

NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

March 29, 2022

Security Video Summary & Sound Spectrum Study

Specialist's Factual & Study Report By Kyle Garner

1. EVENT

Location: Pembroke Pines, Florida
Date: March 15, 2021
Vehicle: Beechcraft B36TC Bonanza
Registration: N236BC
Operator: Private
NTSB Number: ERA21FA154

2. GROUP

A group was not convened.

3. DETAILS OF INVESTIGATION

The National Transportation Safety Board (NTSB) Vehicle Recorder Division received video files downloaded from four security cameras along the accident aircraft's flight path.

3.1. Event Description

The accident aircraft departed from runway 10L at North Perry Airport (HWO), Pembroke Pines, Florida. Shortly after departure the aircraft entered a right bank, pitched nose down, and impacted the ground and a moving vehicle on a residential street. A witness near the departure end of runway 10L reported that the accident aircraft took off, began to climb at a slow rate, the engine "failed completely", and the propeller stopped rotatingⁱ.

There was no Automatic Dependent Surveillance-Broadcast (ADS-B) data generated for the accident flight and there were no onboard recording devices found in the aircraft wreckage, thus, track and speed of the aircraft during the accident flight are unknown. The location of the airport, the aircraft's wreckage, and the four security cameras is shown in Figure 1.

ⁱSee *Record of Conversation – Nicholas Silva*, which is included in the docket for this accident.



Figure 1. Overview of all camera locations, the airport, and the aircraft's wreckage location.ⁱⁱ

3.1.1. Camera 1 Description

Camera 1 was located on airport property and included a view of the ramp and a partial view of aircraft taking off from runway 10L. The location of camera 1 and its approximate viewing angle is shown in Figure 2.

ⁱⁱNote that the conditions in the Google Earth overlay are not necessarily representative of the weather or lighting conditions at the time of the accident.

