NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

March 25, 2014

Video Study

Specialist's Video Study
By Sean Payne

1. EVENT

Location: Mt. Vernon, WA
Date: May 23, 2013, 07:05 P.M. (PDT)
NTSB Number: HWY13MH012

2. GROUP

A group was not convened.

3. SUMMARY

On Thursday, May 23, 2013, about 7:05 p.m. Pacific daylight time, a 2010 Kenworth truck tractor with a 1997 Aspen flatbed trailer hauling an oversize load was traveling south on Interstate 5 near Mount Vernon, Washington. The oversize load was permitted for the route of travel and was following a 1997 Dodge Ram escort[1] vehicle. The oversize load struck the Skagit River Bridge, deforming the overhead sway brace, and span 8 of the 12-span through truss bridge structure collapsed into the Skagit River. The truck-tractor and oversize load passed under the truss structure and came to a stop south of the bridge. Two passenger vehicles, a southbound 2010 Dodge Ram pickup truck towing a Jayco travel trailer and a northbound 2013 Subaru VX Crosstrek, approaching the bridge at the time of the collapse fell with the collapsing bridge span into the Skagit River. Two other vehicles were damaged during the event: a 2000 Kenworth truck tractor with a 1996 utility refrigerated trailer in the southbound passing lane was struck by the oversize load, and a southbound 1995 BMW 525i following the oversize load received undercarriage damage. Nine people were involved in the bridge collapse, three received minor injuries, and six were uninjured.

[1] The terms "pilot vehicle" and "escort vehicle" are used synonymously in the transport industry to refer to a vehicle that accompanies an oversize load and ensures that its dimensions will pass roadway features without incident. This memorandum will use both terms when referring to this vehicle.

4. DETAILS OF INVESTIGATION

The NTSB Vehicle Recorder Division's Image Laboratory received multiple image files from a variety of recording devices:

Type:	Security Video
Operator:	Car Dealership
System Type:	Dropcam
Filename:	Skagit River Bridge Collapse on Camera.mp4
Type:	Security Video
Operator:	Big Box/Grocery Store
System Type:	Unknown
Filename:	ROOFTOP20_5.23.2013.19.0.0_5.23.2013.19.12.0_2
Type:	Dashboard Camera
Operator:	Washington State Police
System Type:	Coban Technologies
Filename:	1224@20130523185509.mpg

4.1. Recorder Description

Dropcam

Dropcam is a Wi-Fi enable security camera that allows customers to record and store images to a Cloud Video Recording[2] system. The Dropcam records at a resolution of 1280 by 720 pixels at a variable recording rate up to 30 frames per second. The recording rate is dependent upon the amount of light available and the amount of motion detected. The camera's lens has a 107 degree field of view and the ability to digitally zoom up to 4x magnification.

Coban Dashboard Camera

Coban is a manufacturer or in-car video systems for law enforcement. The system is designed to be mounted inside police cruisers and capturers a forward looking view of the roadway in front of a patrol car. The system includes a method of video storage and retrieval. The system's specifications are dependent upon what options the law enforcement agency selects when installing the system.

4.1.1. Video Files

Two security camera files entitled "Skagit River Bridge Collapse on Camera.mp4" and "ROOFTOP20_5.23.2013.19.0.0_5.23.2013.19.12.0_2" and one dashcam patrol car video "1224@20130523185509.mpg" were sent to the Vehicle Recorder Laboratory.

[2] Cloud Video Recording – A method of storing surveillance video that utilizes a cloud based, or offsite internet accessible, storage location. Customers subscribe to a service that stores video images for an agreed upon amount of time before they are deleted.

“Skagit River Bridge Collapse on Camera.mp4”

This recording was obtained from a Dropcam located at a nearby car dealership. Metadata shows it was captured at a frame rate of 25.92 fps[3] and resolution of 1280 by 720 pixels. It shows a view of car dealership sales lot with light poles and structures. In the distance the I-5 Bridge in Skagit is visible. The video exhibits significant barrel distortion[4]. The video also does not exhibit the widest possible field of view of 107 degrees which is standard for a Dropcam. This clip has a field of view of approximately 55 degrees, indicating that an unknown amount of digital zoom was utilized. It is 42 seconds and 10 frames in length.

