

National Transportation Safety Board

Office of Research and Engineering

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SOUND SPECTRUM

Specialist's Study

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A. ACCIDENT

Location: Nashville, Tennessee
Date: March 4, 2024
Time: 19:43 central standard time (CST)
Aircraft: Piper Aircraft PA32RT-300T, C-FBWH

B. SOUND SPECTRUM SPECIALIST

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C. DETAILS OF THE INVESTIGATION

1.0 Video Details

The NTSB received a video file recorded by a camera at a private residence approximately 1,800 feet from the reported wreckage site. The file, screen-recorded by non-NTSB personnel, was forwarded to the NTSB for review. The original recording, not a screen-recorded version, was requested from the owner of the camera, however, it was unable to be produced.¹

The video featured a timestamp overlay indicating it began at 19:40:11 CST and ended at 19:43:36 CST on March 4, 2024. The timestamp was not validated against an external source, and all times in this report are expressed in the provided overlay time in CST. The audio was recorded at a sampling rate of 44.1 kHz.

The camera was oriented southwest, capturing footage during nighttime conditions. The aircraft's engine was first audible at 19:41:00, with its lights becoming visible at 19:41:29, moving from right to left across the screen. At 19:41:37, the engine sound became abnormal, and the audio contained several "popping" noises at this time. By 19:42:10, the aircraft began a descending left turn, followed by a descending right turn toward the east at approximately 19:42:50. The aircraft was no longer visible after 19:43:19. A flash of light, corresponding to the aircraft's impact and post-crash fire, was observed at 19:43:28. The video concluded at 19:43:36 CST.

¹ When audio is re-encoded from a screen recording, it is captured from the playback output, processed, and compressed into a new file, often resulting in a loss of original quality.

2.0 ADS-B Data and Google Earth Overlay

ADS-B data from the accident flight was utilized in this analysis, including information on the aircraft's location (latitude and longitude) and groundspeed. The data was sampled at approximately 1 Hz.

Figure 1 is a Google Earth overview of the accident area. The location of the camera, John C. Tune Airport (JWN), the ADS-B track of the accident aircraft including the final recorded data point, and the approximate location of the wreckage are shown. Note that the weather and lighting conditions in the Google Earth overview are not necessarily representative of the weather and lighting conditions at the time of the accident.

3.0 Sound Spectrum Study

The audio from the video was analyzed to determine the operating speed of the aircraft's engine and/or propeller before the accident. The aircraft was equipped with a Lycoming TIO-540-S1AD six-cylinder direct-drive piston engine and a Hartzell three-bladed propeller. For this type of engine, the noise generated by the propeller is strongest at the fundamental blade passage frequency (BPF), which is related to engine RPM.²

For a three-bladed propeller, the relationship between engine RPM and the fundamental BPF is defined in equation 1:

$$\text{RPM} = \text{BPF} \left(\frac{\text{blades}}{\text{sec}} \right) * \frac{1}{3} \left(\frac{\text{rev}}{\text{blades}} \right) * 60 \left(\frac{\text{sec}}{\text{min}} \right) \quad (\text{eqn. 1})$$

According to the engine manufacturer's operator's manual, the engine's normal rated continuous power setting is 2,700 RPM, corresponding to a BPF of 135Hz.³

A spectrogram (Figure 2) was generated to illustrate the frequency content of the audio captured by the camera, spanning 19:40:11 CST to 19:43:36 CST. The x-axis represents time in elapsed seconds of the video and the y-axis represents sound frequency in Hertz (Hz). The color represents sound intensity, with black being the lowest intensity sound and orange being the highest intensity. Although the signal-to-noise ratio was low due to the camera's distance from the flight path and its design which prioritized nearby audio, distinct BPF lines were visible until about 19:41:37. From 19:41:37 to 19:41:43, popping noises were audible and visible in the spectrogram. From 19:41:43 to the end of the recording, no BPF could be identified.

² Smith, M. (1989). "Aircraft Noise." Cambridge University Press.

³ Lycoming TIO-540-S1AD Series Operator's Manual (60297-23A), 4th Edition, November 2005.

3.1 Doppler Effect

The spectrogram reveals a downward slope in the BPF lines and their harmonics over time, indicating the influence of the Doppler effect. The Doppler effect causes sound frequencies to appear higher when the source moves toward an observer, equal as the source passes the observer, and lower when the source moves away.

To simplify the engine speed calculation, a point on the flight path where the Doppler effect was not present was identified. At approximately 19:41:17 CST, the airplane was moving perpendicularly to the camera's line of sight (Location A in Figure 1). At this point, the frequency recorded by the camera matched the frequency emitted by the airplane.

