

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, D.C. 20594

August 1, 2022

Video Study

**NTSB Case Number:
ERA22FA137**

A. ACCIDENT

Location: Hilltown Township, Pennsylvania
Date: February 24, 2022
Time: 16:56 EST
Aircraft: Beechcraft 35-C33

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On February 24, 2022, about 16:56 eastern standard time, a Beech 35-C33, N6129V, was destroyed when it was involved in an accident near Hilltown Township, Pennsylvania. The private pilot and flight instructor were fatally injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 instructional flight.

D. DETAILS OF INVESTIGATION

The goal of this investigation was estimating the engine speed of the airplane based on a video recorded by a camera installed on a residential building. The video was 65 seconds long, had 1920x1080 resolution and frame rate of 20 fps. The camera recorded sound at the rate of 48,000 samples/second. The visual information in the video included only about one half of a second of the airborne airplane. The airplane impacted the ground about one half of a second past this period. Its image was obscured from camera view by a building and vegetation at the time of ground impact. Consequently, this Video Study analyzes only the recorded sound. The visual information in the video was only used to synchronize the recorded sound with ADS-B data.

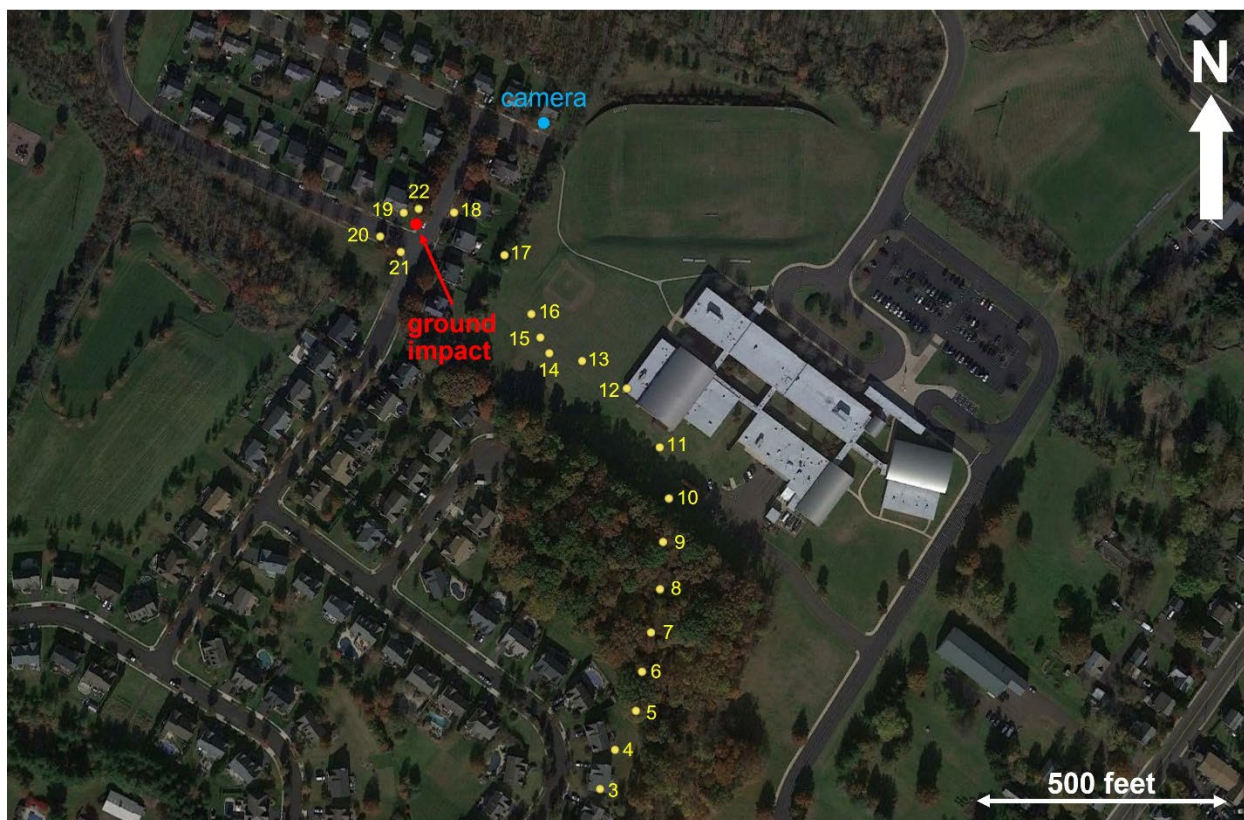


Figure 1. Aerial View of the Accident Area (numbers are video time in seconds)

Figure 1 shows an aerial view of the accident site. The camera was mounted on a house on Morgan Lane. The airplane impacted the ground at the intersection of Brittany Lane and Victoria Lane. The yellow markers in the figure are airplane locations recorded by ADS-B. The numbers near the markers are video time in seconds. The last ADS-B based marker is at time 22 seconds. The airplane impacted the ground at video time 22.6 seconds.

Figure 2 shows the sound signal during the first 25 seconds of the video. The ground impact time is marked by the red broken line. The sound intensity was very low up to about time 8.5 seconds and stayed elevated between 8.5 seconds and 11.5 seconds. The intensity then stayed low until about 18 seconds when it increased to beyond ± 0.2 and stayed elevated until ground impact.

Figure 1 shows that all the way to the airplane location at time 18 seconds, the airplane distance from the camera was decreasing. The recorded sound intensity of a properly operating engine should not be decreasing as the distance from the camera was decreasing. This points to possible intermittent operation of the engine. The very low recorded sound intensity between time 11.5 seconds and time 14.5 seconds could be the result of engine combustion not taking place during these three seconds. It is also possible that there was no combustion between time zero and time 8.5 seconds.

An alternative explanation of the low sound intensity is suggested by this being an instructional flight. The periods of low recorded sound intensity could have been the result of the pilot practicing some particular maneuver or scenario and the low sound intensity was during the periods when the engine was intentionally idling.

