National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

HWY23MH004

VIDEO STUDY

Specialist's Study

October 19, 2023

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A. CRASH

Location:	Williamsburg, Virginia
Date:	December 16, 2022
Time:	1:36 AM Eastern Standard Time (EST)
Truck-Tractor:	2022 Freightliner truck-tractor Combination Unit
Bus:	2000 Eldorado Bus

B. VIDEO STUDY SPECIALIST

Specialist Shane K. Lack
NTSB
Washington, DC

C. SUMMARY

Please refer to the *Crash Summary Report* which is available in the docket for this crash.

D. DETAILS OF THE ANALYSIS

1.0 Overview

The goals of this study were to estimate the speeds and the locations of the vehicles prior to the collision. Analysis is based on a video from an outside-view, forward-facing CM31 Dash Camera installed on the Freightliner truck. This video was part of a system which was to upload video footage and data to a server if an event occurred. Data was provided to the NTSB in the form of 154 video images in the MP4 format. The outside view video had a resolution of 1920x1080 and a frame rate of 30 fps. The video contained a time stamp (hour, minutes, seconds) and speed information based on the Electronic Control Unit (ECU) speed in mph.

Interstate 64 eastbound approaching the crash location has three lanes that are separated by white broken lane lines; the posted speed limit is 70 mph. As seen in the forward-facing video, both the truck and the bus were traveling in the right lane prior to the collision and the collision occurred in the right lane.

The video footage begins approximately 5 seconds prior to the collision. As indicated by Figure 1, it was dark when the crash occurred.