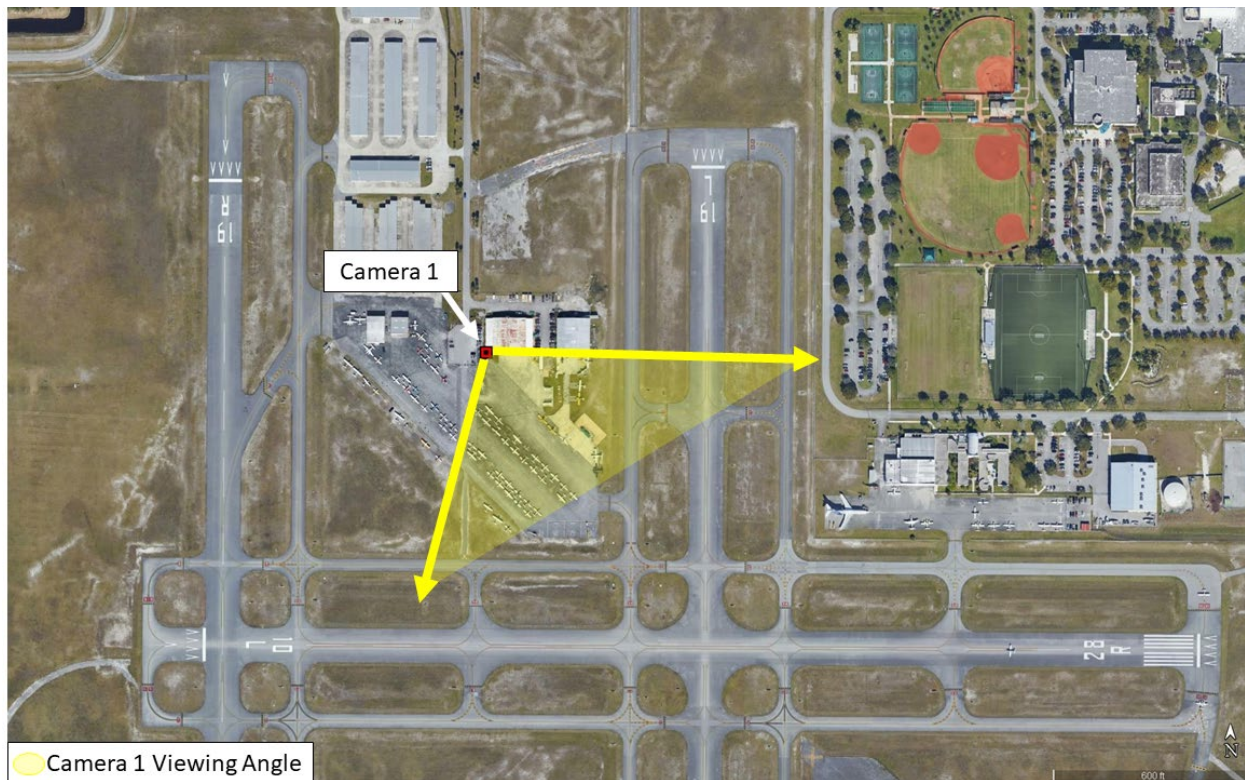


Figure 2. Camera 1 location and approximate viewing angle.ⁱⁱⁱ

The video from camera 1 was one minute and two seconds in duration. Metadata in the file indicated that the video had a resolution of 1280 by 720 pixels and was recorded at an average frame rate of approximately 15 frames per second (fps). A stereo audio track was included in the file sampled at a rate of 32,000 Hertz (Hz).

3.1.2. Cameras 2, 3, and 4 Description

Cameras 2, 3, and 4 were located off airport property at private residences near the aircraft's ground impact location. Camera 4 was located at a residence across the street from the residence that had cameras 2 and 3. The location of cameras 2, 3 and 4 and their approximate viewing areas are shown in Figure 3.

ⁱⁱⁱNote that the conditions in the Google Earth overlay are not necessarily representative of the weather or lighting conditions at the time of the accident.

