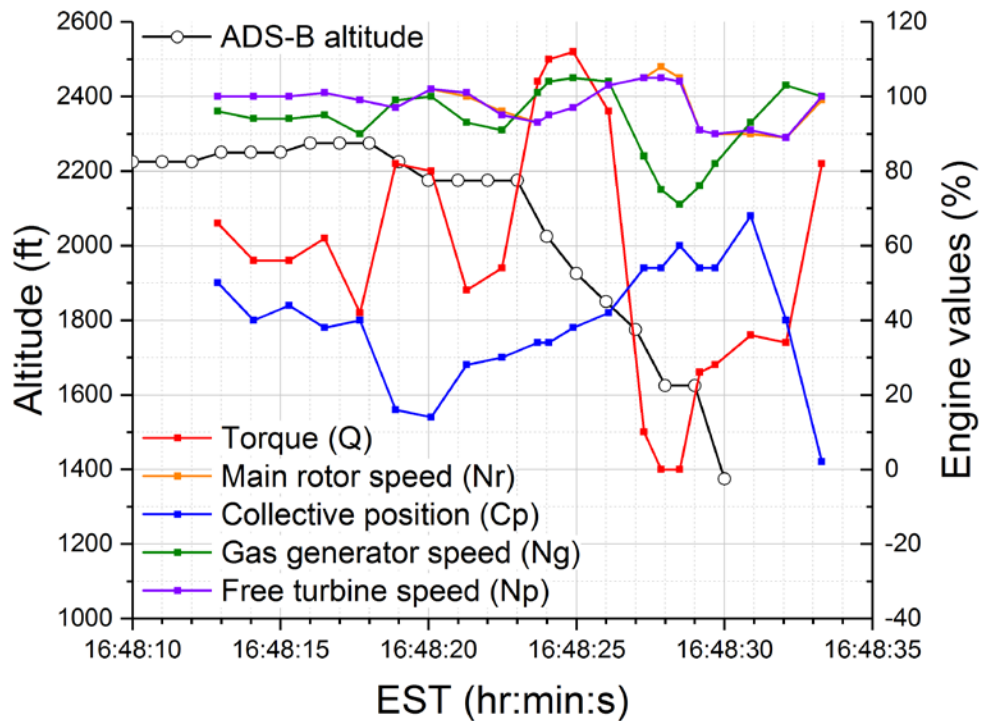


Figure 9. Aircraft altitude from ADS-B and ECU engine data.

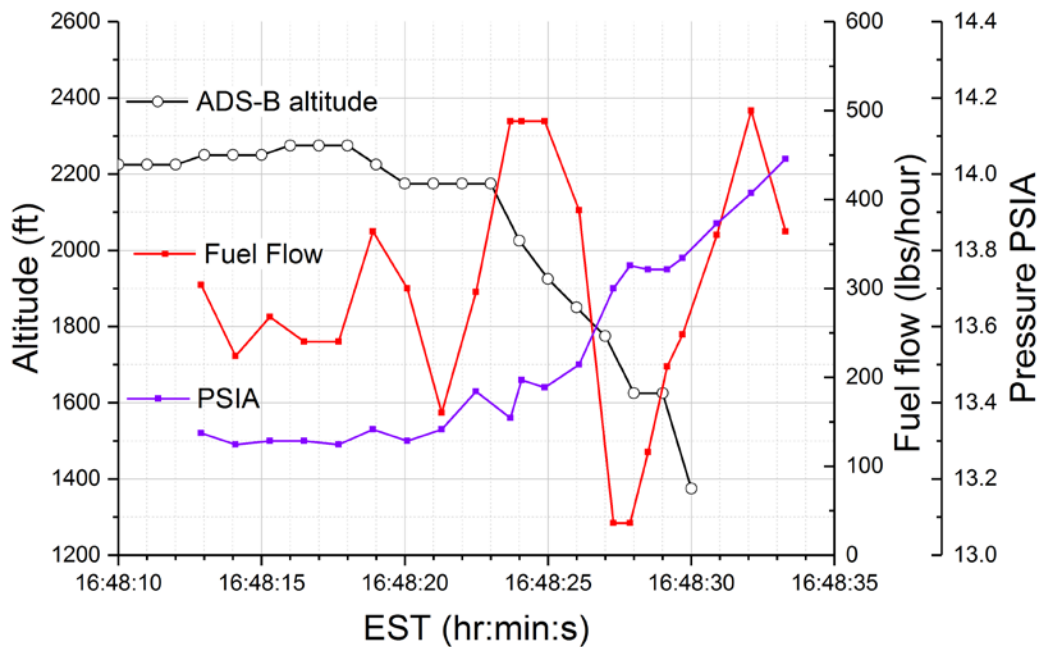


Figure 10. Aircraft altitude from ADS-B and ECU engine data.