The video begins with traffic passing normal in both directions along the Interstate 5 bridge near Skagit. At 34 seconds and 11 frames[5], the cab end of the Accident Combination Unit (ACU) becomes visible behind a light pole. The ACU is traveling southbound on Interstate 5. At 35 seconds and 09 frames, a tractor trailer begins to overtake the ACU. At 36 seconds and 23 frames, portions of the overtaking tractor trailer appear to be seen through the open side of the ACU’s load. At 39 seconds and 03 frames, the ACU’s cab appears to have entered the area immediately preceding the trussed bridge area. At 40 seconds and 19 frames, the first indication of contact with the ACU’s load and the bridge superstructure is noted. At 41 seconds and 03 frames a noticeable distortion in the bridge’s superstructure can be noted. At 41 seconds and 12 frames, the bridge superstructure can be seen falling behind the ACU as it continues to travel southbound. At 41 seconds and 21 frames the roadway appears to be deforming. At 42 seconds and 07 frames, a box truck appears to be traveling over the deformed roadway. At 42 seconds 08 frames image data is lost. At 42 seconds and 10 frames the recording ends.

[3] FPS – Frames per Second – The numbers of individual frames displayed in the video recording per second of video.

[4] Barrel Distortion – The appearance of magnification similar to as if the image was being mapped around a sphere.

[5] All frames a referenced in a 30 frame per second timeline regardless of the rate at which the video was recorded.

Image 4.1: A screen capture of Skagit River Bridge Collapse on Camera.mp4*.*

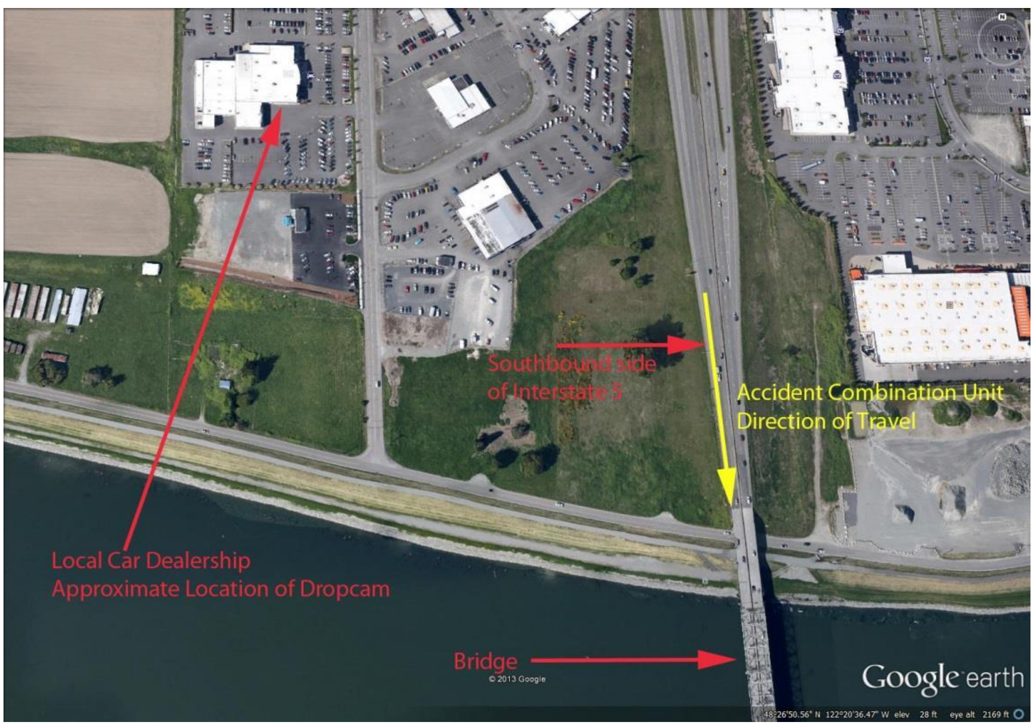

Fig 4.2: A north-up diagram of the location of the Dropcam at a local car dealership.

“ROOFTOP20_5.23.2013.19.0.0_5.23.2013.19.12.0_2”

Image 4.3: A screen capture of “ROOFTOP20_5.23.2013.19.0.0_5.23.2013.19.12.0_2”

Figure 4.4: A north-up diagram of the location of the security video at the Big Box/Grocery store

"1224@20130523185509.mpg"

This recording was obtained from the dashboard camera of a Washington State Police patrol car. Metadata shows it was captured at a frame rate of 29.97 fps and resolution of 720 by 480 pixels. It shows a forward looking view of a highway patrol car as it travels along Interstate 5 and some additional nearby roadways. It is 6 minutes 17 seconds and 26 frames in length.