3.2 Engine RPM Determination at Location A

At Location A, the airplane was about 5,000 feet from the camera. Given the air temperature of 66.2°F, the speed of sound was calculated to be 1,124 feet per second.⁴ This means the sound emitted by the airplane at 19:41:17 reached the camera around 19:41:21.

Figure 3 is a Fast Fourier Transform (FFT) of the audio signal from 19:41:20.5 to 19:41:21.5.⁵ The fundamental BPF at this time was measured as 132.4Hz, corresponding to an estimated engine speed of approximately 2,650 RPM. This is close to the engine's normal rated continuous power setting.

About 16 seconds later, at 19:41:37, popping noises were visible in the spectrogram, as annotated in Figure 2.

3.3 Other Observations

Following the popping noises, no BPF lines were visible in the spectrogram for the remainder of the recording, indicating that the engine had likely stopped operating. This was corroborated by a transmission from the aircraft to air traffic control at about 19:41:56, during which the pilot reported an engine shutdown.

⁴ A METAR from KJWN at 19:50 CST reported the air temperature as 19°C.

⁵ This is video elapsed time 00:01:10.5 to 00:01:11.5, which is shown in the Figure.

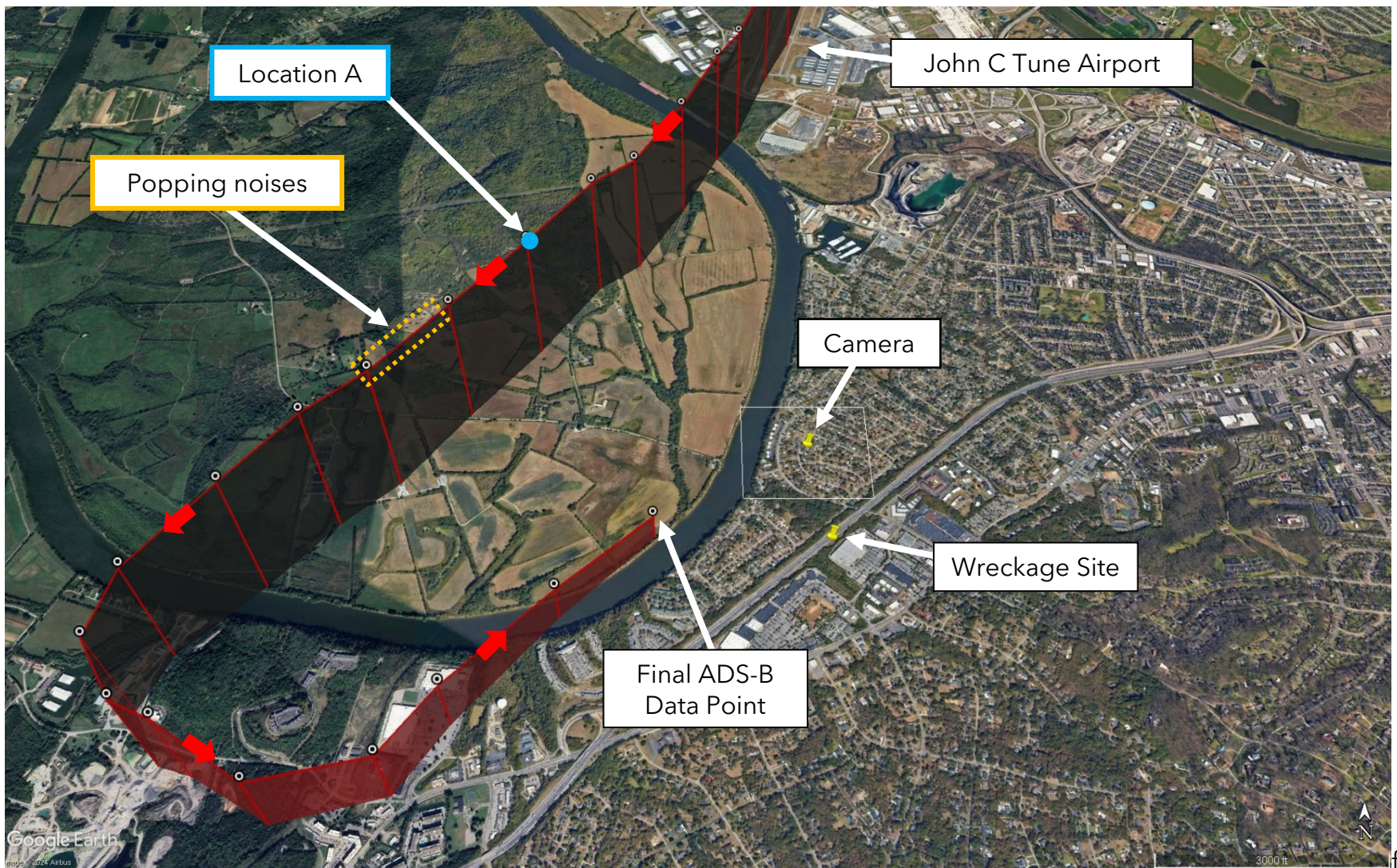


Figure 1. Google Earth overview of the final 3 minutes of the accident flight, annotated with locations and events. Red arrows along the ADS-B flight path show the direction of travel. (Source: Google Earth, annotated by NTSB)