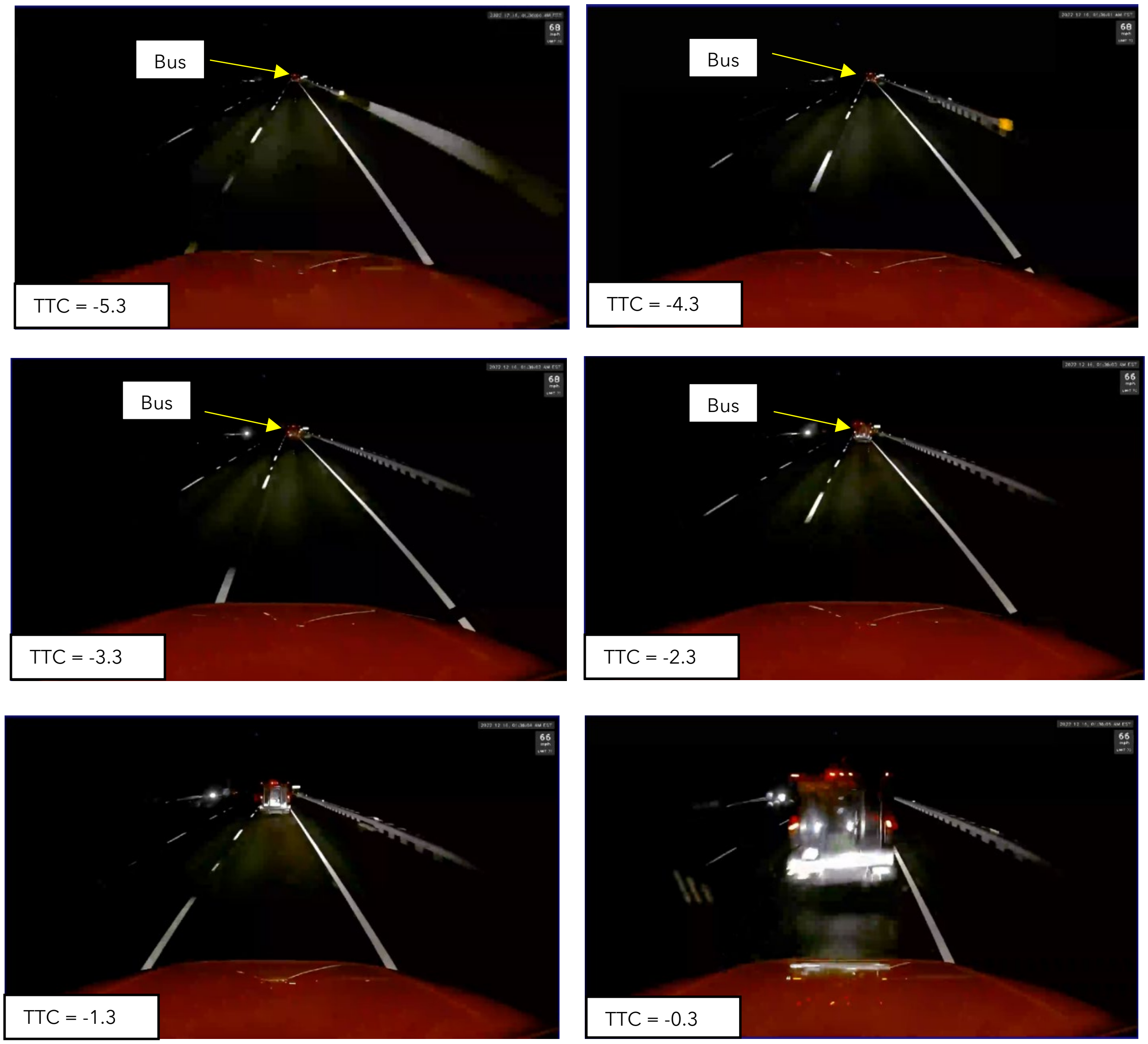


Figure 1. View from truck's forward-facing camera. Annotations indicate the time to collision (TTC) in seconds.

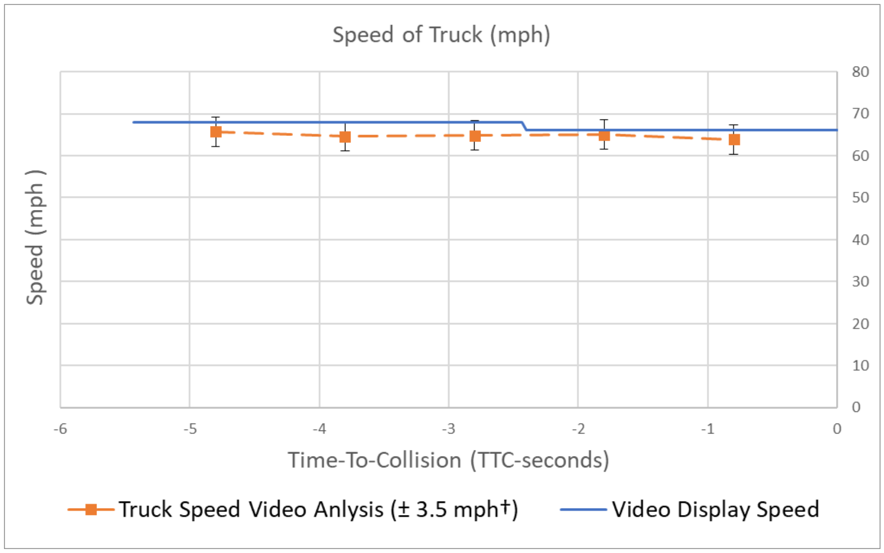
2.0 Methodology, Software and Results

The SynthEyes software (SynthEyes - Andersson Technologies LLC) was used in the study to estimate the speeds and movements of the vehicles prior to the collision. SynthEyes is a commercially available camera tracking/matchmoving software. The basic problem addressed by camera tracking software is to determine the three-dimensional location and orientation of the camera at every frame with respect to landmarks in the scene. The software uses a camera model and image features that are tracked across multiple frames to triangulate the location of image points in 3D space. The set of all triangulated points is referred to as the "solved points". The camera path is determined using non-linear least squares optimization and adjusting the camera properties, location, and orientation simultaneously over all frames to: 1) minimize the total error between the "solved points" and the survey data; and 2) to minimize the error between the "solved points" and the associated image data. The set of camera positions, orientations and properties for all frames based on the minimization is referred to as the "camera solve". The camera solve maps the 3-D survey space onto the set of 2D images from the video and can be used to show how properly scaled objects placed in the survey space would appear in the actual video. Two different mathematical lens models were used to evaluate the data in the study, the Brown-Conrady model and the SynthEyes classic camera model. Both camera models produced similar measurement results.

