

NATIONAL TRANSPORTATION SAFETY BOARD

Vehicle Recorder Division
Washington, D.C. 20594

January 28, 2022

Sound Spectrum Study

Specialist's Factual Report
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1. EVENT SUMMARY

Location: La Belle, FL
Date: May 6, 2021
Aircraft: Aerostar 600
Registration: C-FAAZ
Operator: Private
NTSB Number: ERA21FA212

2. DETAILS OF INVESTIGATION

The National Transportation Safety Board (NTSB) Vehicle Recorder Division received the following doorbell camera file:

Recorder Manufacturer/Model:	Unknown Doorbell Camera Model
Recorder Serial Number:	Unknown
Filename:	IMG_6840.mov

2.1. Video File Description

The video file was 960 by 960 pixels in resolution, in color, and recorded at an average framerate of approximately 15 fps.¹ The file contained a 16,000 Hz audio track, in mono. The video describes the accident airplane approaching almost directly and flying over the doorbell camera which recorded the video. The video is attached to this report as attachment 1.

The audio track was exported, retaining its original attributes, as a mono .wav file.

2.1.1. Sound Spectrum Study

Audio from the doorbell camera was evaluated in order to potentially determine the speed of each of the engines' propellers as it passed the camera.

Figure 1 is an exported screenshot from the video file at 13 seconds and 7 frames elapsed. The screenshot shows the aircraft is about to pass directly overhead.

¹ In some camera systems, file compression schemes could cause variable frame rates. In these instances, metadata often reports an average frame rate.



Figure 1. A screenshot exported at 13 seconds and 7 frames elapsed which shows the aircraft about to pass over the camera.

At 14 seconds and 7 frames elapsed, audio indicated the aircraft had passed behind the camera.

The sound spectrum was then evaluated at 14 seconds elapsed, which was assumed to represent the sound of the aircraft as it passed directly over the house.

Figure 2 is a screenshot of the area of interest of the recording examined in a spectrogram. The duration of the spectrogram (x-axis) is the entire duration of the doorbell recording (approximately 26 seconds). The frequency range highlighted is from 0 Hz to approximately 570 Hz (y-axis). The color range denotes the intensity in decibels (dB) of the frequency and is shown next to the y-axis. A yellow line indicates 14 seconds elapsed, which is the time of interest for this study, an assumption of the time the aircraft passed nearly directly overhead of the camera. The start of the sound of impact is indicated as a red bar.

Also annotated are two frequency traces like associated with the aircraft's engine and propellor system. These traces are labeled "Engine A" and "Engine B". It is not possible from this data alone to detect which trace corresponds with the left (number 1) engine and which trace corresponds with the right (number 2) engine.

Inset into figure 2 is a Fast Fourier Transform (FFT) analysis of the frequency range. The FFT is constructed at the selected time (14 seconds elapsed) indicated by the yellow bar. Two points are denoted in the FFT, one point at 80.89 Hz and another point at 47.92 Hz. The attributes of the FFT are also shown.

The accident aircraft was equipped with two Lycoming TSIO-520-K1F5 direct drive piston engines, each equipped with a three bladed controllable pitch propeller. The maximum propeller rpm of this engine and propeller combination is around 2700 rpm. The noise generated by the propeller for this type of engine configuration is generally the strongest at the fundamental blade passage frequency (BPF) with higher harmonics decaying by 5-10 decibels (dB).² For example, at 2700 rpm the propeller noise would be most evident at the blade passage frequency (BPF) of 150 Hz (eq. 1).

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

Using data from the spectrogram above, and substituting 80.89 Hz and 47.92 Hz for BPF in equation 1, the following RPM calculations are obtained:

- For 80.89, a propellor RPM of 1618 RPM is obtained
- For 47.92 Hz, a propellor RPM of 958 RPM is obtained

Acoustic Beating

Acoustic beating occurs when two signals are operating at very close, but not identical frequencies. It is caused by summing the signal from both sources and the resulting constructive and destructive interference manifests as a low frequency droning noise. In a spectrogram, this would result in a signal appearing as a dashed-like line.

The signals for Engine A and Engine B were reviewed for acoustic beating in this time frame. As shown in figure 2, no acoustic beating was obvious.