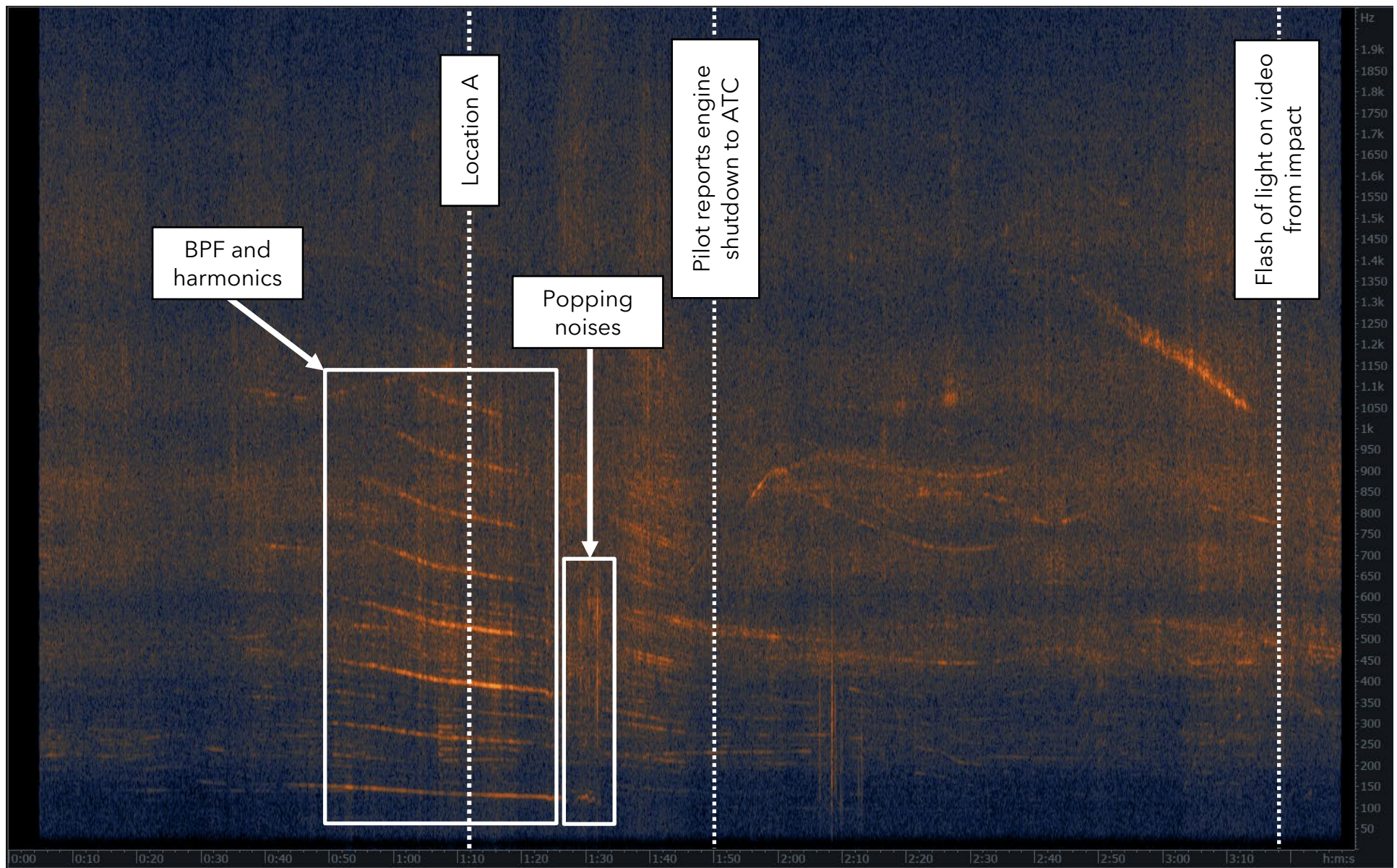


Figure 2. Spectrogram of audio from 19:40:11 CST to 19:43:36 CST, the full duration of video. (Source: iZotope RX 7, annotated by NTSB)

