NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

December 28, 2012

Video/Audio Study

Specialist's Study Report
By Doug Brazy

1. EVENT SUMMARY

Location:	Key West, Florida
Date:	October 31, 2011
Time:	1940 Eastern Daylight Time (EDT)
Aircraft:	Israel Aircraft Industries Gulfstream G150, Registration N480JJ
Operator:	Hendrick Motorsports
NTSB Number:	ERA12FA056

2. GROUP

A group was not convened.

3. SUMMARY

On October 31, 2011, at about 1940 eastern daylight time (EDT), an Israel Aircraft Industries G150, N480JJ, went off the end of the runway on landing roll out. The nose landing gear collapsed and the airframe sustained structural damage. Visual meteorological conditions prevailed and an instrument flight rules (IFR) flight plan was filed. The certificated airline transport rated pilot-in-command (PIC), airline transport rated co-pilot and one passenger reported minor injuries. One passenger sustained serious injuries. The flight departed from Witham Field Airport (SUA) Stuart, Florida at 1900 EDT. The flight was conducted under the provisions of 14 Code of Federal Regulations Part 91 as a personal flight.

Examination of the crash site revealed the airplane departed the runway, crossed a 600 foot overrun, impacted the far side of a ditch, crossed a dirt road, cleared another ditch, and came to a stop 820 feet from the departure end of the runway.

The NTSB Vehicle Recorder Laboratory received a Cockpit Voice Recorder (CVR) from the accident airplane and video recording from the Key West Airport surveillance system.[1]

[1] The CVR recording along with a transcript are documented in a separate report entitled **Cockpit Voice Recorder 12 - Factual Report of Group Chairman**, available in the public docket for this investigation.

This report examines sound spectrum data from the CVR recording and images captured by the surveillance system, for any useful information related to the airplane's touchdown location and/or groundspeed at the time of touchdown.

4. DETAILS OF INVESTIGATION

4.1. Cockpit Voice Recorder Sound Spectrum Data

In general, a "sound spectrum" examination is an analysis of recorded audio signals in terms of their frequency content and energy. In this case, the audio from the CVR was examined for sound frequencies associated with the airplane's nose gear (tires, specifically) as it rolled over the grooved runway surface during the landing rollout. As the tires roll across the transverse runway grooves, this type of noise can often be captured by the Cockpit Area Microphone (CAM) channel on the CVR, as it was in this case.

Figure 1 is a spectrogram chart of the audio captured by the CVR CAM channel, over the last 42 seconds of the recording. This spectrogram is a three-dimensional representation of audio which depicts frequency on the vertical axis, elapsed time on the horizontal axis, and the relative sound energy as function of color. White areas on the chart represent little or no sound energy, blue represents a higher level of energy than white, and orange-yellow indicates the highest levels of sound energy.