The video begins as the patrol car is entering an onramp for Interstate 5 North. At 0 minutes 0 seconds and 13 frames a timestamp of "May23 2013 06:55:11PM" is displayed and continues to flash every 3 seconds for the duration of the recording as it updates. At 0 minutes 06 seconds and 16 frames, a message of "IGN ON" is displayed in the upper right hand corner of the recording. At 0 minutes 10 seconds and 05 frames "IGN ON" disappears from the recording. At 0 minutes 23 seconds and 10 frames, the patrol car completes merging onto Interstate 5 and continues to travel northbound. At 1 minute, 03 seconds and 25 frames, the patrol car passes exit 226 on the northbound side of Interstate 5. At 2 minutes 17 seconds and 06 frames, the patrol car passes exit 227 northbound on Interstate 5. At 03 minutes 03 seconds and 17 frames, the patrol car enters under the trussed area of the Interstate 5 bridge in Skagit. At 03 minutes 10 seconds and 10 frames the patrol car passes out from under the trussed area of the Interstate 5 bridge. At 03 minutes 23 seconds and 20 frames, the patrol car passes exit 229. At 04 minutes 24 seconds and 21 frames, the patrol car passes exit 230. At 05 minutes 13 seconds and 05 frames, the flashing light of the pilot vehicle becomes visible on the southbound side of Interstate 5 as the patrol car rounds a bend in Interstate 5 North. Ten frames later the ACU becomes visible behind an exit sign traveling southbound on Interstate 5. At 05 minutes 17 seconds and 06 frames, the pilot vehicle begins to cross out of the dashcam's field of view. Around 05 minutes 18 seconds and 10 frames, a maroon cab tractor trailer becomes visible behind a light pole. This vehicle is behind the ACU and is traveling southbound on Interstate 5. At 05 minutes 19 seconds and 06 frames, the ACU begins to pass out of the Dashcam's field of view. Around 05 minutes 22 second and 05 frames, a green cab tractor trailer becomes visible in the southbound land of Interstate 5. At 05 minutes 22 second and 19 frames, the patrol car enters the exit lane for exit 231. 8 frames later the maroon cab tractor trailer begins to pass out of the Dashcam's field of view. At 05 minutes 25 seconds and 15 frames, the green cab tractor trailer passes out of the dashcam's field of view. At 05 minutes 45 seconds and 04 frames the patrol car exits Interstate 5 entirely. Nothing else of interest is captured on the dashcam and the recording ends at 06 minutes 17 seconds and 26 frames.

Image 4.5: A screen capture of the patrol car video showing the Accident Combination Unit (ACU) in file 1224@20130523185509.mpg”.

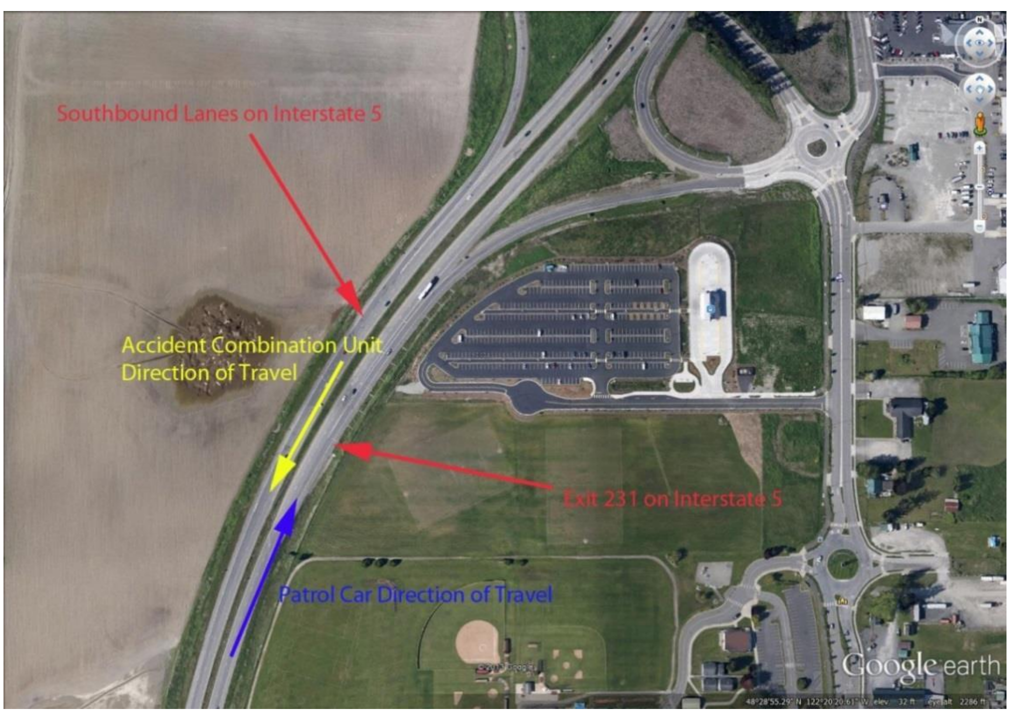

Figure 4.6: A diagram of the location of the patrol car in the vicinity of exit 231 on Interstate 5.