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At 16:48:17.7, the collective was lowered from 40% to 14% by 16:48:20 when it was then raised to 68% by 16:48:30.9. When the collective was lowered, the ADS-B geometric altitude shows a local reduction in altitude while ADS-B pressure and the ECU altitude (calculated from pressure measurements) show a local increase in altitude. However, the trend of all altitude readings was a decrease in altitude, indicating that the aircraft did not respond as expected to the increase in collective after 16:48:20.

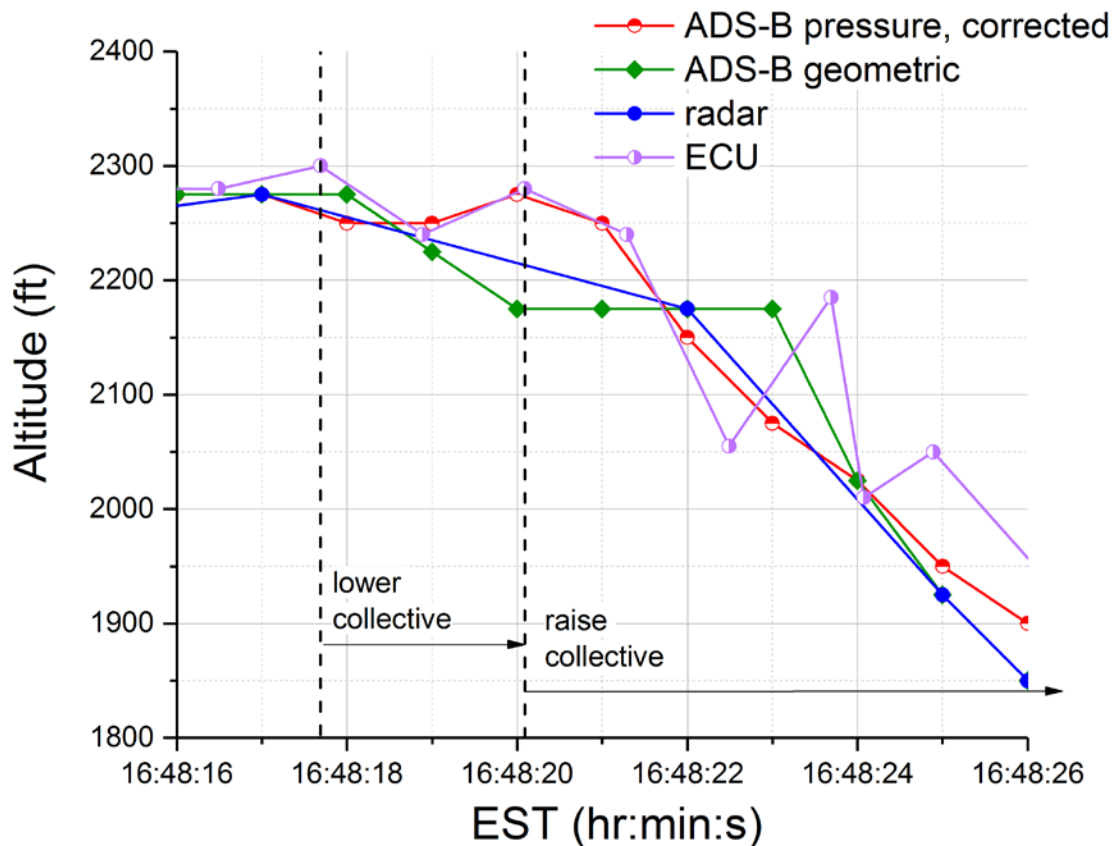


Figure 11. Aircraft altitude from ADS-B, radar, and ECU and collective movement.