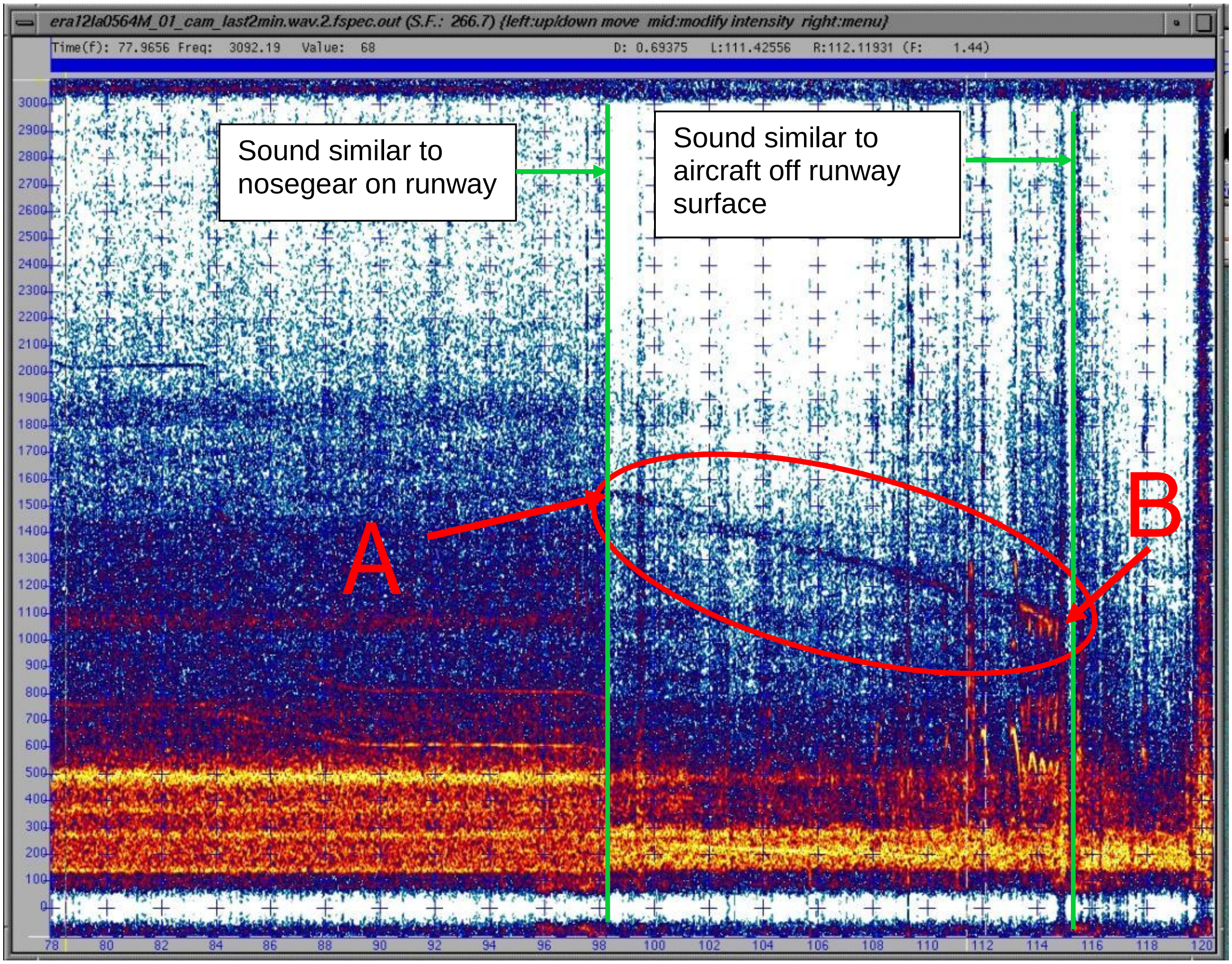

Figure 1 - Spectrogram of CVR CAM Channel Audio

The diagonal blue line (circled in red) is consistent with the noise that was generated by the airplane's nose wheel tires as they rolled over the grooved runway surface. The frequency of this noise is directly proportional to the airplane's groundspeed. As the airplane slowed down, the tires encountered the runway grooves at a progressively slower speed, which caused the noise generated to continually decrease in frequency.

This signature is first visible at the point labeled "A", which is simultaneous with the CVR group transcription of "sound similar to nose gear on runway". At this time, the frequency of the tire noise was 1547 Hz which is equivalent to a ground speed of about 114 knots. See equation 1 below. At about the same time, the Pilot Monitoring (non flying pilot) made a speed callout of 110 knots.[2]

[2] This callout was most likely in reference to the airspeed indicator which can differ from groundspeed, based on wind and other factors.

Eq. 1

$$\text{Groundspeed (Knots)} = \boldsymbol{F}\ \frac{(Grooves)}{(\text{second})} \times \boldsymbol{D}\frac{(Inches)}{(Groove)} \times \frac{1\ (foot)}{12\ (inches)} \times \frac{1\ \ nautical\ mile}{6076.1\ \ feet} \times \frac{3600\ (Seconds)}{1\ (hour)}$$

Where:

F is the tire noise frequency in Hz (Number of grooves per second encountered by the nose wheel tire)

D is spacing or gap distance, between the runway grooves in inches (measured as 1.5 inches for runway 9/27 at KEYW)

Similarly, the last signature related to the nose wheel noise occurred at the location marked “B” in Figure 1, which was concurrent with the CVR group’s observation of sounds similar to the airplane departing the runway surface. At that time, the frequency of the tire noise was measured as 1074 Hz, which is equivalent to a ground speed of about 80 knots.

A table of all measured frequencies groundspeed calculations can be found in Attachment I.