Discussion

The spectrogram shows two signals within the frequency range of three bladed propeller operation. It is not possible to correlate which signal corresponds with which engine. One signal potentially corresponds with “Engine A” and shows the characteristics of a three bladed propellor turning at approximately 1618 RPM. The other signal potentially corresponds to “Engine B” and shows the characteristics of a three bladed propellor turning at approximately 958 RPM.

The sound spectrum indicates the observed frequency decreased as the aircraft approached the camera, but at the position in which the study was conducted (directly over the camera), the Doppler effect would have been near zero.

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

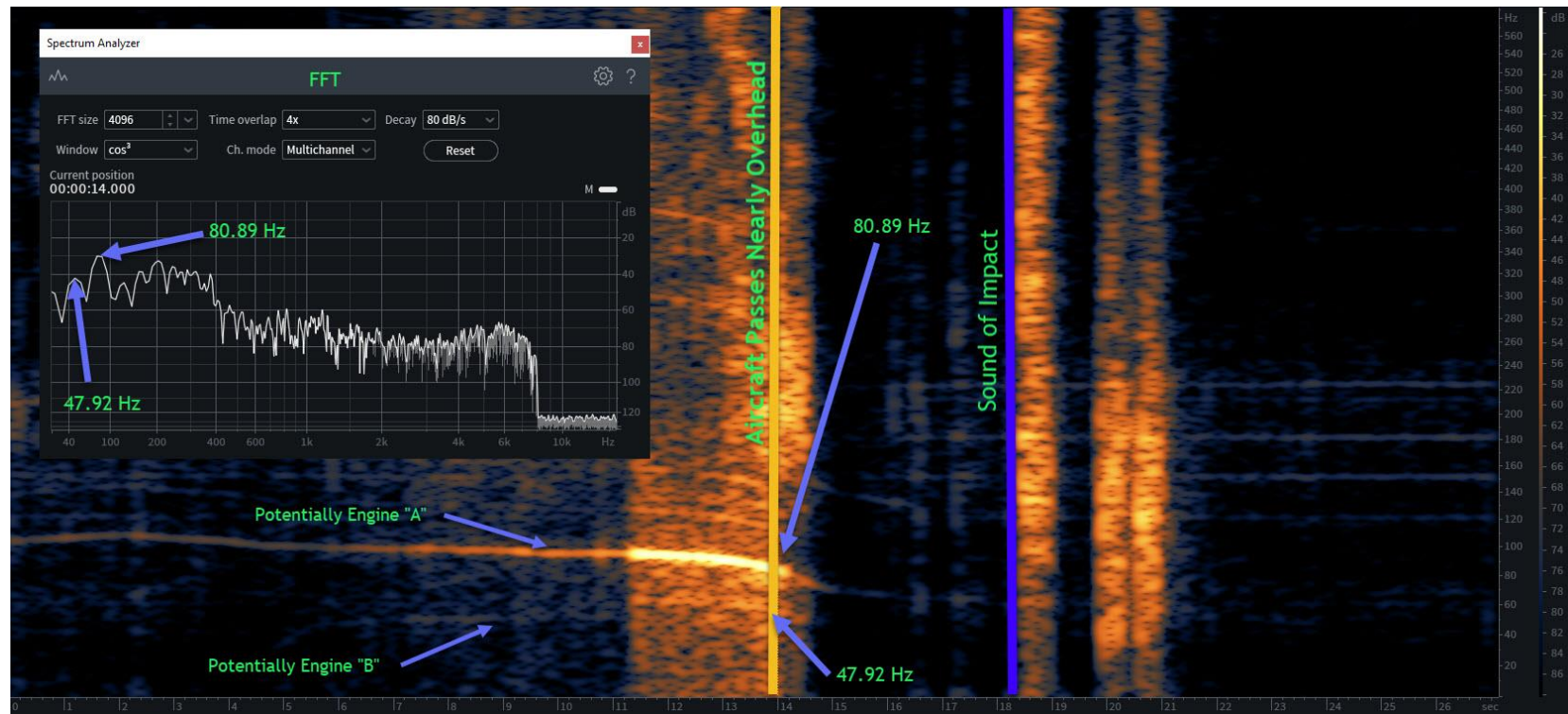


Figure 2. A screenshot of the acoustic software displaying a spectrogram for the doorbell recording. A FFT window is inset.