The software can be used to examine an image sequence from a video and determine 1) how the camera moved, 2) what the camera's angle of view was, and 3) the locations of points visible in the images relative to landmarks in the real world (3D space). SynthEyes can also be used to determine the location of objects (in the video) and how they moved in the 3D environment. Locations of points estimated with the software can be compared with survey data to determine the accuracy of measurements. For further information on the software and limitations please refer to reference manuals for the software.

Point cloud data from a drone survey conducted by the NTSB was entered into SynthEyes and used along with the image data to estimate the speed of the truck prior to the collision and develop a camera solve. Screen shots of the camera solve are shown in Figures 3 - 5. As indicated by Figure 2, the results of the video analysis indicate that the truck was traveling 66±3.5 mph about 5 seconds prior to the collision but had slowed to 64±3.5 mph prior to the collision. These results are consistent with the video display speeds which indicate that the truck had slowed from 68 to 66 mph over the last 5 seconds before the collision (see Figure 4).

Once the motion of the truck and the camera properties were estimated, the position of the bus was measured by moving a scale model of the bus along the roadway in the camera solve and comparing the predicted image size of the bus based on the camera solve to the crash video images (see Figures 5 - 7). The scale model used in the measurements was a box with the same exterior dimensions as the bus. The box was placed to coincide with the bus in the video image very close to the time of the collision, and the analysis was performed by backing up in time away from the time of collision. The box was moved backward at a constant rate; if the box appeared larger than the bus in the image then the box was moving at a faster average speed than the bus in the final seconds before the collision. Table 1 shows the average speed of the bus calculated during segments measured by the time to collision (TTC). As indicated by Table 1, the results of this analysis indicate that the average speed of the bus over the last 4 seconds prior to the collision was 25±5 mph and the average speed of the bus over the last two seconds prior to the collision was 20±5 mph.



† Uncertainty is measured over 1 second

Figure 2.

Table 1. Estimates of average speeds of the bus.

Time over which speed was averaged (TTC (sec))	Measured Average Speed
-4.3 to -0.3	25 ± 5 mph
-3.3 to -0.3	25 ± 5 mph
-2.3 to -0.3	20 ± 5 mph

