NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

July 26, 2021

Sound Spectrum Study

NTSB Case Number:
DCA20LA100

A. ACCIDENT

Location: Camp Dwyer, Afghanistan
Date: April 20, 2020
Time: 0800 local time
Aircraft: Sikorsky S-61N helicopter

B. AUTHOR

Dan T. Horak
NTSB

C. ACCIDENT SUMMARY

On April 20, 2020, at approximately 0800 local time, a Sikorsky S-61N, N908CH, experienced a loss of control in flight and rolled on its side during an emergency landing at Camp Dwyer, Afghanistan. The three crew members onboard were seriously injured and the helicopter sustained substantial damage. The flight was operating under the provisions of Title 14 *Code of Federal Regulations* Part 135 as a cargo flight under contract to the Department of Defense.

D. DETAILS OF INVESTIGATION

The Onboard Image, Audio, and Data Recorder Specialist's Factual Report for this accident shows that the Appareo Vision 1000 device stopped recording at time 03:32:07.5. It is estimated that recording stopped at the time of ground impact or shortly past the time of ground impact. Figure 5 in that report shows that the longitudinal, lateral and normal accelerations started exhibiting fluctuating transients with magnitudes larger than magnitudes up to that time at about time 03:31:57, i.e., about 10.5 seconds before data recording stopped.

The Appareo Vision 1000 recorded two channels of audio at the rate of 32,000 samples/second. Channel 1 recorded crew audio and channel 2 recorded ambient sound with the Vision 1000 microphone. Spectrum analysis was performed on the ambient sound channel signal. Figure 1 shows the last 20 seconds of the recorded signal, ending when data recording stopped. The time axis shows the time till end of data. Consequently, time zero seconds in the figure corresponds to Appareo time 03:32:07.5 and time 20 seconds corresponds to Appareo time 03:31:47.5.