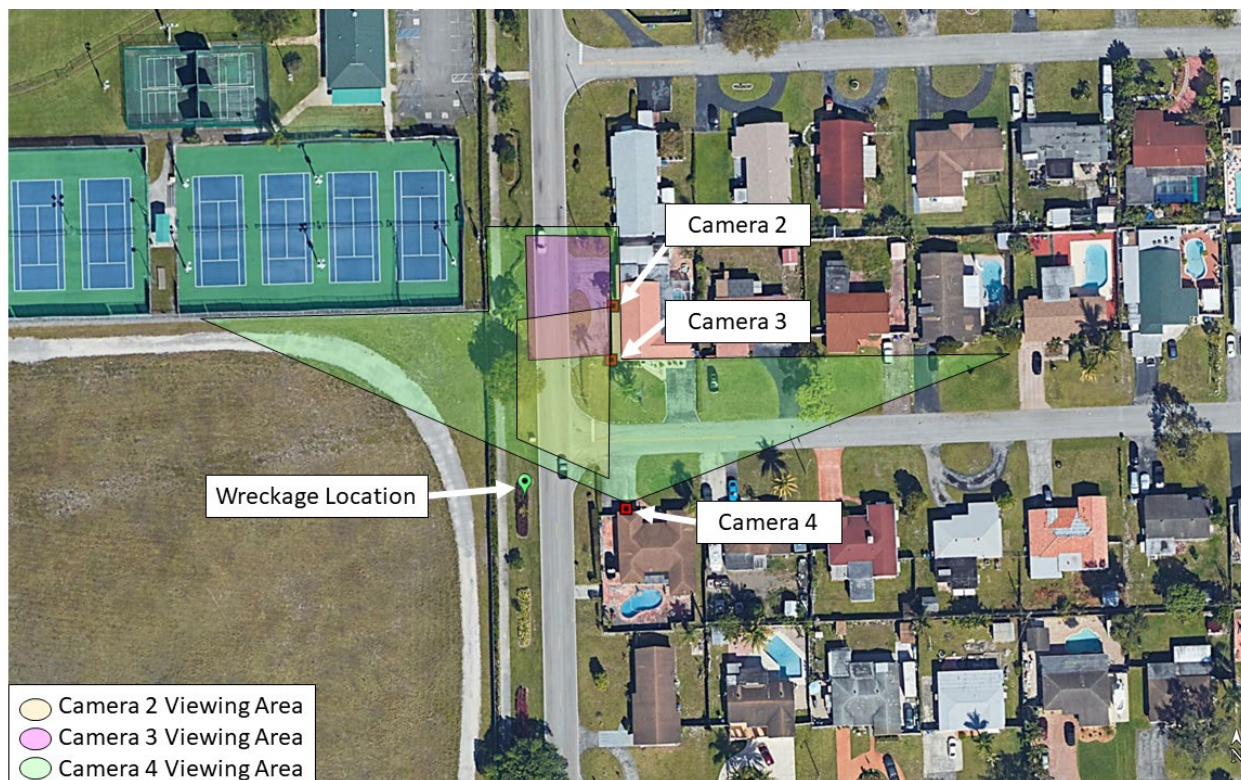


Figure 3. Location of cameras 2, 3 and 4 and their approximate viewing areas.^{iv}

The video from camera 2 was 28 seconds in duration and the video from camera 3 was four minutes and 15 seconds in duration. Each video was captured from the camera's remote playback interface software using the Apple iOS screen recording feature, thus, no metadata for the original videos was available. There was no audio data included in either file.

The video from camera 4 was one minute and five seconds in duration. Metadata in the file indicated that the video had a resolution of 1920 by 1080 pixels and was recorded at a frame rate of 20fps. A stereo audio track was included in the file sampled at a rate of 48,000 Hz.

3.1.3. Video Timing

The video from cameras 2, 3 and 4 included a timing overlay in local time, however, each video indicated the accident aircraft impacted the ground at a different time. Because the timing could not be validated, for the remainder of this report the video time is referenced as total elapsed seconds from the beginning of each recording.

3.2. Video Summary

In agreement with the Investigator-in-Charge, a group did not convene, and a summary of each video was prepared.

^{iv}Note that the conditions in the Google Earth overlay are not necessarily representative of the weather or lighting conditions at the time of the accident.

3.2.1. Camera 1 Summary

The following events were observed at the times indicated in Table 1. Only selected events pertinent to the investigation are included in the table.

Table 1. Camera 1 video summary.

Camera 1 Elapsed Time (mm:ss)	Comment
00:01	<i>[Start of video]</i> View was of multiple general aviation aircraft parked on the ramp at HWO with runway 10L in the distance. Weather was partly cloudy with no visible precipitation. The camera was mounted facing towards the southeast. The accident aircraft was seen accelerating down runway 10L (moving from right to left on the video). Sound consistent with an aircraft taking off was noted.
00:07	The accident aircraft lifted off runway 10L and began to climb.
00:24	The accident aircraft began to bank to the right.
00:29	The accident aircraft was no longer visible. ^v
00:33	Sound consistent with a different aircraft taking off was noted.
00:38	A large fireball appeared in the distance.
01:02	A black smoke plume was visible in the distance. <i>[End of video]</i>

3.2.2. Camera 2 Summary

The following events were observed at the times indicated in Table 2. Only selected events pertinent to the investigation are included in the table.

Table 2. Camera 2 video summary.

Camera 2 Elapsed Time (mm:ss)	Comment
00:01	<i>[Start of video]</i> View was of front patio of private residence with a residential street in the distance. An awning over the front patio obstructed the view of the sky. The camera was mounted facing toward the southwest.
00:02	A vehicle was visible on the residential street in the distance travelling toward the camera.

^vThe aircraft was likely no longer visible due to its distance from the camera and temporal compression of the video data by the security camera system.

00:04	The vehicle continued to travel toward the camera. The right wingtip of the accident aircraft became visible just below the awning. The aircraft appeared to be in a nose down, right bank. A few frames later, the right wingtip impacted the front lawn of the residence.
00:05	The aircraft was still in a right bank. The outboard half of the right wing had impacted the ground and fuel spillage (blue mist) was visible. The right side of the cockpit became visible as the propeller impacted the forward passenger door of the passing vehicle.
00:06	After the aircraft impacted the vehicle, the aircraft began to slide across the street. Fuel spillage obscured most of the view of the aircraft as it slid. The vehicle had spun around post-impact and was now facing away from the camera.
00:07	The spilled fuel ignited, and a large fireball erupted. The fire snaked along the ground and into the private residence's front lawn.
00:23	The camera view was obstructed by a person opening the front door of the private residence.
00:28	<i>[End of video]</i>

3.2.3. Camera 3 Summary

The following events were observed at the times indicated in Table 3. Only selected events pertinent to the investigation are included in the table.