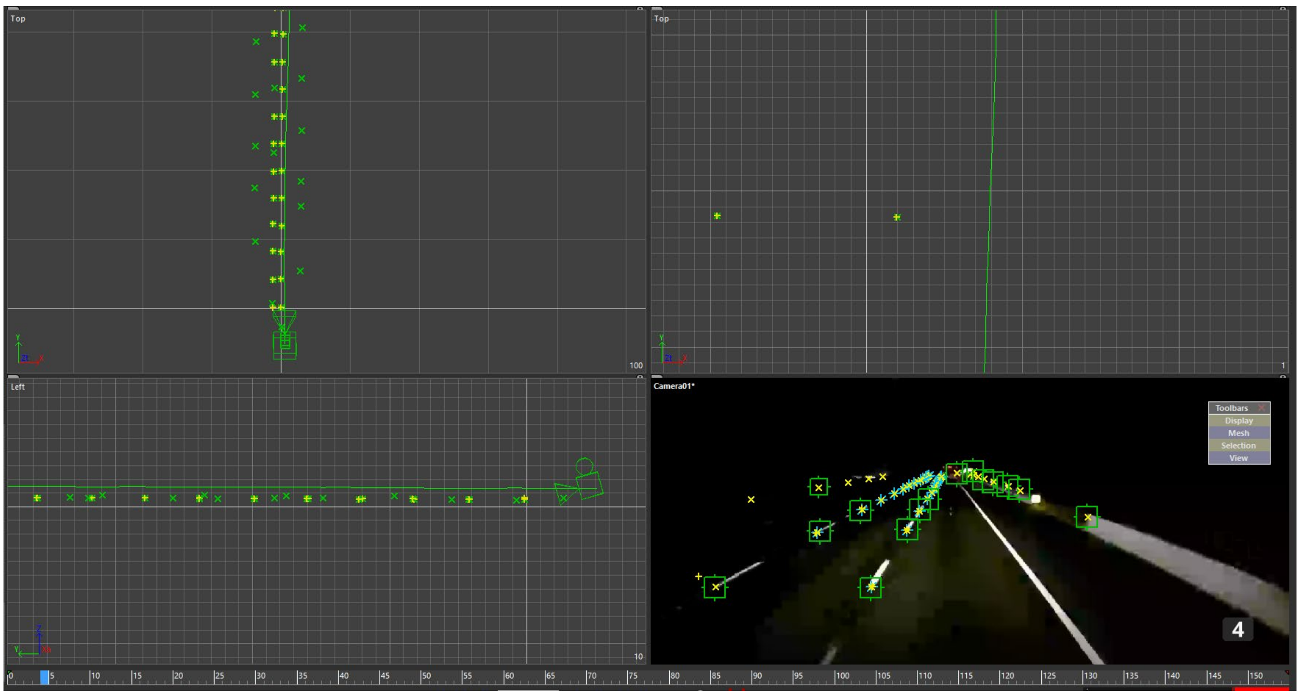


Figure 3. A screen shot of the camera tracking result. The solved points (triangulated) are indicated by the green and yellow x's. The survey data is indicated by the yellow plus signs. The tracked image features are indicated by the green squares in the 2D image on the lower right. The green line indicates the solved path of the camera. SynthEyes optimizes the camera path by adjusting the camera parameters, position, and orientation simultaneously over all frames to minimize the 1) error between the solved points and the survey data, and 2) the error between the solved points and the tracked points in the images.

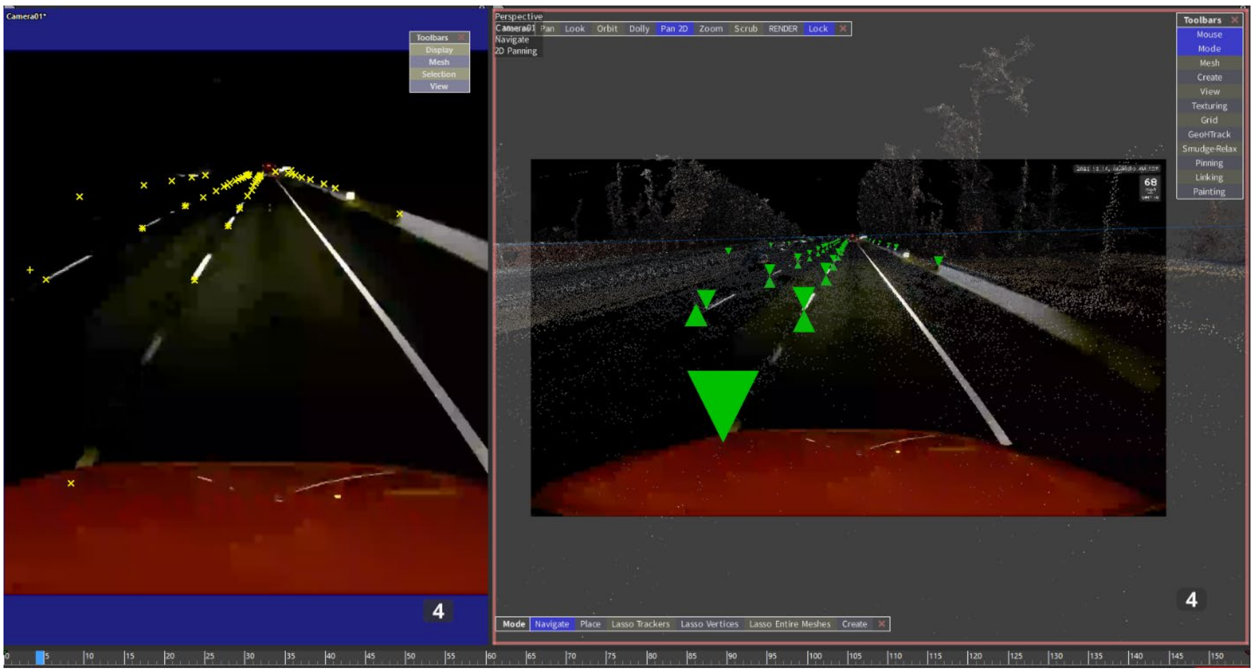


Figure 4. A screen shot of the camera solve results. The image on the right shows the 3D drone survey data mapped on to the image on the left using the camera solve. As indicated by the close alignment of the upward and downward green triangles in the image on the right, the 3-D survey data closely matches the image data.