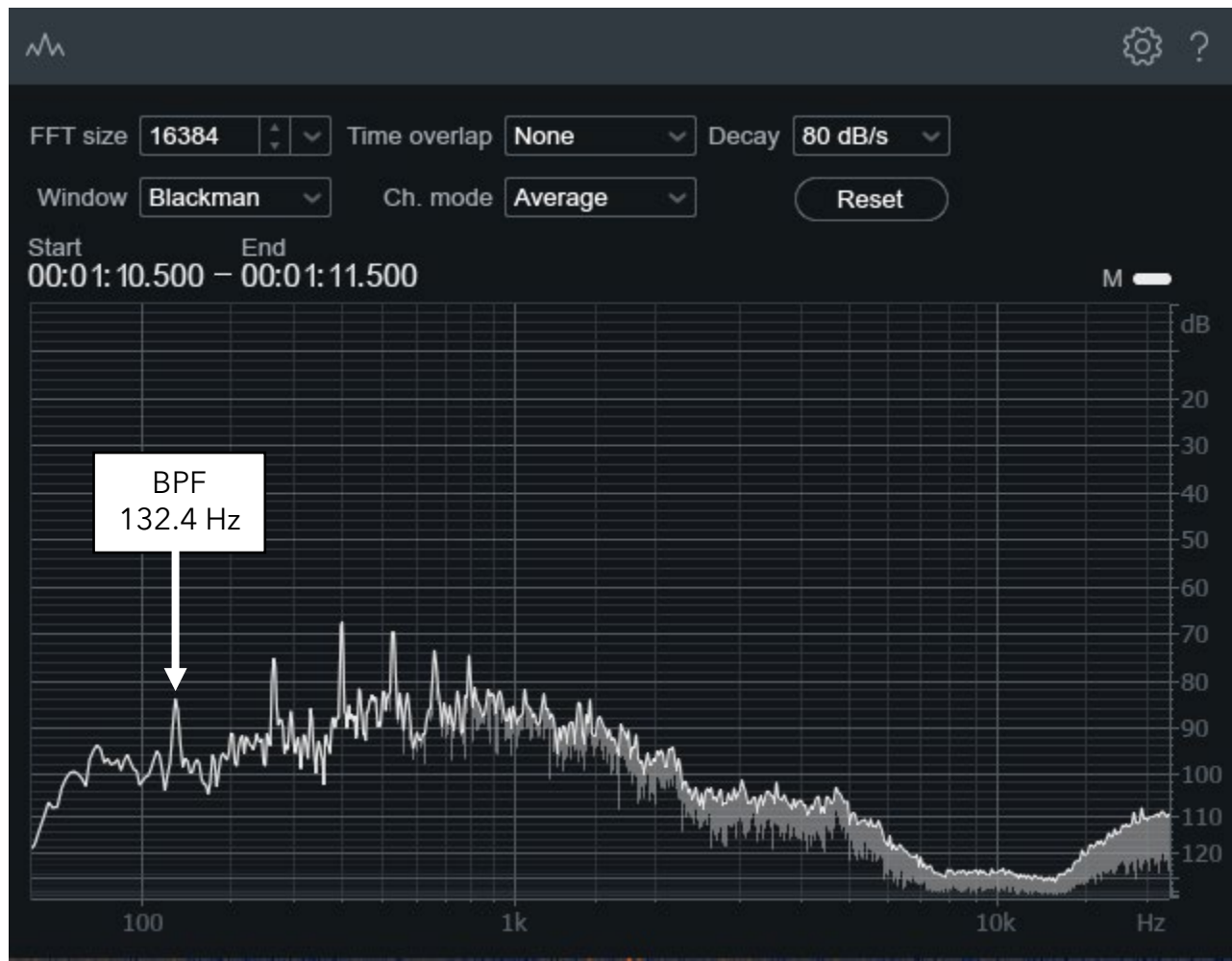


Figure 3. FFT of the audio signal from 19:41:20.5 to 19:41:21.5 CST. (Source: iZotope RX 7, annotated by NTSB)

3.4 Sound Spectrum Study Conclusion

The sound captured by a camera at a private residence near the wreckage site was analyzed to estimate the operating speed of the aircraft's engine and/or propeller during the final moments of the flight. The calculated RPM shortly before the engine ceased operation and about two minutes before the aircraft impacted terrain was consistent with the normal rated continuous power setting for this engine type. After popping noises were audible and the pilot reported to ATC that the engine had shutdown, no lines of BPF were observed and an RPM calculation could not be made.

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