Correlation with Video and Photo Study

A security camera video and several photos of the aircraft descent are discussed in a Video Study [1]. The security video captured ten seconds of the aircraft's descent though at low resolution. The Video Study estimated that during those 10 seconds the aircraft went from an altitude of 2,000 ft to 1,200 ft. This is not consistent with the other recorded altitude measures (Figure 8), which recorded 8 seconds between 2,000 ft and 1,200 ft. However, only the ECU pressure recording captured the descent from 1,400 ft to 1,200 ft and the pressure measurement and subsequent altitude calculation may be irregular. Assuming the video begins at an altitude of 2,000 ft, the estimated time of the video is shown in blue on Figure 12. The Video Study estimated a descent

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speed that started at about 25 ft/s (1500 fpm) and increased to 142 ft/s (8520 fpm), with a constant acceleration of 0.37 g towards the ground.

A series of four photos, taken over the course of two seconds, showed the aircraft spinning as it descended. It was estimated that the series of photos was taken between 16:48:22 and 16:48:27 (shown in yellow on Figure 12). The Video Study details the determination of the aircraft's altitude and attitude in the photographs and estimated that the yaw rate was at least 92 ± 5 deg/s in the clockwise direction. A clockwise yaw is consistent with the helicopter turning counter to the rotation of the rotor blades. The photos also showed that the aircraft was rolling to the right at a rate of about 14 deg/s. The photos occur when the collective was raised, but the aircraft lost altitude.

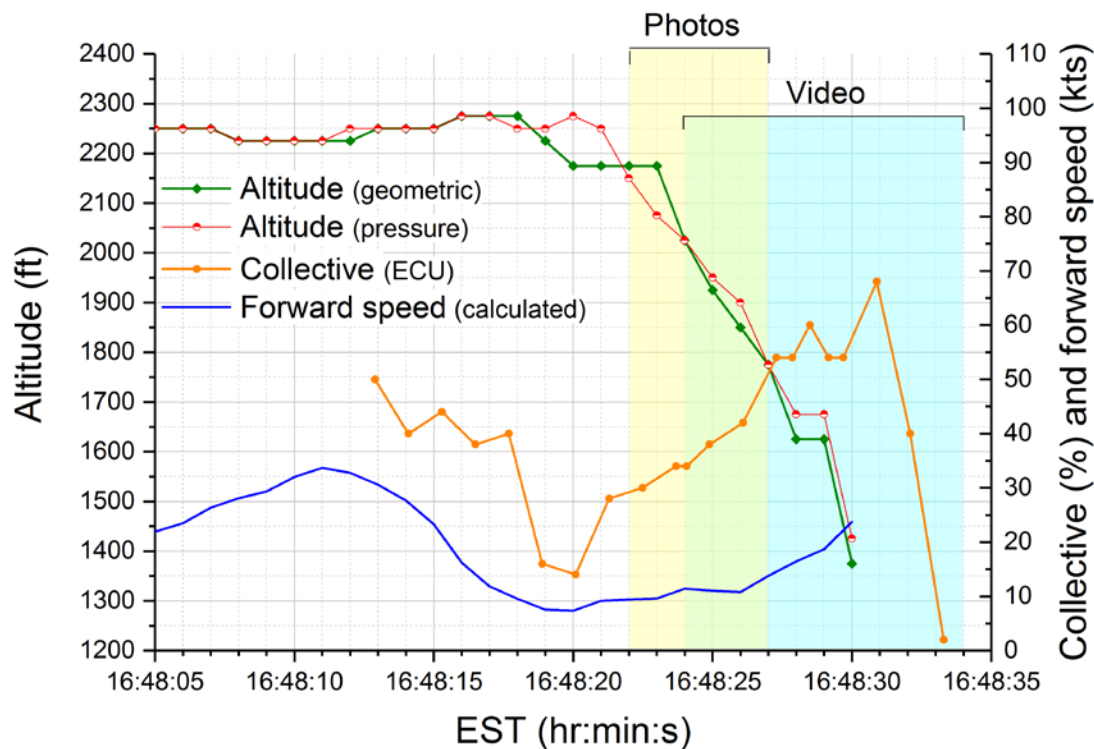


Figure 12. Aircraft altitude from ADS-B, collective movement, and forward speed with photo and video periods marked.

Vortex Ring State

Vortex ring state is an aerodynamic condition where the helicopter descends into its own downwash and is unable to produce enough lift to maintain altitude. The result is that the aircraft continues to descend even though 20% to maximum power is applied [2]. It is also referred to as “settling with power”.

Bell Helicopter provided the NTSB with the area of predicted vortex ring state for a Bell 407 with a gross weight of 4,633 lbs at sea level. Figure 13 shows this predicted area with the aircraft’s forward speed and average vertical speed overlaid. The blue shaded area represents combinations of forward speed and vertical speed when vortex ring state is predicted to develop.

