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SOUND SPECTRUM STUDY

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A. ACCIDENT

Location: Lake Placid, New York
Date: October 1, 2023
Time: 16:08 eastern daylight time
Aircraft: Cessna 177RG

B. SUMMARY

B.1. The accident

On October 1, 2023, at 1608 eastern daylight time, a Cessna 177RG, N545PZ, owned and operated by Lake Placid Air Service was substantially damaged when it was involved in an accident near Lake Placid, New York. The pilot and pilot-rated passenger sustained fatal injuries. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 aerial photography flight.

B.2. Objective of the Sound Spectrum Study

The objective of this study was the estimation of the speed of the airplane engines based on the sound in a video that was recorded with a camera mounted on a residential building.

C. DETAILS OF THE INVESTIGATION

The analyzed video was recorded with a camera installed on a residential building. It had 320x240 resolution and frame rate of 15 fps (frames per second). It recorded sound at the rate of 8000 samples per second. The video lasted 16.3 seconds.

There was a second video available. It was recorded with a camera installed on the same residential building. It had 320x240 resolution and frame rate of 15 fps. It recorded sound at the rate of 8000 samples per second. The video lasted 11.4 seconds. This video was less useful for estimating the speed of the airplane engine than the other video and, therefore, was not used in this study.

Figure 1 is an aerial view of the accident area. It shows the camera location and the location of ground impact. The twelve red circular markers in the figure are at locations available from GPS data recorded by a Garmin GPSMAP 396 GPS receiver that was on board the airplane. The markers are labeled with GPS times past 16:00:00 in format M:SS. The last available point was at time 16:08:47. Based on the distance between the last two locations and their times, it is estimated that ground impact was at about 16:08:49.5.

C.1. Sound spectrum analysis

The sound in the video was analyzed with the FFT (Fast Fourier Transform) algorithm that used 8192-point windows. The windows were 1.024 seconds wide and the frequency resolution was 58.6 cpm (cycles per minute). Figure 2 shows twelve spectra with window starting times between 2 seconds and 13 seconds in increments of one second.

The spectrum in the window starting at time 2 seconds is the first one where a spectral peak due to the two-bladed propeller BPF (blade passage frequency) can be seen. The frequency of the peak is 4805 cpm, corresponding to engine speed of $4805/2=2402.5$ rpm. The recorded BPF was affected by the Doppler effect. Compensating for the Doppler frequency shift will be detailed below. The last window that shows a spectral peak due to the BPF starts at video time 11 seconds. The frequency of the peak is 3926 cpm.

The frequencies of the BPF peaks in Figure 2 had to be compensated for the frequency shifts due to the Doppler effect. To accomplish it, it was necessary to synchronize the GPS time seen in Figure 1 with the times in Figure 2 that are video times. The synchronization is described next.

C.2. Compensating for the Doppler frequency shift

Figure 3 shows the sound signal recorded in the video. The highest signal intensity was at time 9.5 seconds. Ground impact was at time 14 seconds. Human voices were audible in the video. One of the high-intensity voice events is marked in the figure.

It was estimated above, using Figure 1, that ground impact was at GPS time 16:08:49.5. Figure 3 shows that ground impact was at video time 14 seconds. This suggests that video time zero seconds corresponds to GPS time $16:08:49.5-00:00:14=16:08:35.5$. Since the time of maximum intensity is at video time 9.5 seconds, the corresponding GPS time is $16:08:35.5+00:00:09.5=16:08:45$ that would be time 8:45 in Figure 1. There is no data point at this time in the Garmin record. It was estimated that the location corresponding to this GPS time would be approximately one third of the way from the 8:44 location to the 8:47 location in Figure 1. This location is close to where the camera-to-airplane distance was shortest, thus resulting in maximum sound signal intensity. Consequently, it was concluded that the video time and the GPS time were synchronized with accuracy better than one second.

For the purpose of the analysis, the term Doppler multiplier was defined to be the number by which a frequency is multiplied due to the Doppler effect when it is

recorded by the camera. To estimate the engine speed, the corrected BPF was desired at three locations. The first location was the one corresponding to the processing window in Figure 2 that starts at video time 5 seconds. Video time 5 seconds corresponds to GPS time 8:40.5 in Figure 1. The Doppler multiplier can be computed based on the airplane locations at times 8:38 and 8:41. Accounting for the airplane speed and direction of motion in this segment and considering the camera location, the Doppler multiplier is 1.08. Therefore, the estimated engine speed is $4688/2/1.08=2170$ rpm.