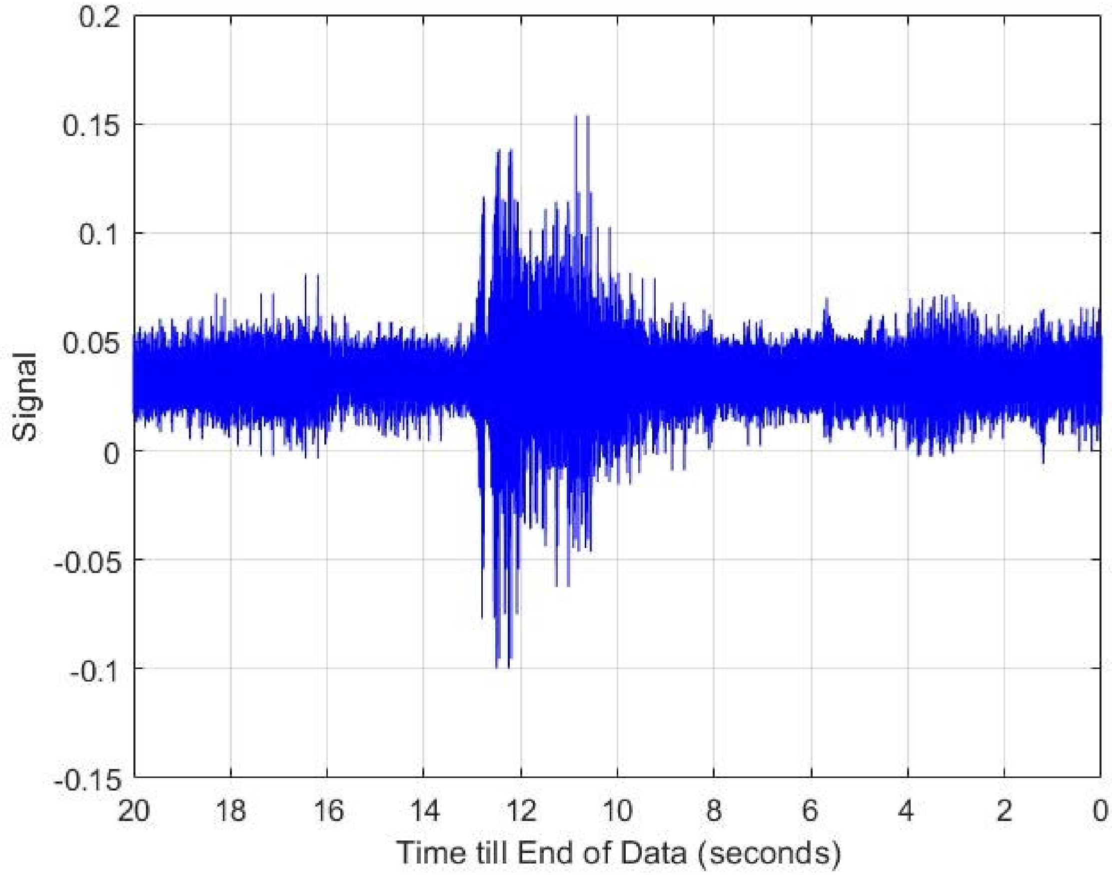

Figure 1. Ambient Sound Signal

Up to about time 13 seconds till end of data, the rms (root mean square) value of the signal was about 0.008. The rms value before the time shown in Figure 1 was also about 0.008. At time 12.8 seconds till end of data in Figure 1, the intensity of the signal increased significantly and stayed elevated for about 3 seconds. The rms value during these 3 seconds was about 0.02, i.e., about 2.5 times higher than the rms value before these 3 seconds. Past time 8 seconds till end of data, the rms value was back to about 0.008.

To investigate this 3-second transient, Fast Fourier Transform (FFT) spectrum analysis was performed in 1.024 seconds wide processing windows that covered the time shown in Figure 1. The FTT algorithm used 32,768 points, resulting in frequency resolution of 58.6 cycles/minute (cpm). The starting times of the processing windows were increased in steps of 1 second covering the signal range shown in Figure 1. Figure 2 shows ten FFT plots, from starting time 17.25 till end of data to starting time 8.25 till end of data.