Table 3. Camera 3 video summary.

Camera 3 Elapsed Time (mm:ss)	Comment
00:01	<i>[Start of video]</i> View was of front patio of private residence with residential street in the distance. An awning over the front patio obstructed the view of the sky. The camera was mounted facing toward the northwest.
00:04	The right wingtip of the accident aircraft appeared just below the awning. The right wingtip impacted the front lawn of the residence.
00:06	A flash of light from the fuel igniting was noted.
00:24	Multiple witnesses arrived and assisted the occupants of the vehicle that was struck.
02:33	First responders arrived.
04:15	<i>[End of video]</i>

3.2.4. Camera 4 Summary

The following events were observed at the times indicated in Table 4. Only selected events pertinent to the investigation are included in the table.

Table 4. Camera 4 video summary.

Camera 4 Elapsed Time (mm:ss)	Comment
00:01	<i>[Start of video]</i> View was a wide-angle view of the driveway of a private residence and a residential street to the left. The private residence with cameras 3 and 4 was noted across the street. The camera was mounted over the garage door and was facing toward the north. The sky was partially obscured by a portion of the house.
00:16	A white truck on the street became visible, travelling south toward the camera. Sound consistent with the truck accelerating was noted.
00:23	The white truck passed the camera and was no longer visible.
00:24	A vehicle on the street became visible, travelling north away from the camera.
00:25	The right wingtip of the accident aircraft became visible. The aircraft appeared to be in a nose down, right bank. The flaps on the right and left wing appeared to be retracted. The landing gear also appeared to be retracted. A few frames later, the propeller impacted the forward passenger door of the passing vehicle. A large quantity of fuel spillage was noted.
00:26	The aircraft, now on the ground, began to slide across the street. All passenger doors on the right side of the aircraft opened.
00:27	The fuel ignited. The ignition source appeared to come from forward of the aircraft's passenger compartment.
00:28	A large fireball erupted.
01:05	<i>[End of video]</i>

3.3. Sound Spectrum Study

One channel of the audio from cameras 1 and 4 were extracted to attempt to determine the operating speed of the engine during departure and prior to impact. The files from camera 2 and 3 contained no audio, thus, they are not discussed in the sound spectrum study.

The aircraft was equipped with a Continental Aerospace Technologies TSIO-520-UB series 300 horsepower, six-cylinder, turbocharged, direct-drive engine with a three-bladed propeller. According to the engine Type Certificate Data Sheet (TCDS)^{vi}, the engine was rated and limited to a speed of 2700 revolutions per minute (rpm).

The principal source of piston engine noise is the regular firing of the cylinders. The fundamental frequency, F , in Hz of this noise is given by the following expression for a four-stroke engine:

^{vi}Federal Aviation Administration TCDS No. E8CE

$$F = \frac{NR}{120} \quad (1)^{vii}$$

where N is the number of cylinders and R is the rpm. Using (1), for the event aircraft's engine configuration the fundamental frequency at the maximum rated power of 2700rpm was 135 Hz.

3.3.1. Sound Spectrum – Camera 1

Figure 4 is a spectrogram showing the frequency content of one channel of audio from camera 1 from 0s to 16s elapsed time. The x-axis represents time in elapsed seconds and the y-axis represents sound frequency in Hz. The color represents sound intensity, with blue being the lowest intensity sound and pink being the highest intensity. Lines of frequency representing approximately 130Hz and the first harmonic of 260Hz are annotated for reference.