The second location of interest corresponds to the processing window in Figure 2 that starts at video time 9 seconds. Video time 9 seconds corresponds to GPS time 8:44.5 in Figure 1. The airplane was flying approximately perpendicularly to the line from the airplane to the camera, resulting in a very small Doppler frequency shift. The estimated engine speed is $4160/2=2080$ rpm.

The third location of interest was the one corresponding to the processing window in Figure 2 that starts at video time 11 seconds, three seconds before ground impact. Video time 11 seconds corresponds to GPS time 8:46.5 in Figure 1. The Doppler multiplier can be computed based on the airplane locations at times 8:44 and 8:47. Accounting for the airplane speed and direction of motion in this segment and considering the camera location, the Doppler multiplier is 0.94. The estimated engine speed is $3926/2/0.94=2088$ rpm.

During the time period between video time 5 seconds and video time 12.024 seconds (between GPS times 16:08:40.5 and 16:08:47.5), the three estimated speeds were 2170 rpm, 2080 rpm and 2088 rpm. Considering the 58.6 cpm FFT frequency resolution and other unavoidable estimation uncertainties, the speed in this time period can be specified as approximately constant at 2125 rpm ± 45 rpm.

D. CONCLUSIONS

The speed of the engine of an airplane that crashed shortly after taking off was estimated via spectrum analysis of the sound recorded in a video. It was estimated that the engine speed was approximately constant at 2125 rpm ± 45 rpm during a seven second period that ended two seconds before ground impact.