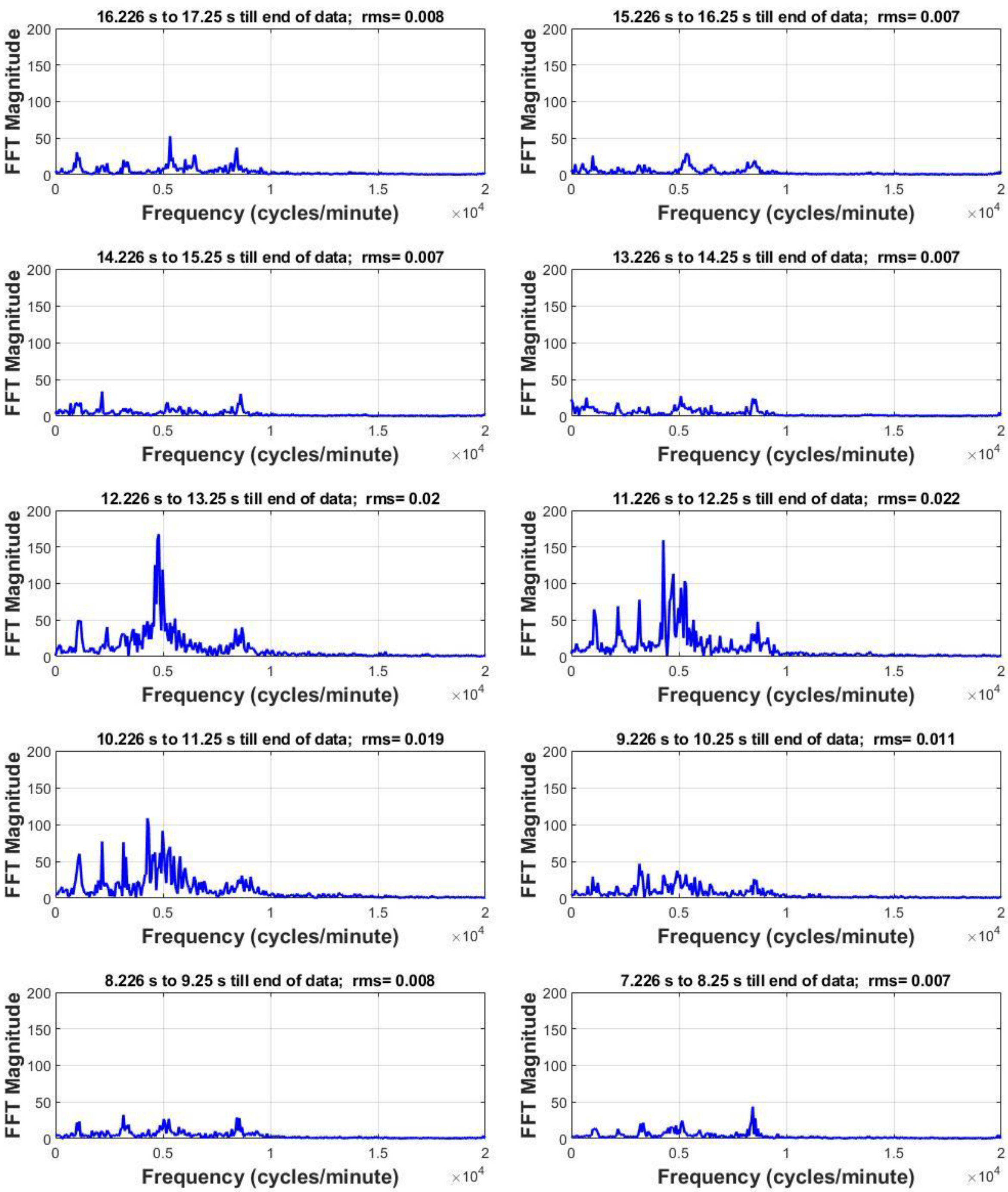

Figure 2. Ten Spectrum Plots

Figure 3 shows an enlarged plot of the spectrum in the window starting at 12.25 seconds till end of data. The signal during the one second starting at this time has the rms value of 0.022, the largest value observed in the analyzed 20 seconds shown in Figure 1. There are five marked spectral peaks in the spectrum, labeled A through E. Table 1 lists the frequencies of these computed peaks as well the frequencies of five expected harmonics based on the assumption that the frequency of a peak is a harmonic of a fundamental frequency (peak A). For example, the expected frequency of peak C, the third harmonic, is listed in Table 1 as 3×1065=3195. The frequency of the expected frequency of peak A was set to 1065 cpm because it generates the best match of the computed frequencies. Recall that the frequency resolution of the FFT algorithm was 58.6 cpm.