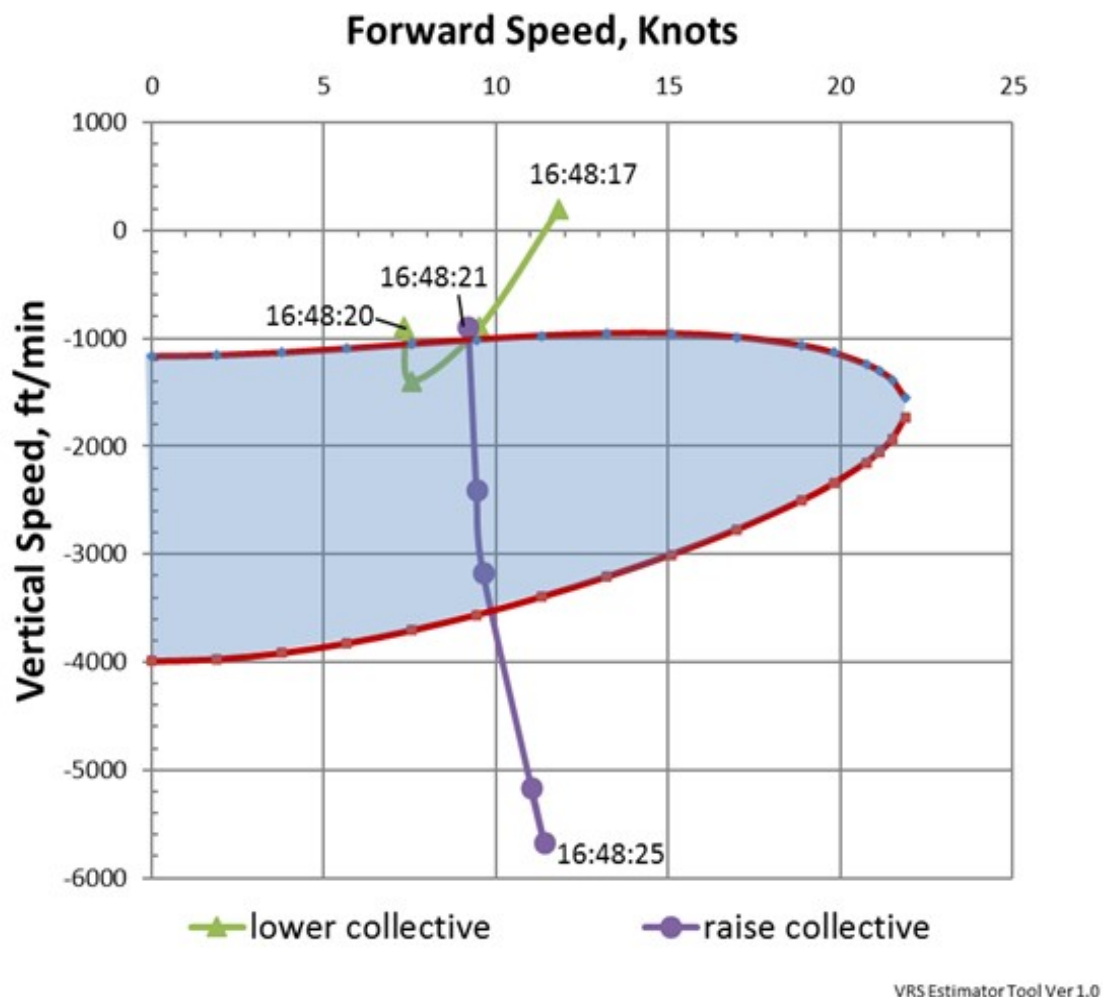


Figure 13. Bell 407 region of predicted vortex ring state for a 4633 lbs aircraft at sea level.

The aircraft’s forward speed dropped below 20 kts at about 16:48:16, before the initial lowering of the collective (Figure 14). Below 20 kts the aircraft is at risk of entering vortex ring state for

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vertical speeds greater than 1,000 ft/min downwards. While each individual altitude data source differs at specific points in time, the average vertical speed (Figure 14) puts the aircraft at risk of vortex ring state during the time the collective was lowered. The collective was raised, and engine power increased (Figure 9), but the aircraft did not climb.