FIGURES

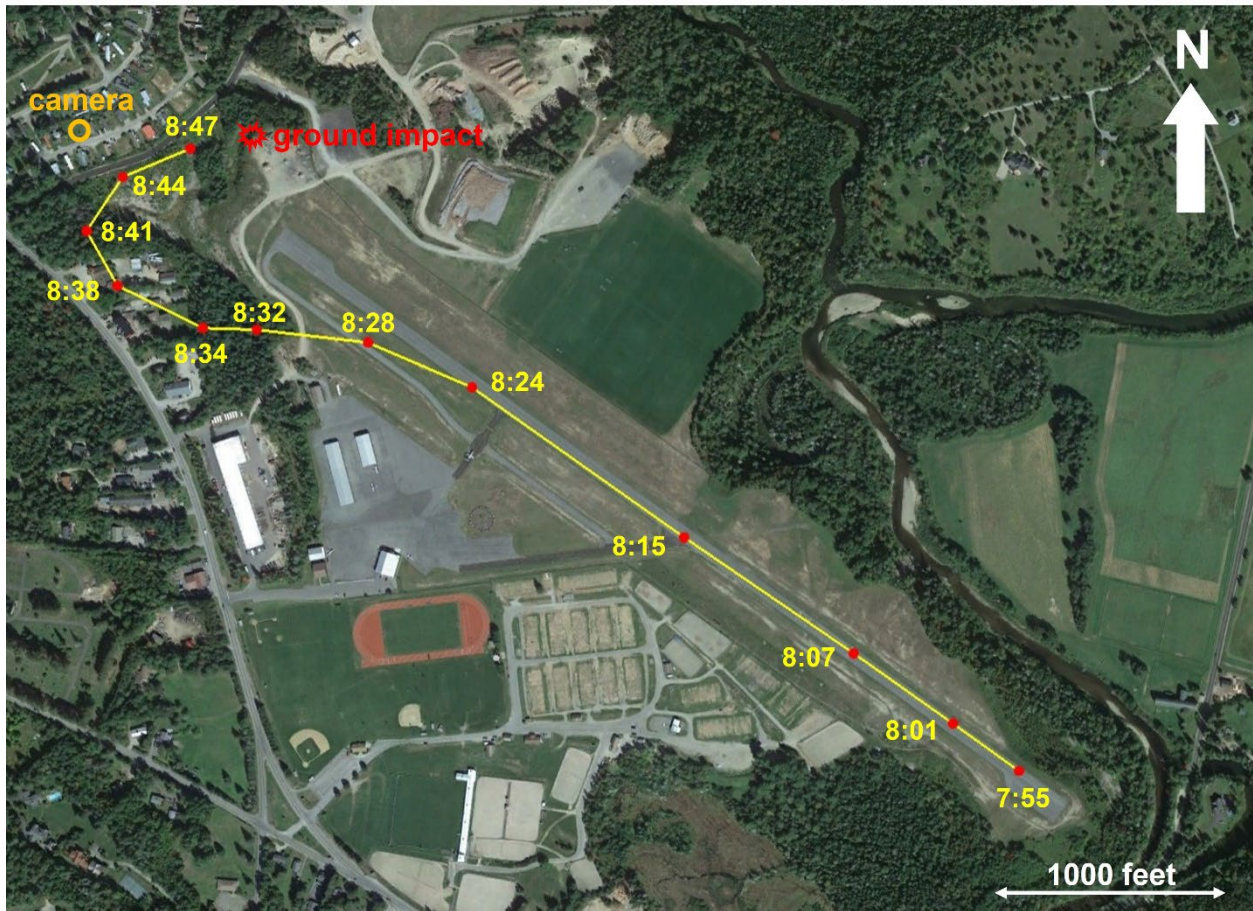


Figure 1. Aerial view of the accident area. The markers are labeled with GPS times past 16:00:00 in format M:SS.