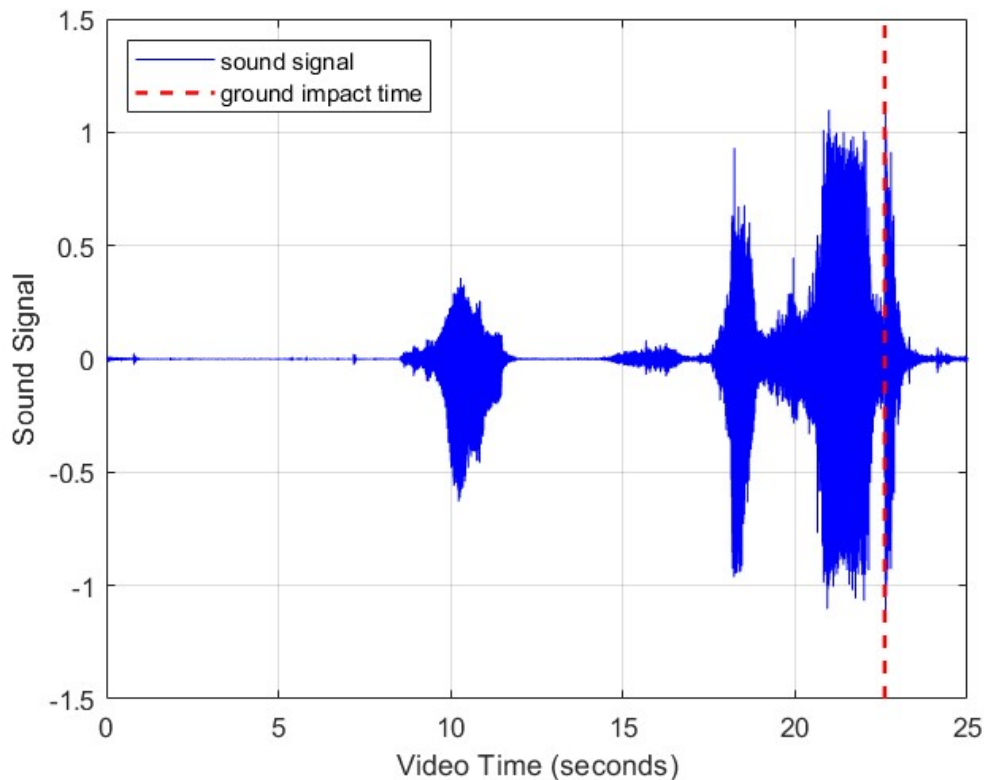


Figure 2. Recorded Sound Signal Intensity

Engine speed was estimated via spectrum analysis of the sound recorded by the camera. The sound was recorded at the rate of 48,000 samples/second. The spectrum was computed with a 65,536 point Fast Fourier Transform (FFT algorithm, resulting in 1.365-seconds-wide FFT processing windows and frequency resolution of 44 cycles/minute.

Figure 3 shows 12 spectra computed in FFT processing windows with starting times incremented by one second from two seconds to 13 seconds. The spectra at window starting times of 9, 10 and 11 seconds correspond to the elevated signal intensity period between 8.5 seconds and 11.5 seconds seen in Figure 2. These spectra are dominated by a large magnitude impulse train in frequency.

Impulse trains in frequency are generated by impulse trains in time. To investigate the time signal that generated the impulse trains in frequency, the time signal is plotted in Figure 4 between time 10.2 seconds and time 10.3 seconds. The figure shows that the time signal includes a train of impulses. The spacing between the impulses is 0.00685 seconds that corresponds to frequency of $60/0.00685=8759$ impulses/minute.