4.2. Surveillance Video

The surveillance video recording contained views from two separate cameras. One camera had a view of the approach end of runway 27 (the accident runway), which captured images of the airplane during a portion of the landing sequence. The other view was toward the approach end of runway 9 which had a partial but poor view of airplane; this camera view was not analyzed. The images were captured at a rate of 2 frames per second.

Figure 2 shows the view from the runway 27 camera as the airplane was landing.

Figure 2 - Surveillance Camera Image

None of the airplane's landing gear were visible in any of the images, therefore it was not possible to precisely determine where the airplane had touched down along the runway.

However, an examination of the relative position of the lights on the airplane over a sequence of several images revealed some details about the landing.

First, the locations of the landing light, the vertical stabilizer, and the left wingtip were marked in each image. Figure 3 shows an enlarged view of the airplane with an example of the markings for each reference (T1 is the top of the vertical stabilizer, L1 is the forward most region of the landing light, and W1 is the right wingtip light).

Figure 3 - Light Position Annotation

These references were marked on each image in a series of 8 images, which were recorded at ½ second intervals.[3] The references are labeled 1 through 8 in Figure 4. By comparing the relative positions of these references over time, the attitude of the airplane can be characterized. For example, if the airplane was in a level unchanging attitude with all three of the landing gear on the runway, the relative vertical positions of these references should not change when compared to the ground.

Conversely, if the airplane was ascending, descending, flaring, or derotating, the relative positions of these references should appear to change over time.

A review of these positions indicates that the airplane was not completely down with all 3 gear on the runway, prior to the 7th image in the series (the image shown in Figure 4). The elevation of the landing light (which is attached to the nose gear strut assembly) was continually decreasing from image 1 through image 7, suggesting that the nose gear was likely not on the ground.[4] The vertical stab reference point was also fluctuating prior to image 7.

All three references appear to remain at the same vertical height between image 7 and image 8. This may indicate that all 3 gear were on the ground at some time between

[3] Images 1 through 8 can be seen in Attachment II.
[4] A small amount of vertical motion of the landing light should occur as the strut compresses on landing.

these two images, however it's not possible to distinguish the gear being on the ground from what could be a constant altitude "float" at some small distance above the ground.