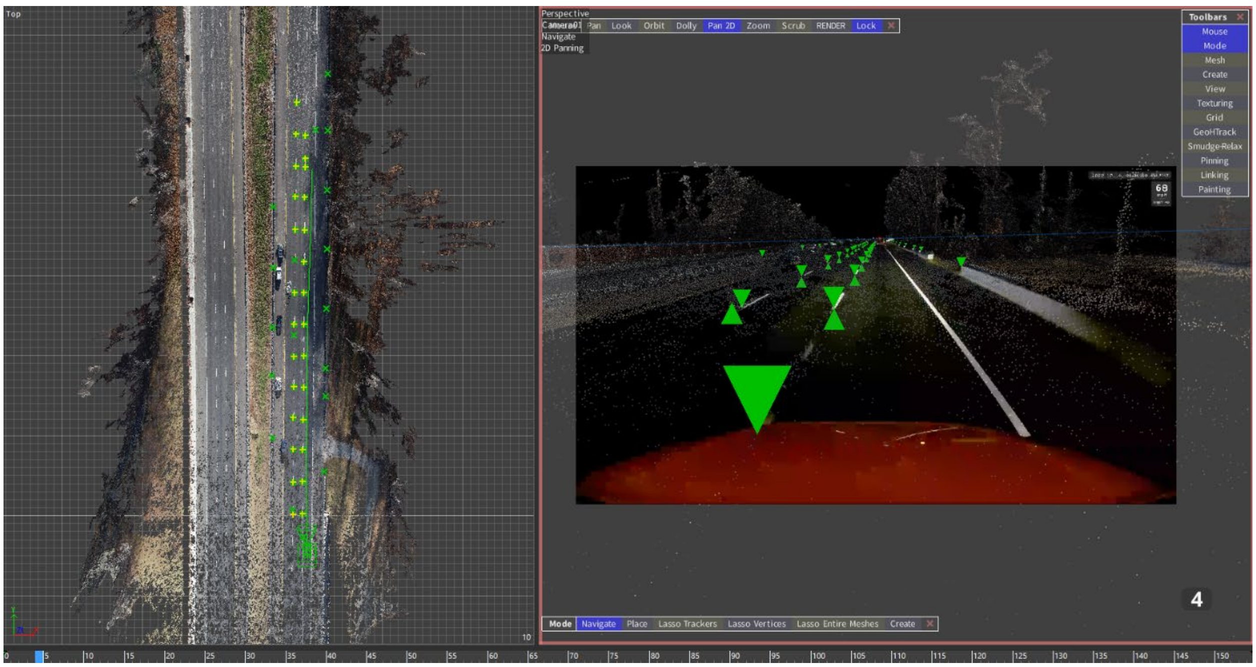


Figure 5. Another screen shot of the camera solve. The image on the left shows an overhead shot of the 3D drone survey data used in the solve. The image on the right shows the 3D drone survey mapped onto a 2D video image using the camera solve.