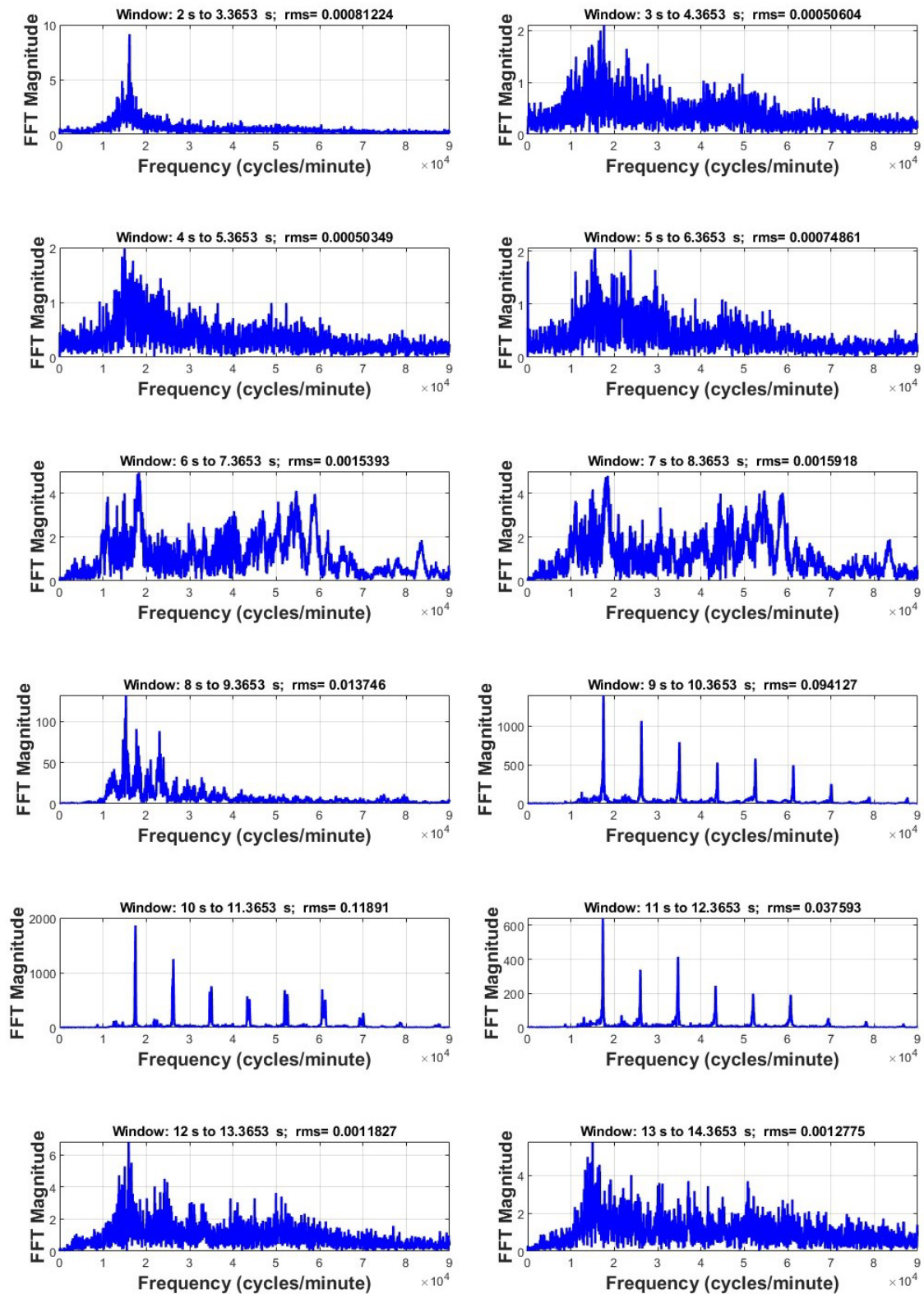


Figure 3. Sound Spectra between 2 seconds and 14.3 seconds

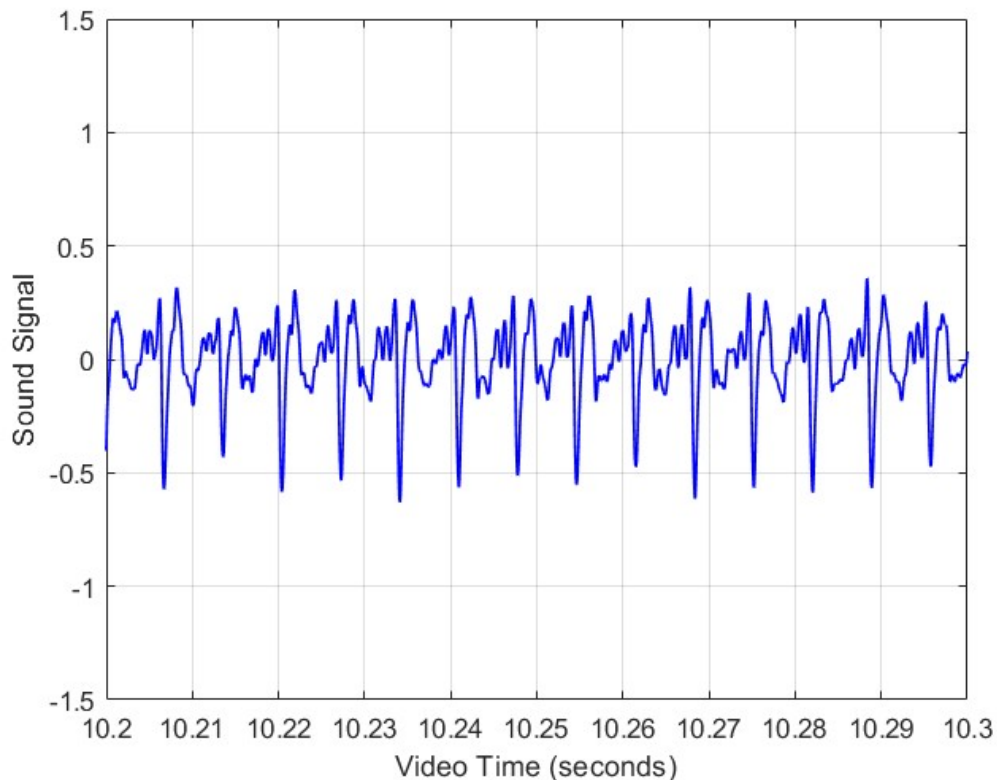


Figure 4. Zoomed Sound Signal

The signal in Figure 4 is not symmetrical with respect to its mean. The negative peaks reach below -0.5 while the highest positive peak is below 0.4. This asymmetry is in effect between time 10 seconds and time 11.5 seconds, as can be seen in Figure 2. Signals like the one in Figure 4 can be the result of the microphone recording a sound at a fundamental frequency as well as some of its higher harmonics, each phase-shifted with respect to the fundamental component.

The sound signal between 18 seconds and 18.7 seconds also has an asymmetric distribution, includes evenly-spaced impulses in time, and its spectrum includes impulses in frequency. However, the time and frequency impulses are less dominant than those between 8.5 seconds and 11.5 seconds.

Past time 18.7 seconds, the signal is mostly symmetrical with respect to its mean. The two time-segments with signal asymmetry, between 10 seconds and 11.5 seconds and between 18 seconds and 18.7 seconds, could be indications that the engine was not operating smoothly. The higher harmonics that caused the recorded sound signal to look like the signal in Figure 4 could be due to combustion noise and/or exhaust noise emitted by an engine that was not operating smoothly.