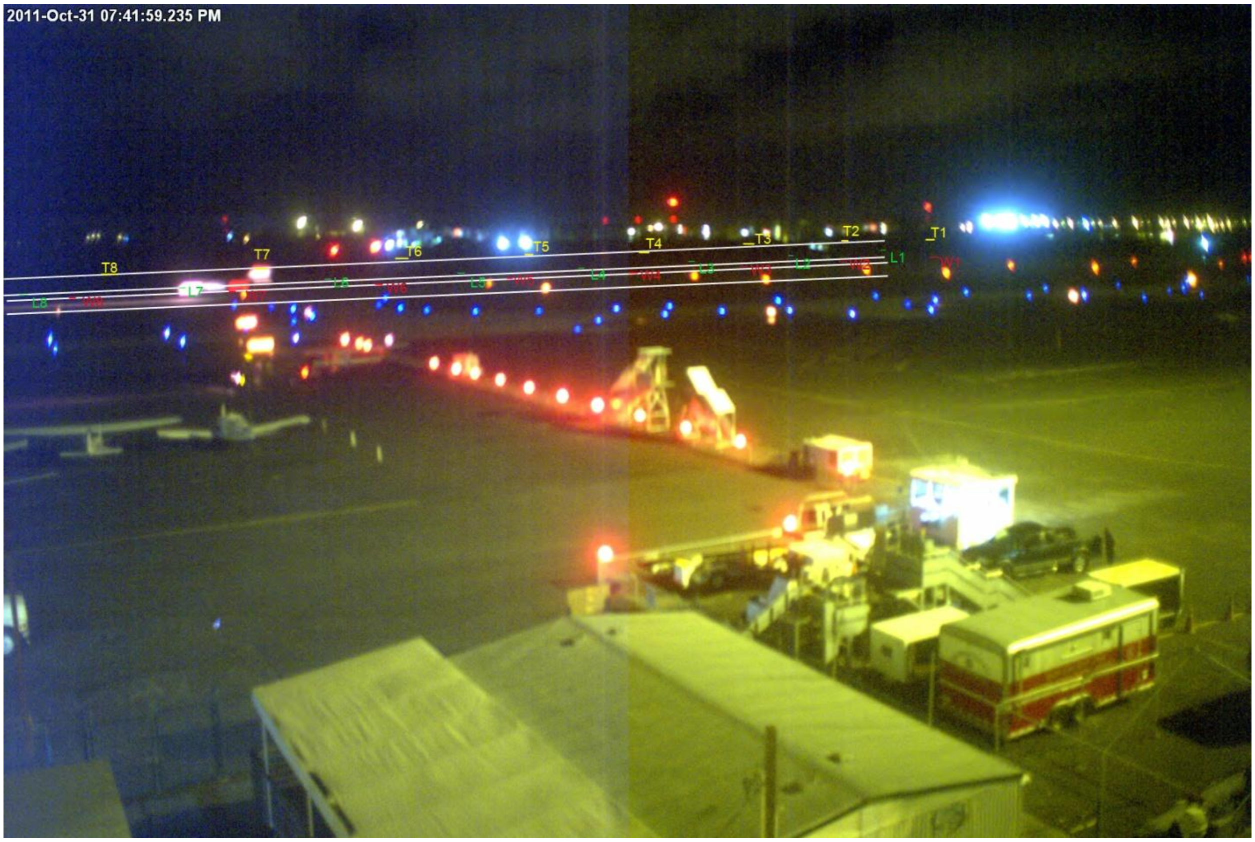

Figure 4 - References Points and Level Lines

4.2.1. Airplane Position and Estimated Ground Speed

The position of the airplane was calculated for images 6, 7 and 8. Using these 3 positions, the airplane's groundspeed was estimated between image 6 and 7, and between images 7 and 8.

Airplane position was determined by comparing the airplane to fixed geographical references that could be 1) seen in the image and 2) identified in an overhead satellite image using Geographical Information System software.

For example, if an imaginary line were drawn from the camera location through the center of the vertical stabilizer, that line would cross through the taxiway light annotated in Figure 5 below.

Figure 5 - Airplane Position

Figure 6 and 7 show the same imaginary line (in yellow) in an overhead view of the airport using Geographical Information System (GIS) software. The line runs from the camera position (located at the Air Traffic Control Tower), through the taxiway light, and extended to the runway. Assuming the airplane landed on or near the runway centerline, the position can be estimated with reasonable accuracy.