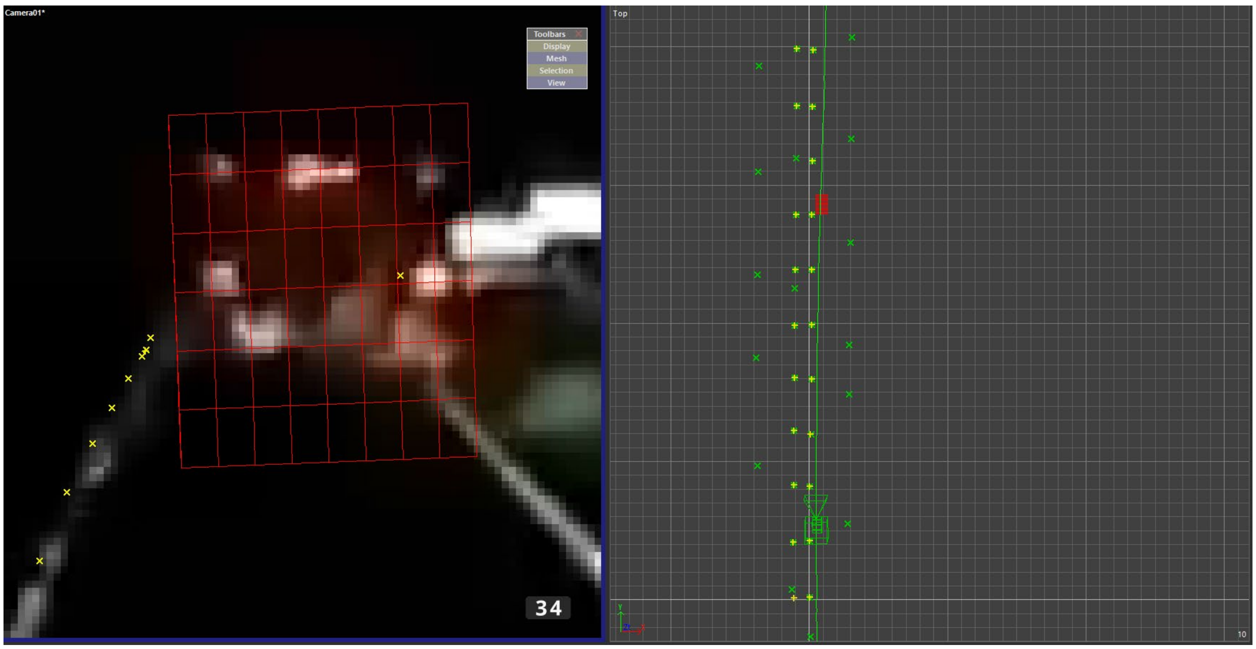


Figure 6. The video image on the left shows the bus approximately -4 seconds prior to the collision (image is zoomed). The red box represents the size the bus would have appeared in the video had it averaged 30 mph over the last 4 seconds prior to the collision based on the camera solve (shown on the right). That the video image is smaller than the red box indicates that the bus was traveling at an average speed of less than 30 mph over the last 4.0 seconds prior to the collision.