At video time 10.25 seconds, corresponding to Figure 4, the airplane speed toward the camera was about 90 feet/second. This speed was estimated based on ADS-B

latitude, longitude and altitude data. Consequently, due to the Doppler effect, the recorded sound frequency was 8.5% higher than the frequency emitted by the airplane. Therefore, the frequency component recorded as 8759 cycles per minute (cpm) was generated by the airplane at the frequency of $8759/1.085=8073$ cpm.

The airplane propeller had three blades and in a six-cylinder, four-stroke Continental IO-470 series engine cylinder firing occurs three times per shaft revolution. Therefore, both the propeller and the engine generate sound components at a frequency that is three times the engine speed. This leads to the estimate of the engine speed of $8073/3=2691$ rpm, at the high end of its rated speed. It is believed that the unusual sound signal in Figure 4 is due to combustion and/or exhaust noise generated by the engine that was not running smoothly rather than the propeller wake reaching the camera.

Similar analysis of the sound signal between 18 seconds and 18.7 seconds resulted in an engine speed estimate of 2788 rpm, slightly above the rated maximum continuous operation speed. In this time interval, the distance of the airplane from the camera was decreasing primarily due to the vertical speed of the descending airplane.

Figure 5 shows the pressure altitude of the airplane based on ADS-B data. The elevation of the crash location is 403 feet MSL. The airplane altitude started decreasing slowly approximately at video time zero and continued decreasing until ground impact. It is likely that the descent started at about video time zero because, as the low sound intensity between time zero and time 8.5 seconds seen in Figure 2 indicates, there probably was no combustion or the engine was idling during these nine seconds.

At video time 22 seconds, the largest spectral peak was at 16480 cpm. It is estimated that this frequency was the second harmonic of three times the engine rotational speed. After adjustment for the Doppler effect, the estimated engine speed at time 22 seconds was 2532 rpm. Therefore, the engine was operating near its expected speed between time 18 seconds and the time of ground impact that occurred at 22.6 seconds.

The above analysis of the recorded sound detected fluctuating intensity between video time zero and video time 22.6 seconds. The very low intensity up to time 8.5 seconds and between time 11.5 seconds and time 14.5 seconds indicates that there probably was no combustion or the engine was idling during these time periods. As seen in Figure 5, the rapid descent toward ground impact started at about video time 11.5 seconds when combustion stopped or the engine started idling.