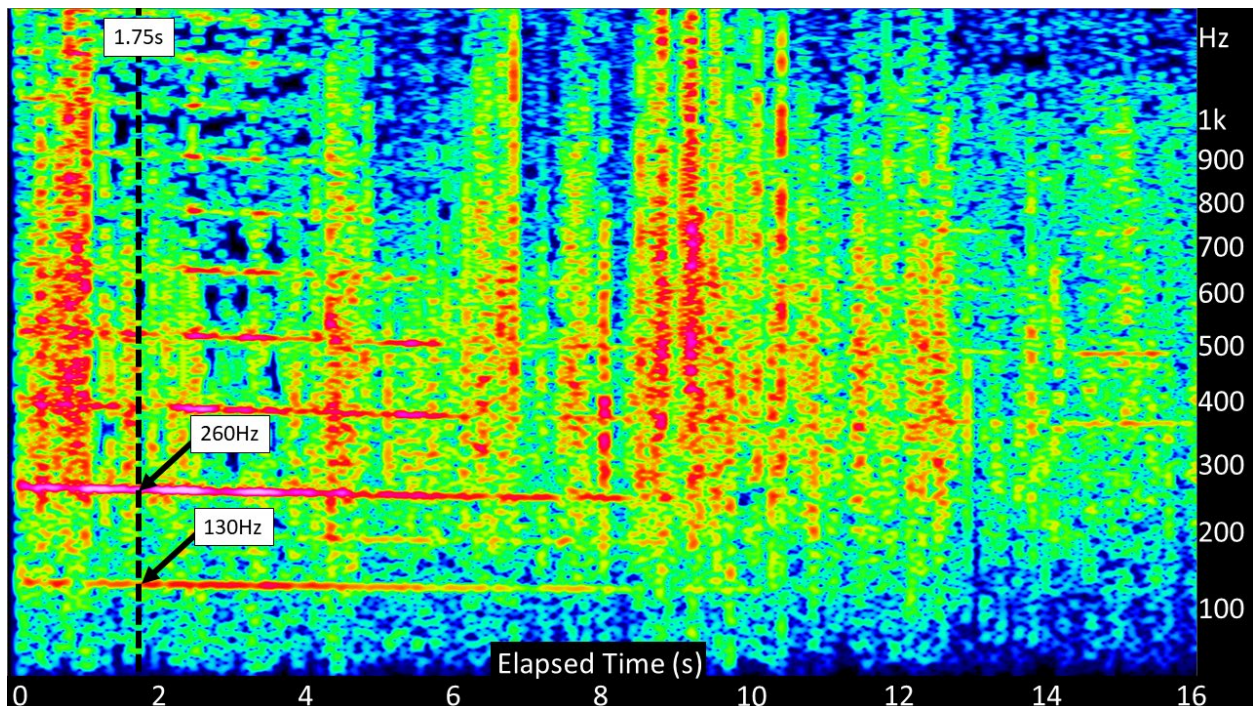


Figure 4. Spectrogram of camera 1 audio file from 0s to 16s.

Note the gradual downward slope of the lines of intense frequency as time passes, suggesting that the influence of the Doppler effect should be considered.

The Doppler effect causes sound frequencies emitted from a source to appear higher to a stationary observer if the source is moving toward the observer, equal as the source passes the observer, and lower as the source moves away from the observer. The observed frequency, f_0 , is given by the following expression:

^{vii}G. Jerry and P. Lilly, "Engine Exhaust Noise Control," JGL Acoustics, 2008.

$$f_0 = \frac{c}{c \pm v_s \cos(\theta)} f_s \quad (2)$$

where c is the speed of sound in air, v_s is the velocity of the source, θ is the angle of the line of sight from the observer to the source, and f_s is the source frequency. If the source is moving toward the observer, the sound source velocity component is positive. If the sound source is moving away from the observer, the sound source velocity component is negative.

As the aircraft accelerated down runway 10L for takeoff, the aircraft was closest to camera 1 at approximately 1s elapsed time. At this time, the angle of the line of sight from the observer to the source, θ , was about 90° (see Figure 5). Thus, at 1s elapsed time per (2) the sound source velocity component is zero and the source frequency is equal to the observed frequency.

The camera was located about 870 feet (ft) from the centerline of runway 10L thus, the time for the sound waves to travel to the camera should be considered. At 870 ft, the sound emitted at the point of closest passage would take approximately 0.75s to reach the camera. Therefore, the sound waves corresponding to closest passage arrived at the camera at approximately 1.75s elapsed time. Per Figure 4, the fundamental frequency at 1.75s was 130Hz. Using (1), this corresponds to an estimated engine speed during the takeoff roll of about 2600rpm, or slightly below the maximum rated 2700rpm for this engine.