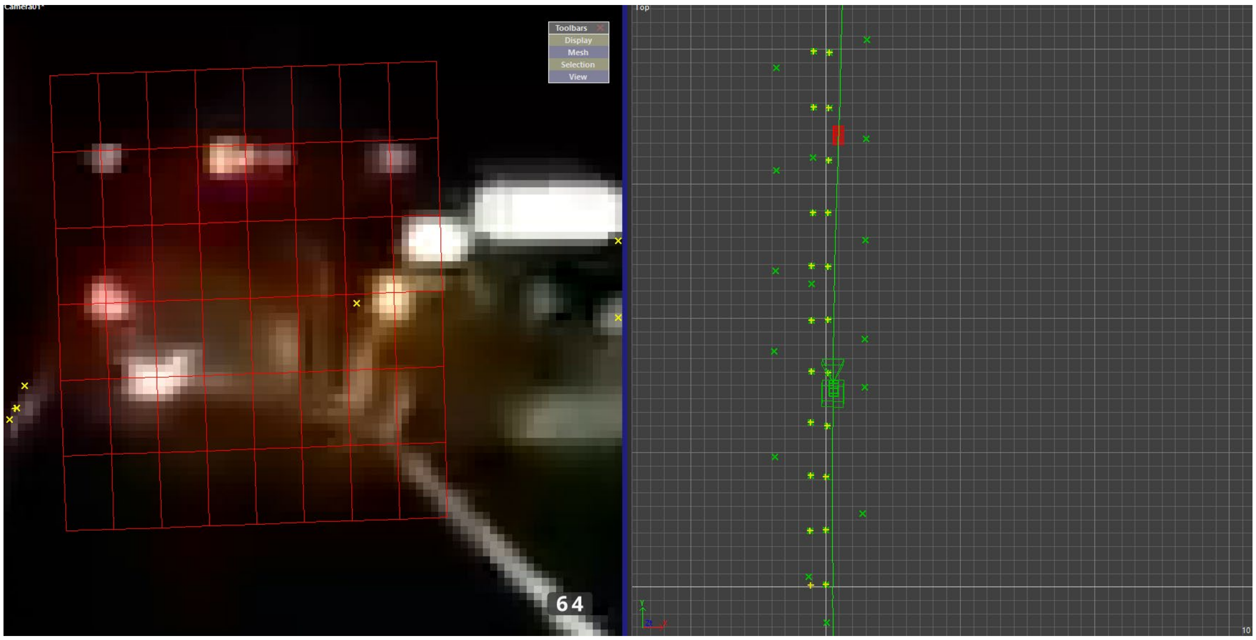


Figure 7. The video image on the left shows the bus approximately -3 seconds prior to the collision (image is zoomed). The red box represents the size the bus would have appeared in the video had it averaged 30 mph over the last 3 seconds prior to the collision based on the camera solve (shown on the right). That the video image is smaller than the red box indicates that the bus was traveling at an average speed of less than 30 mph over the last 3.0 seconds prior to the collision.

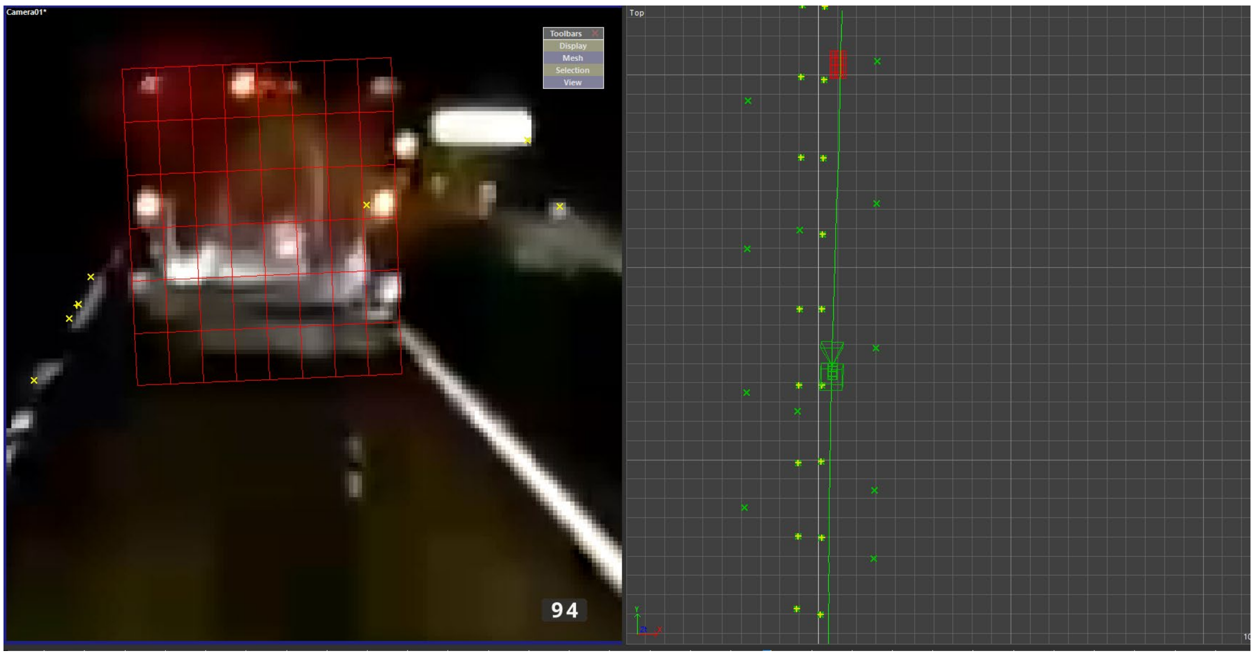


Figure 8. The image on the left shows the bus approximately -2 seconds prior to the collision (image is zoomed). The red box represents the size the bus would have appeared in the video had it averaged 20 mph over the last 2 seconds prior to the collision based on the camera solve (shown on the right). That the video image is similar in size to the red box indicates that the bus averaged approximately 20 mph over the last 2.0 seconds prior to the collision. Additional measurements used to quantify the uncertainties indicated an average speed of 20±5 mph over the last 2 seconds before the collision.