The asymmetrical nature of the signal between 10 seconds and 11.5 seconds and between 18 seconds and 18.7 seconds indicates non-smooth engine operation. Both time segments of non-smooth operation occurred after periods when it is estimated that there was no combustion or the engine was idling. This could indicate that when combustion resumed or the engine was exiting idle state, the engine was not operating smoothly.

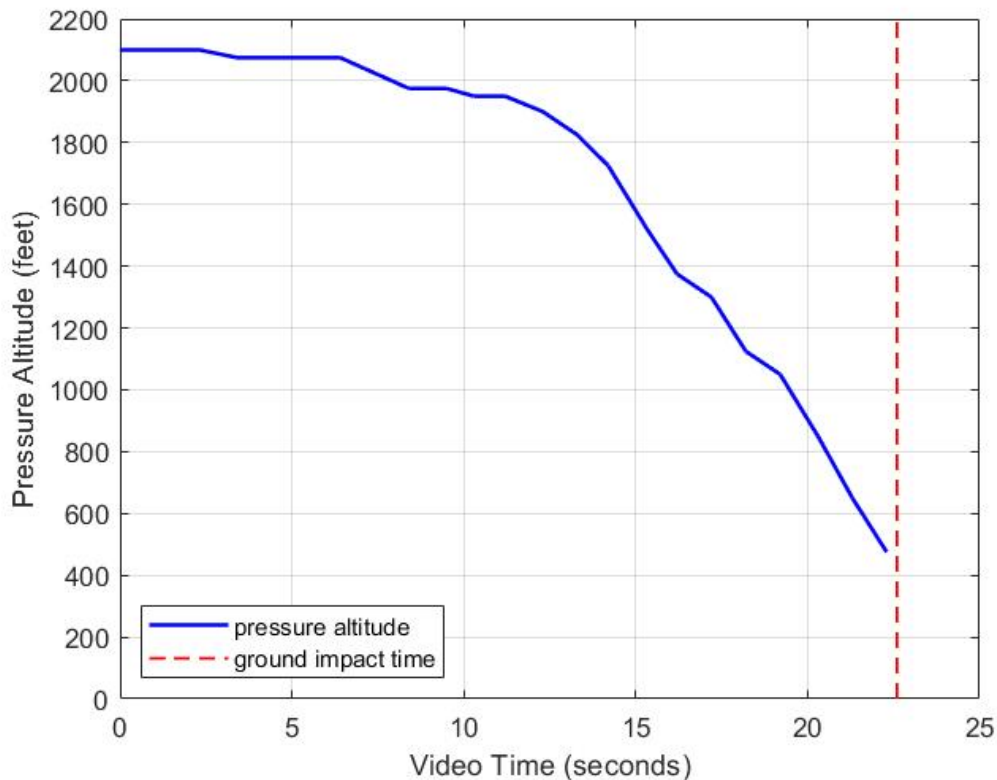


Figure 5. Airplane Pressure Altitude (from ADS-B record)

Figure 2 shows that after the period of non-smooth operation between 18 seconds and 18.7 seconds, the engine operated smoothly until ground impact. However, at that time, the airplane was already descending at the average rate of 9080 feet/minute as can be seen in Figure 5.

During the analyzed video time segment, there were periods when there was no combustion or the engine was idling, and there were periods of non-smooth engine operation. When there was detectable combustion sound and the engine was operating either smoothly or non-smoothly, the engine speed was close to the expected operating speed of about 2600 rpm.

E. CONCLUSIONS

The engine speed of an airplane that crashed was estimated by analyzing the sound recorded by a camera mounted on a residential building. It was found that the engine was operating near its expected operating speed but erratically. During the last eleven seconds before ground impact, there was a three-seconds-long period when there probably was no combustion or the engine was idling. The airplane rapid descent toward ground impact started approximately when this three-seconds-long period started.