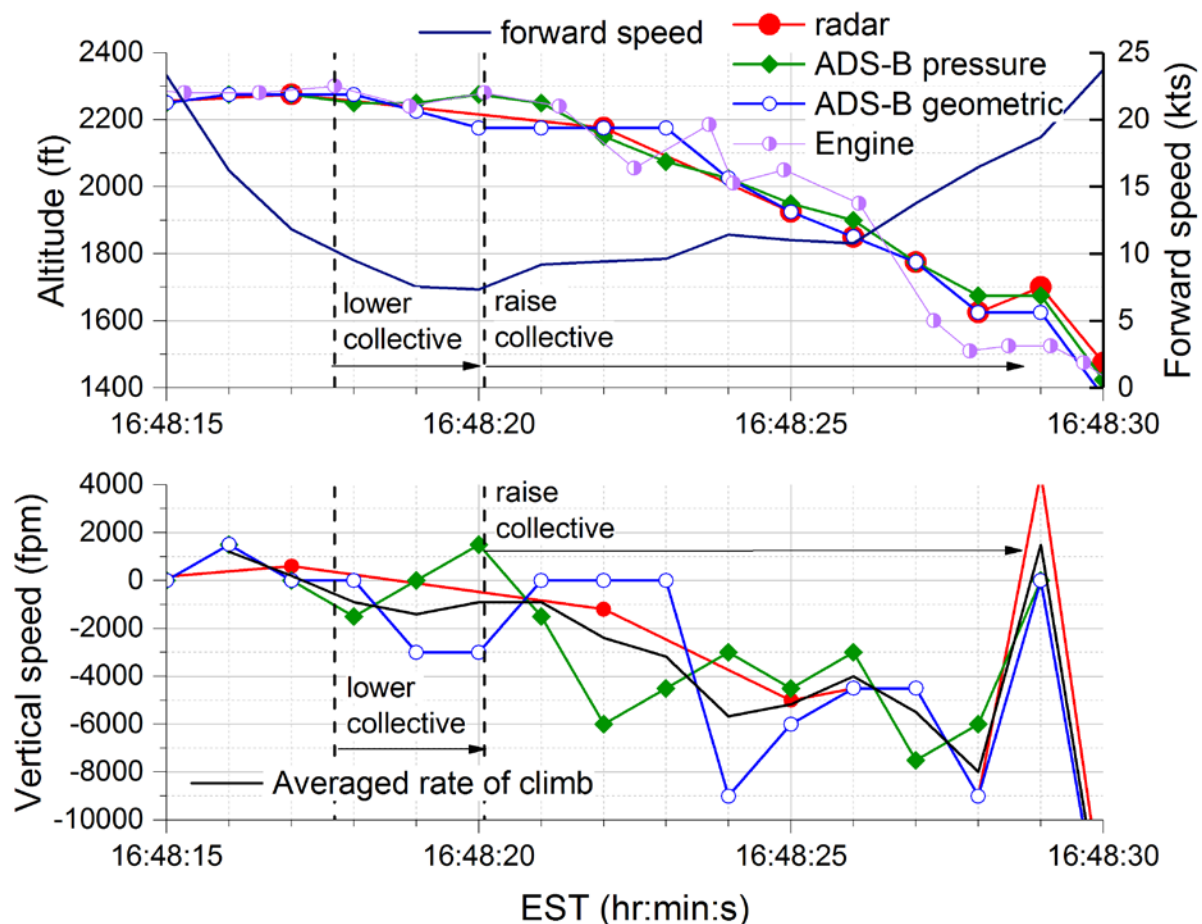


Figure 14. Aircraft altitudes and calculated vertical speed from different sources.

A fully developed vortex ring state is characterized by an unstable condition in which the helicopter experiences uncommanded pitch, roll, and yaw oscillations, has little or no collective authority, and achieves a descent rate that may approach 6,000 feet per minute (fpm) if allowed to develop. As discussed in the Video Study, the aircraft was recorded rolling and yawing during its descent, but since the cyclic and rotor pedal positions were not recorded, it cannot be determined to what extent these motions were commanded.

E. CONCLUSIONS

After 16:48:16, the helicopter's low forward speed and increasing descending vertical speed put it in or near a region where vortex ring state was predicted by the manufacturer. Photos and videos of the descent, which were determined to be after 16:48:22, showed the helicopter rolling and spinning as it descended.

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F. REFERENCES

1. Video Study, ERA17FA274, National Transportation Safety Board, 17 November 2017.
2. Helicopter Flying Handbook, Federal Aviation Administration, Flight Standards Service, 2012.
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/