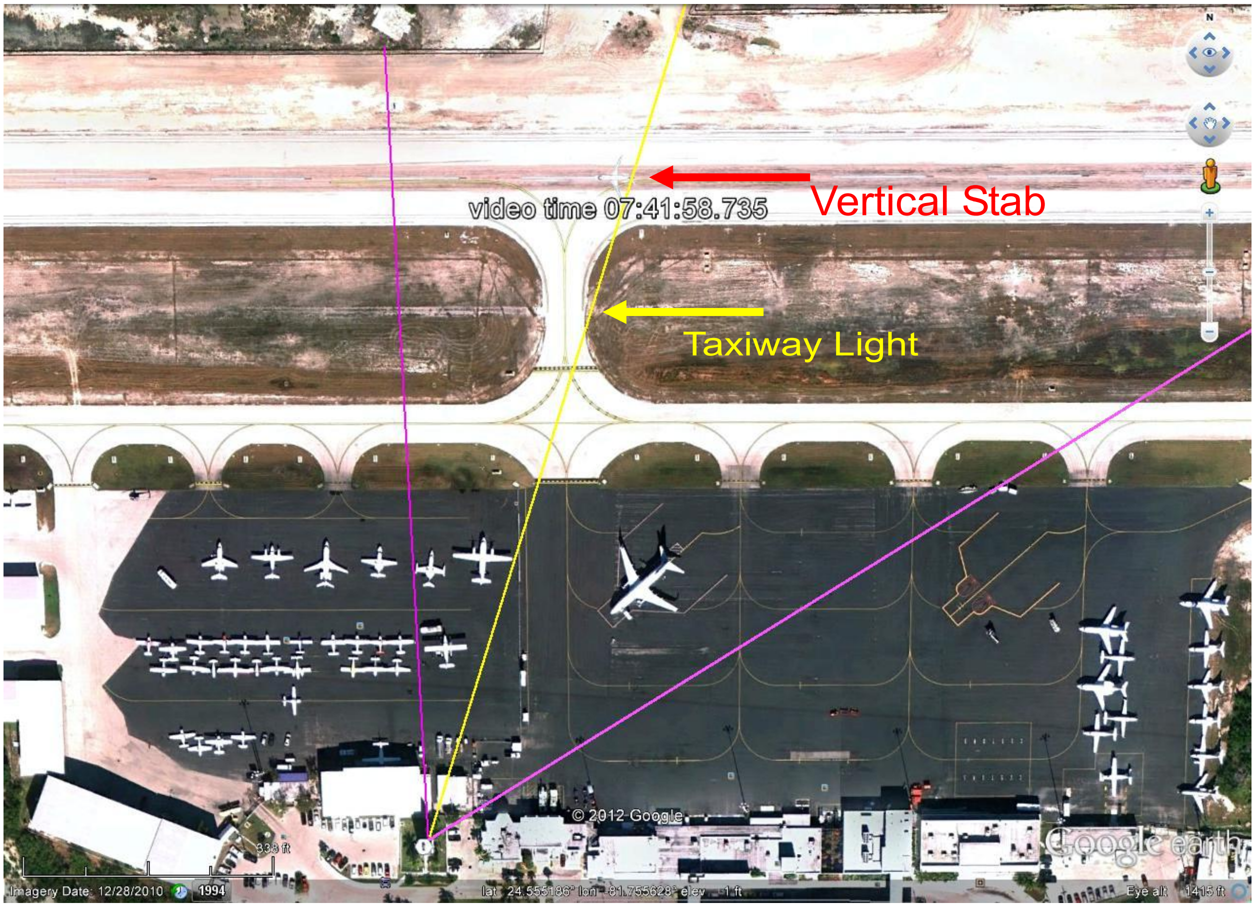

Figure 6 - Camera Line of Sight

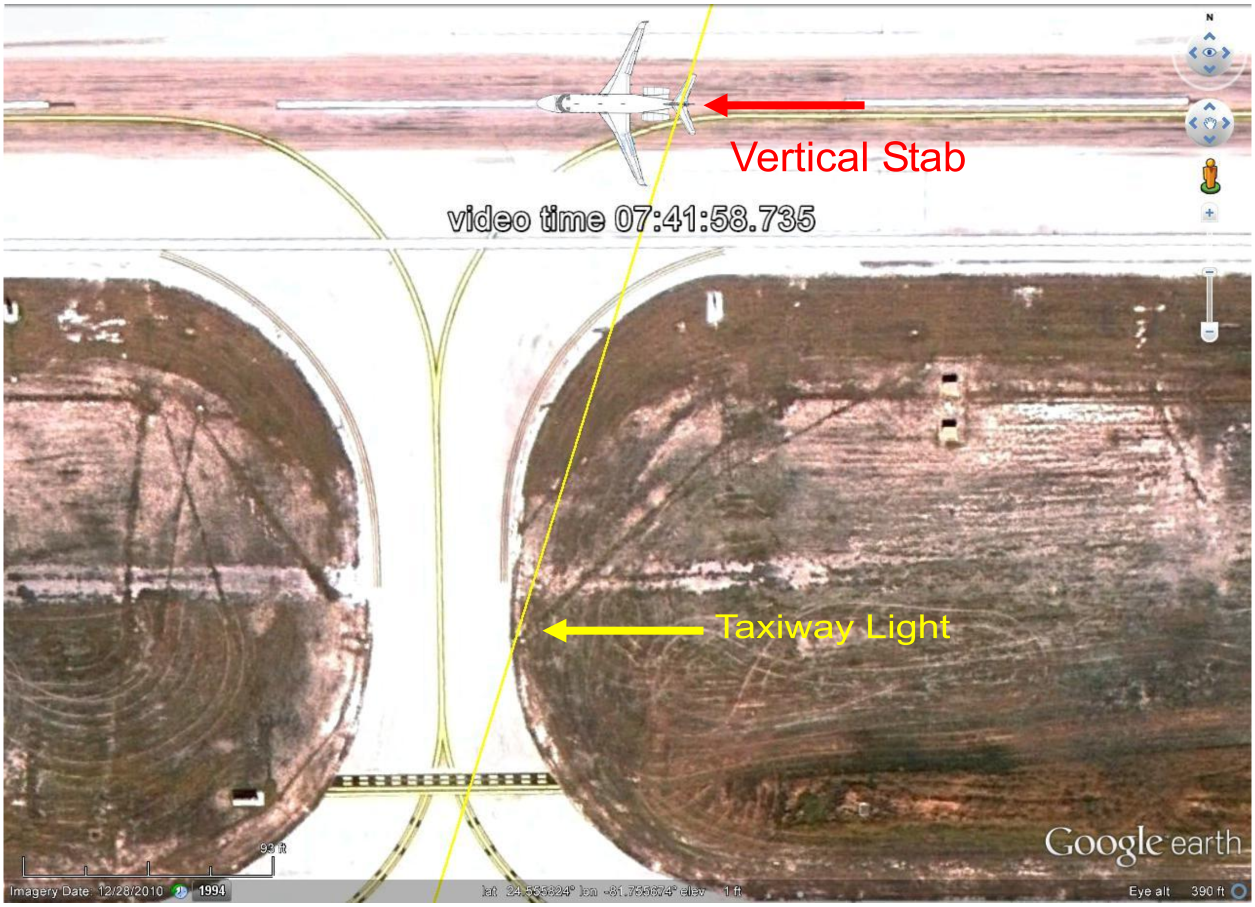

Figure 7 - Camera Line of Sight - enlarged view

Using this same procedure, the position of the airplane was determined at three different times in the surveillance video. By using the distance between these positions (measured using the GIS software) and the timing information from the video recording, the ground speed was calculated as about 119 knots averaged between position A and C.