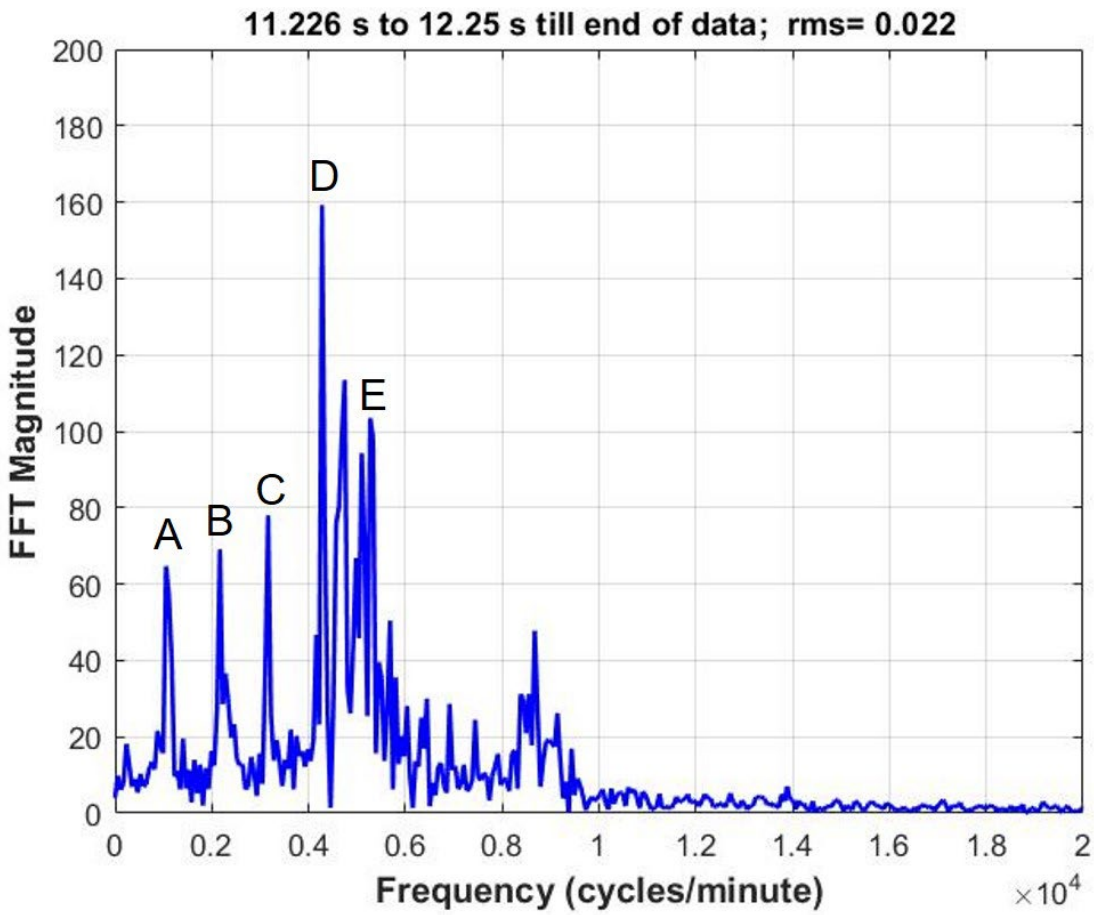

Figure 3. Spectrum Starting at Time 12.25 seconds till End of Data

The close agreement between the computed frequencies and the expected frequencies in Table 1 indicates that the five marked spectral peaks in Figure 3 are five harmonics of a fundamental frequency. The nominal main rotor speed of the S-61N helicopter is 203 rpm. It has five blades so that its blade passage frequency is 203×5=1015 blades/minute. Looking at the expected frequency column in Table 1 that is based on the 1st harmonic at 1065 cpm, it can be estimated that the main rotor speed was 1065 rpm and it was at the 1088/1015=1.05 or 105% level relative to the 100% rated rotor speed.

Table 1. Frequencies of Spectral Peaks

Peak Number	Peak Letter	Computed Frequency (cpm)	Expected Frequency (cpm)
1	A	1055	1065
2	B	2168	2130
3	C	3164	3195
4	D	4277	4260
5	E	5273	5325

Figure 4 shows an expanded view of the spectrum in a processing window starting at time 14.25 seconds till end of data, i.e., two seconds earlier than the spectrum shown in Figure 3.