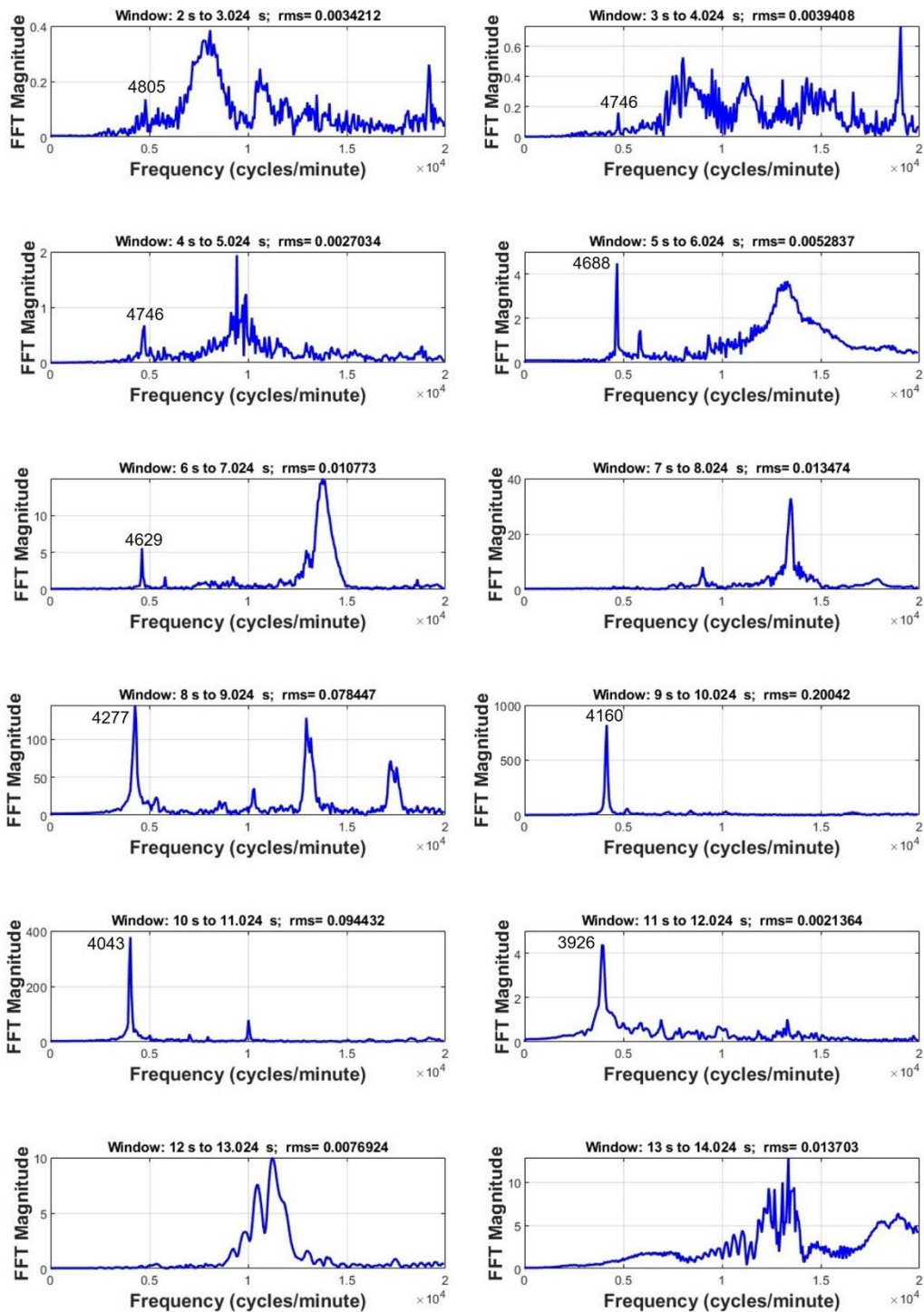


Figure 2. Sound spectra

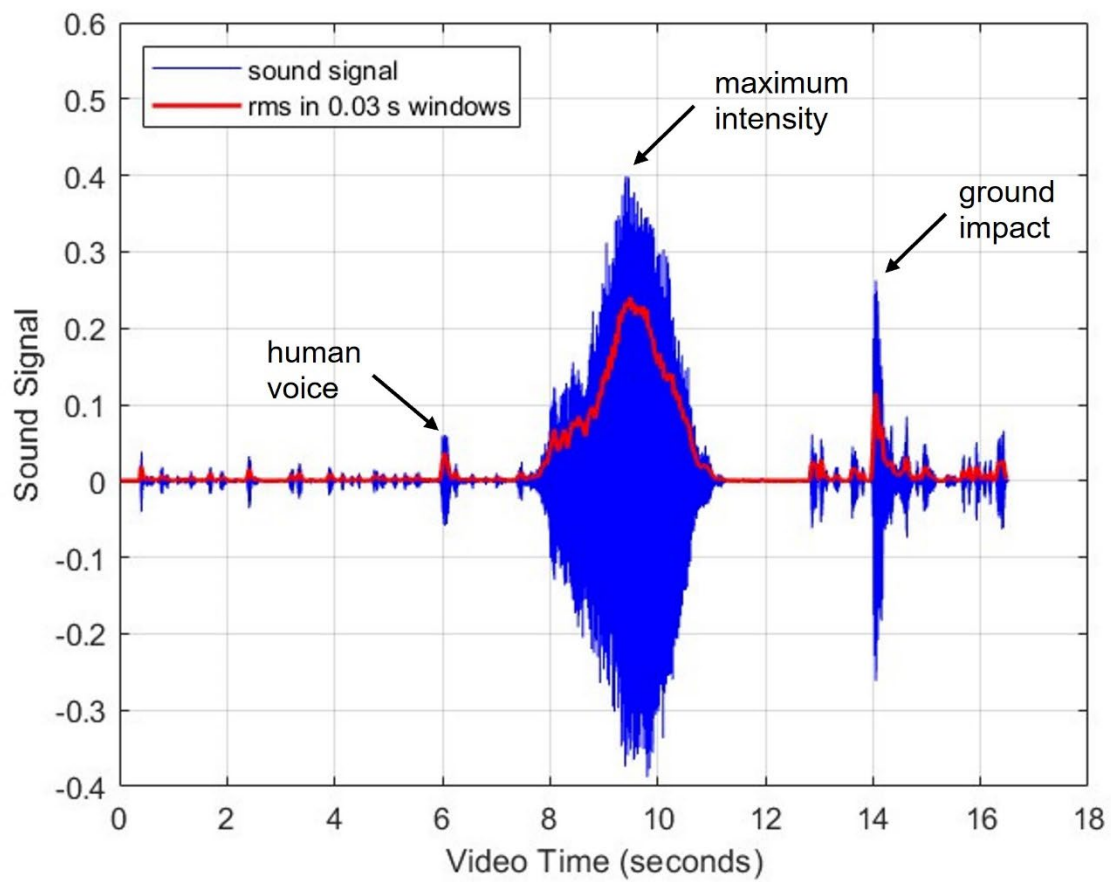


Figure 3. Sound signal intensity