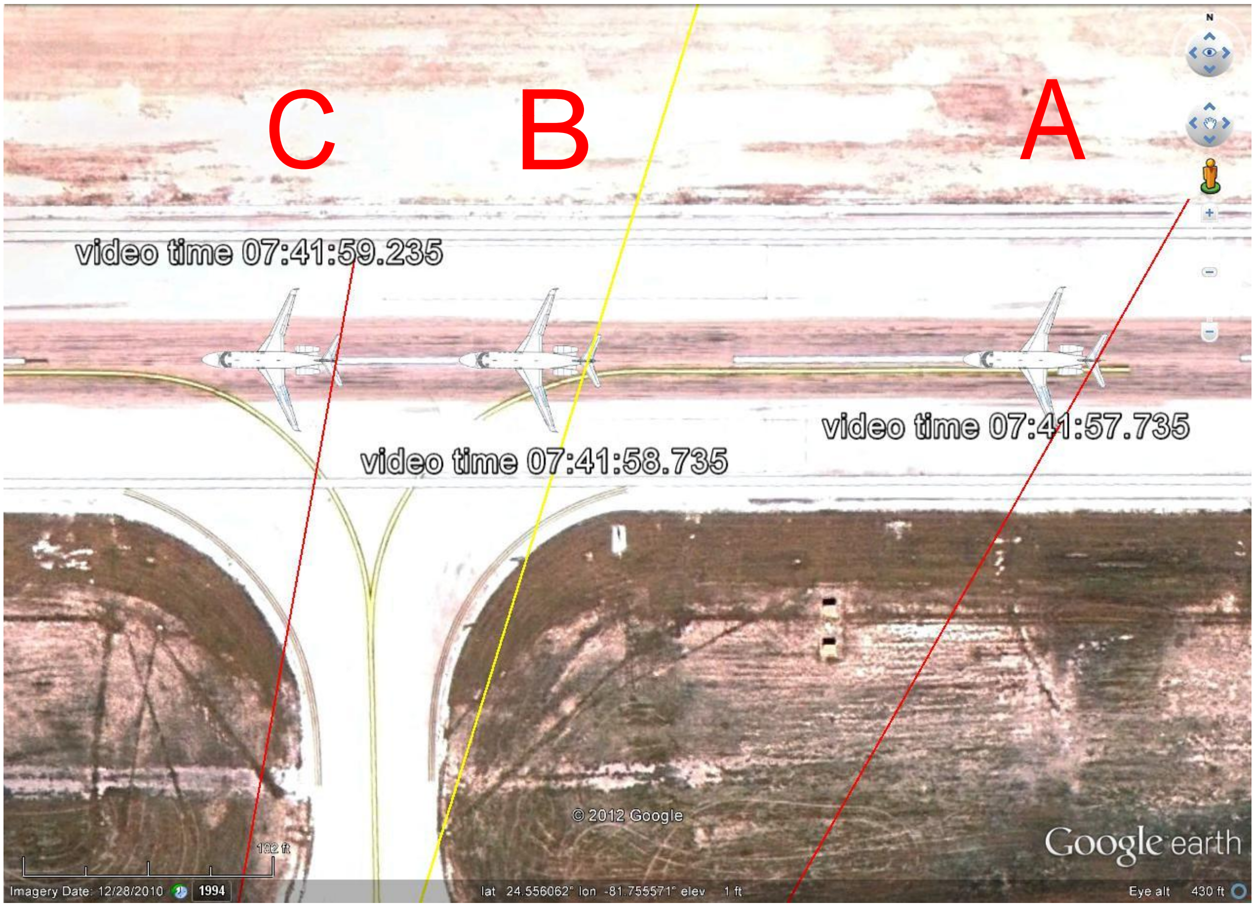

Figure 8 - Three Positions - Groundspeed Calculation

4.3. Calculation Uncertainty

The calculations for groundspeed based on the sound spectrum audio examination are most sensitive to the runway groove spacing measurements. While some uncertainty exists in the frequency measurement within the audio software, the effects are very small in comparison to the groove spacing measurement. For example, the first speed calculation of 114 knots was based on a groove spacing measurement of 1.5 inches, as was measured at 5 locations along the runway. An error of 1/16 of an inch (the smallest graduation on the ruler used for the measurement, see Attachment III) in this measurement would result in an uncertainty of about +/- 5 knots in this case.

The calculation for groundspeed based on the surveillance video information is assumed to be accurate to within about +/- 8 knots. The basic assumptions used for this calculation are:

- The airplane is on or near the runway centerline
- The timing information between successive images is perfectly accurate (time is specified to the nearest 1 millisecond)
- The calculated airplane positions were accurate to within +/- 10 feet (this yields the 8 knot uncertainty)

5. Other Information

The data presented in this report were provided to the NTSB Airplane Performance Specialist assigned to this investigation. More details and information about the landing speeds and distances are available in a separate report entitled <u>Airplane Performance Study</u> in the NTSB public docket for this investigation.

Doug Brazy
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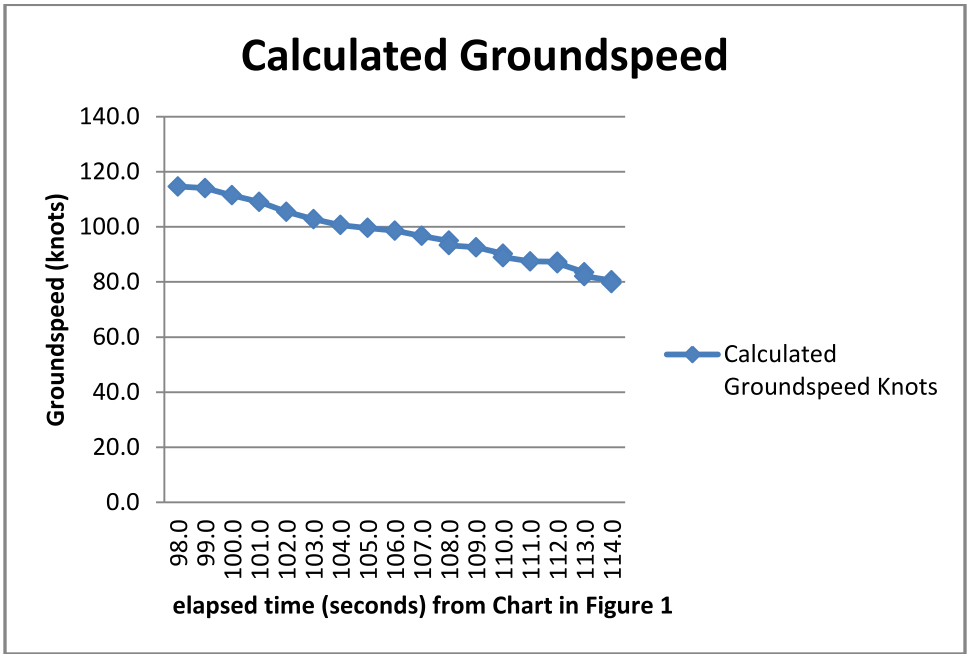
Attachment I - Sound Spectrum Data