3.0 Survey Data and Uncertainties

A comparison of the survey data, the solved points and the estimated error for the camera solve is shown in Figure 9. As indicated by the data in the table, the maximum error for the solved points was 0.10 feet with an average error of 0.08 feet for all points. The accuracy in locating points on the drone survey was estimated to be ±1.0 feet. The error associated with the regression curves used to estimate the speed of the truck's camera (two standard error) was ±1.4 feet.

SynthEyes measures the error in the image space in Horizontal Pixels (HPIX). The overall HPIX error for this project was 2.3 HPIX which according to the software documentation is within acceptable ranges for this type of project given the accuracy of the survey data. (The error in the 2D image space is the difference between the solved point in the 2D image and the location of the image feature measured in HPIX. The overall HPIX is the RMS error of the HPIX for all points.)

Figure 9. Comparison of survey data with SynthEyes results and error (screen shot).

	Survey Data				Solved Position			
Pt #	X(ft)	Y(ft)	Z(ft)		X'(ft)	Y'(ft)	Z' (ft)	Error(ft)
#27	x=-10.916	y=82.9039	z=5.77405		-10.989	82.879	5.706	0.103
#10	x=0.480625	y=82.069	z=5.02826		0.517	82.080	5.098	0.079
#9	x=1.08589	y=119.635	z=5.69178		1.163	119.640	5.685	0.078
#28	x=-11.5769	y=41.7235	z=5.30553		-11.516	41.747	5.329	0.069
#8	x=1.75352	y=159.406	z=5.74457		1.688	159.399	5.743	0.066
#30	x=3.65777	y=446.27	z=6.80831		3.698	446.284	6.853	0.062
#1	x=3.52166	y=435.397	z=6.78504		3.504	435.386	6.754	0.037
#21	x=-10.2226	y=238.855	z=6.37358		-10.196	238.860	6.350	0.036
#12	x=0.461158	y=1.67715	z=5.49422		0.435	1.669	5.473	0.035
#7	x=1.69761	y=198.968	z=6.03432		1.699	198.962	6.002	0.033
#15	x=-7.49066	y=476.217	z=7.07594		-7.523	476.210	7.076	0.033
#20	x=-9.53413	y=278.42	z=6.34334		-9.563	278.418	6.354	0.031
#2	x=3.09212	y=397.404	z=6.58127		3.069	397.399	6.574	0.025
#11	x=0.456626	y=42.5033	z=5.2557		0.434	42.498	5.246	0.025
#24	x=-10.3084	y=198.427	z=5.97009		-10.298	198.434	5.991	0.025
#18	x=-9.05857	y=357.032	z=6.49914		-9.047	357.039	6.517	0.023
#6	x=1.85745	y=238.613	z=5.95379		1.837	238.610	5.962	0.023
#35	x=3.8496	y=475.063	z=6.97233		3.853	475.062	6.951	0.021
#16	x=-8.17419	y=436.093	z=6.88687		-8.167	436.099	6.903	0.018
#3	x=2.63047	y=356.648	z=6.39011		2.644	356.649	6.399	0.017
#26	x=-11.1917	y=122.433	z=5.47226		-11.191	122.434	5.486	0.014
#17	x=-8.82097	y=398.646	z=6.7134		-8.814	398.647	6.703	0.013
#14	x=-7.2306	y=515.837	z=7.22597		-7.230	515.837	7.214	0.012
#25	x=-10.5119	y=160.353	z=5.83744		-10.514	160.357	5.848	0.011
#5	x=1.95696	y=278.341	z=6.07654		1.968	278.339	6.078	0.011
#4	x=2.30605	y=317.237	z=6.24292		2.308	317.234	6.242	0.004
#29	x=-11.119	y=1.33031	z=6.56592		-12.532	7.575	4.678	0.000

E. DISCUSSION

The results of the video analysis described in this report indicate the average speed of the bus over the last 4 seconds prior to the collision was 25±5 mph and the average speed of the bus over the last 2 seconds prior to the collision was 20±5 mph. The results of the video analysis indicate that the truck was traveling 66±3.5 mph about 5 seconds prior to the collision but had slowed to 64±3.5 mph prior to the collision. The posted speed limit is 70 mph. The results of the measurements of the truck's speed are consistent with the video display speeds which indicate that the truck had slowed from 68 to 66 mph over the last 5 seconds before the collision.

Submitted by:

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