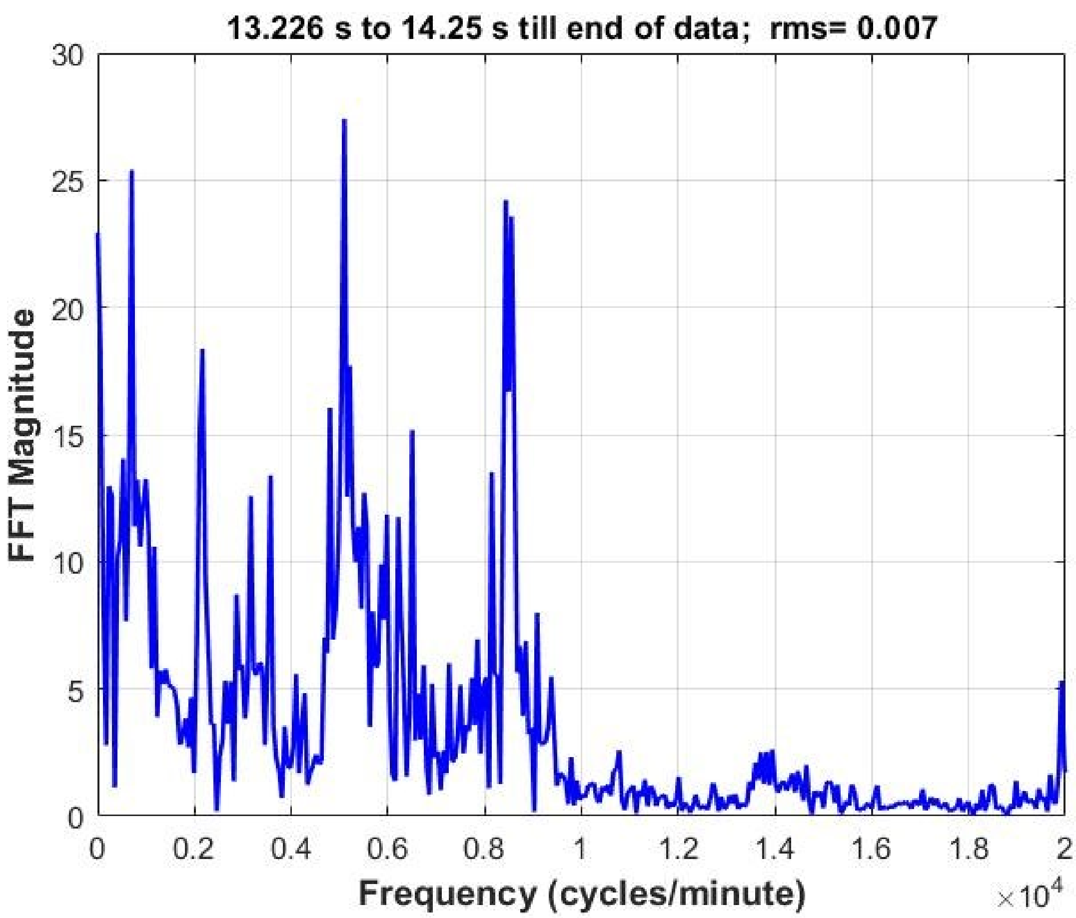

Figure 4. Spectrum Starting at Time 14.25 seconds till End of Data

The spectral peaks in Figure 4 do not correspond to harmonics of the main rotor blade passage frequency and their magnitudes are small compared to the spectral peaks in Figure 3. This observation suggests that the three seconds of elevated signal intensity seen in Figure 1 involved the main rotor. It cannot be determined based on the sound signal alone how and why the main rotor caused the elevated sound intensity.

The Appareo Vision Summary report for this accident indicated that the gas generator speeds were Ng1=88% and Ng2=87% up to Appareo time 03:31:54.25 (13.25 seconds till end of data). After Appareo time 03:31:59.75 (8.25 seconds till end of data), the values were Ng1=95% and Ng2=93%. This change in the gas generator speeds occurred during the signal intensity transient seen in Figure 1.

The Vision Summary report also indicated that at time 03:31:57.25 (10.25 seconds till end of data), the AUX Hydraulics pressure decreased to 1300 psi. At time 03:31:59.25 (8.25 seconds till end of data), both PRI and AUX Hydraulics pressures were down to 1300 psi. These pressure changes occurred shortly after the signal intensity transient seen in Figure 1.

Spectral analysis also examined frequencies up to 60,000 cpm, looking for signatures due to the gas generator speed Ng (or N1) and the power turbine speed Np (or N2). The 100% Ng for the helicopter engines is 26,300 rpm and the 100% Np is 18,966 rpm. Analysis found spectral peaks at about 53,700 cpm and at about 44,900 cpm. The frequencies of these peaks remained constant during the 20 seconds shown in Figure 1.

The measured frequencies of 53,700 cpm and 44,900 cpm are near the second harmonic frequencies of the engine 100% Ng and 100% Np speeds respectively, but they could not be reliably associated with them. Specifically, the measured frequency of 53,700 cpm was too high to correspond to the second harmonics of Ng1 and Ng2 that were below their 100% rated values as indicated in the Appareo Vision Summary report. Furthermore, Ng1 and Ng2 increased by about 8% after the signal intensity transient seen in Figure 1 and the measured frequency of 53,700 cpm did not increase. Also, 44,900 cpm was too high to correspond to the second harmonic of Np.

E. <u>CONCLUSIONS</u>

Ambient sound recorded by an Appareo device mounted in a helicopter that crashed was analyzed. Both time-domain and frequency-domain analyses detected a 3-second sound transient that started about 13 seconds before the recorded sound data ended. The sound spectrum computed in a time window during the transient included spectral peaks at the harmonics of the main rotor blade passage frequency.