Table of Sound Spectrum Data and Calculations

Spectrum Chart Time (Figure 1)	CVR Time (See CVR Factual Report)	Measured Frequency of Tire Noise Signature	CVR comment	Calculated Groundspeed	Calculated Groundspeed
(seconds)	Hours:Minutes:Seconds.s	Hz		inches/second	Knots
98	19:42:02.6	N/A	[Speed callout of 110 knots]		
98.2	19:42:02.8	1547.36	"[sound…similar to nosewheel on runway]"	2321	114.6
99.41	19:42:04.0	1539.66		2309	114.0
100.55	19:42:05.2	1504.19		2256	111.4
101.49	19:42:06.1	1472.6		2209	109.1
102.57	19:42:07.2	1423.4		2135	105.4
103.44	19:42:08.1	1387.78		2082	102.8
104.67	19:42:09.3	1358.37		2038	100.6
105.26	19:42:09.9	1344.58		2017	99.6
106.04	19:42:10.7	1330.79		1996	98.6
107.03	19:42:11.6	1305.17		1958	96.7
108.01	19:42:12.6	1281.53		1922	94.9
108.57	19:42:13.2	1259.85		1890	93.3
109.09	19:42:13.7	1250		1875	92.6
110.03	19:42:14.6	1218.47		1828	90.2
110.75	19:42:15.4	1200.74		1801	88.9
111.44	19:42:16.1	1181.03		1772	87.5
112.02	19:42:16.6	1179.06		1769	87.3
112.4	19:42:17.0	1171.18		1757	86.7
113.5	19:42:18.1	1127.23		1691	83.5
113.8	19:42:18.4	1108.16		1662	82.1
114.15	19:42:18.8	1087.73		1632	80.6
114.36	19:42:19.0	1074.11		1611	79.5
115.05	19:42:19.7	N/A	"[momentary decrease in sound, similar to aircraft not touching ground]"		
120.4	19:42:25.0	N/A	end of recording		

Chart of Calculated Groundspeed vs. Time



Attachment II – Surveillance Video

Table of Data Extracted from Surveillance Video

Video Timestamp	DISTANCE FROM Runway 27 Threshold	Difference (Distance Travelled)	Difference (Time)	Calculated groundspeed	Comment
HH:MM:SS.sss	(feet - measured from nose of airplane)	(feet)	(sec)	(knots)	
07:41:57.735	951				
07:41:58.735	1150	199	1.00	117.9	
07:41:59.235	1252	102	0.50	120.9	
	Overall Average:	301	1.50	118.9	average from start to finish
				7.9 (+/-knots)	Groundspeed uncertainty (based on calculated Airplane positions assuming +/- 10 foot accuracy)

Images from Surveillance Video

Image 1
07:41:56.235 PM

Image 2
07:41:56.735 PM

Image 3
07:41:57.235 PM

Image 4
07:41:57.735 PM

Image 5
07:41:58.235 PM

Image 6
07:41:58.735 PM

Image 7
07:41:59.235 PM

Image 8
07:41:59.735 PM

Attachment III
Runway Groove Measurements
(Provided by the Key West International Airport)

1) Runway
Asphalt Grooved, 4800′ x 100′

2) Groove Spacing
Continuous grooves in a lateral direction across centerline are at 1 ½ "intervals.

3) Attached are photos as requested

4) Groove Dimensions listed are at 1 ½ " intervals

	2500′	3000′	3500′	4000′	4500′
1.	¼ x ¼	¼ x ¼	¼ x ¼	¼ x ¼	¼ x ¼
2.	¼ x ¼	¼ x ¼	¼ x ¼	¼ x ¼	¼ x ¼
3.	¼ x ¼	¼ x ¼	¼ X 3/16	¼ x ¼	¼ x ¼
4.	¼ x ¼	¼ X 3/16	¼ X 3/16	¼ X 3/16	¼ X 3/16
5.	¼ x ¼	¼ x 3/16	¼ x ¼	¼ x 3/16	¼ x 3/16
6.	¼ x ¼	¼ x ¼	¼ x 3/16	¼ x ¼	¼ x ¼
7.	¼ x ¼	¼ x ¼	¼ x ¼	¼ x 3/16	¼ x ¼
8.	¼ x ¼	¼ x ¼	¼ x ¼	¼ x ¼	¼ x 3/16
9.	¼ x ¼	¼ X 3/16	¼ X 3/16	¼ x ¼	¼ x ¼
10.	¼ x ¼	¼ x ¼	¼ X 3/16	¼ x ¼	¼ x ¼

(Note: Table shows groove width x groove depth (inches) at each location along the runway)

Photo of Groove Spacing Measurement