Figure 5. Doppler effect – aircraft at position closest to camera.

Note that the lines of intense frequency associated with the aircraft engine's fundamental frequency seem to dissipate at approximately 12s elapsed time.

3.3.2. Sound Spectrum – Camera 4

Figure 6 is a spectrogram showing the frequency content of one channel of audio from camera 4 from 6s to 26s elapsed time. The x-axis represents time in elapsed seconds and the y-axis represents sound frequency in Hz. The color represents sound intensity, with blue being the lowest intensity sound and pink being the highest intensity.

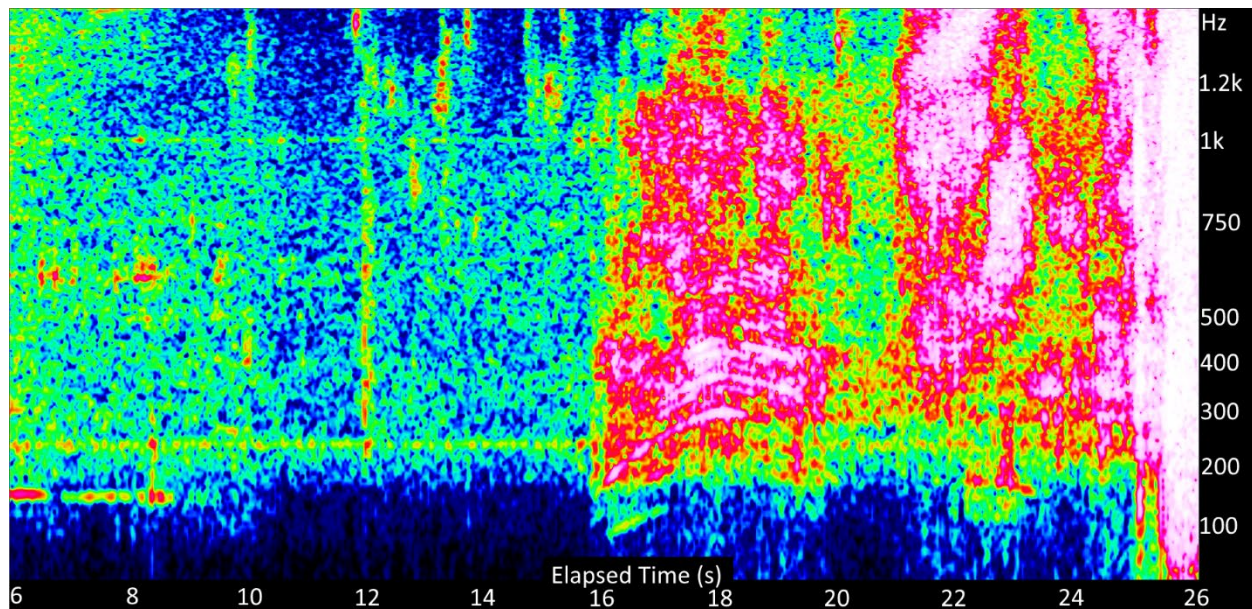


Figure 6. Spectrogram of camera 4 audio file from 6s to 26s.

Note from Table 4 that the aircraft impacted the ground between 25 and 26s, which is shown as an increase in sound intensity on the spectrogram at the same time. Of interest is the increase in intensity between 16s and 23s, however, as discussed in Table 4 this sound is likely from the white truck accelerating and then passing the camera during this time.

No sound energy consistent with the aircraft's engine was noted on the camera 4 audio recording, likely due to a low signal-to-noise ratio or because the engine was not operating prior to impact.

3.3.3. Sound Spectrum Study Conclusions

The goal of this sound spectrum study was to determine the engine operating speed using audio data from camera 1 and 4. The primary conclusions from this study follow:

- Audio data from camera 1 indicated that the aircraft's engine during takeoff from runway 10L was likely operating at about 2600rpm at the point of passage closest to the camera.
- No sound energy consistent with the aircraft's engine was noted on the camera 4 audio recording, likely due to a low signal-to-noise ratio or because the engine was not operating prior to impact.