4.2. Timing and Correlation

Due to the precise timing requirements to conduct this video study, the time of events are expressed as Video Elapsed Time in a reference frame unique to each of the respective recordings. This measurement of video elapsed time is the time from the beginning of the recording measured in whole seconds and carryover frames.

The car dealership's Dropcam file was provided in a 25.92 frame per second time base, which makes it possible to correlate frame count as a function of time in hundredths of a second. For this study, a singular video frame from the car dealership's Dropcam aligns to .0386 seconds of elapsed time as calculated in the equation below. This value becomes important when using the frame count as a way to determine the Accident Combination Unit's speed across the image plane.

$$\left(\frac{1sec}{25.92\ frames}\right) = 0.0386\ sec/frame$$

When examined in non-linear video editing software[6], times are read in a 30 frame per second time base. The time for a singular video frame in a 30 frame per second time base is shown in the equation below.

$$\left(\frac{1sec}{30\ frames}\right) = 0.0\overline{3}\ sec/frame$$

No attempt was made to align the three videos with each other as sufficient information was not available.

4.3. Video Study

4.3.1. Image Calibration:

To conduct an analysis of the accident combination unit's average speed during the moments immediately preceding contact with the bridge's structure, calibration data must be collected of the interstate highway as it relates to perspective of the Dropcam at the car dealership. This calibration data is used as a basis for both a software motion tracking analysis and alternatively, a manual distance over time comparison.

For a manual distance over time calculation of the vehicle's average speed, the location of the camera is identified and landmarks in the foreground are plotted. Rays are then drawn from the camera's location through the landmarks and subsequently across the interstate. Distance is measured along the interstate highway where each ray intersects the accident vehicle's lane of

[6] Non-Linear Video Editing Software – A software method of editing video material without destroying or altering the original video source

travel. As the accident vehicle passes each landmark, the time in the recording is noted. Knowing the overall distance traveled and the time in which it takes the accident vehicle to cover the known distance, an average speed can be calculated for the accident vehicle.

4.4. Distance/Position Study – Manual Solution:

"Skagit River Bridge Collapse on Camera.mp4"- Dropcam

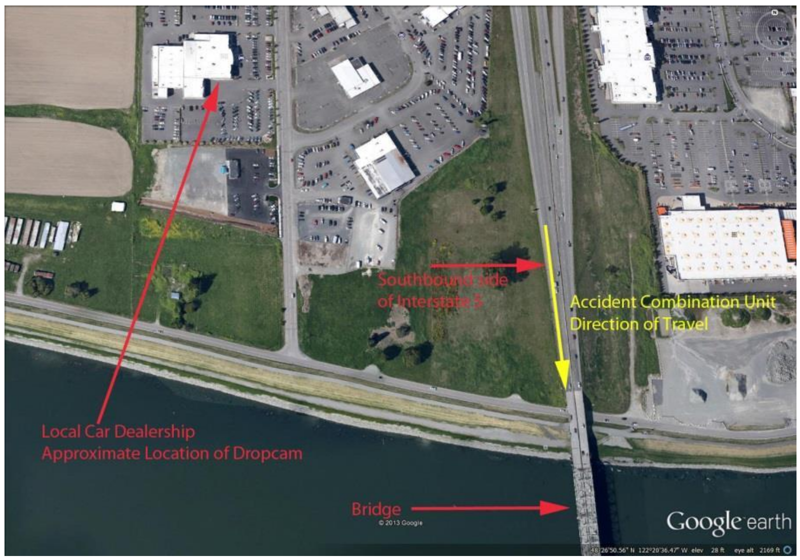

Figure 4.7: The camera's position translated to Google Earth.

In order to create an equation to calculate the vehicle's groundspeed while traveling in the right lane of Southbound Interstate 5, known points must be identified from the car dealership's Dropcam file and translated to a mapping program. The video was provided in a resolution of 1280 by 720 pixels which provided adequate fidelity to identify key landmarks. Additionally, to aid in landmark identification, the car dealership was able to provide images from a handheld camera of higher resolution. The provided photo was oriented in the same manner as the Dropcam. This image was used to help with landmark correlation and is shown below in Image 4.8.

Image 4.8: A daylight view of the approximate perspective of the car dealership's Dropcam.

The recorded images showing the accident sequence are then examined to find reference points common to both the recorded video and a geographical reference source. To accomplish this, the daylight image of the Dropcam camera perspective was compared to screen capture from the accident recording.

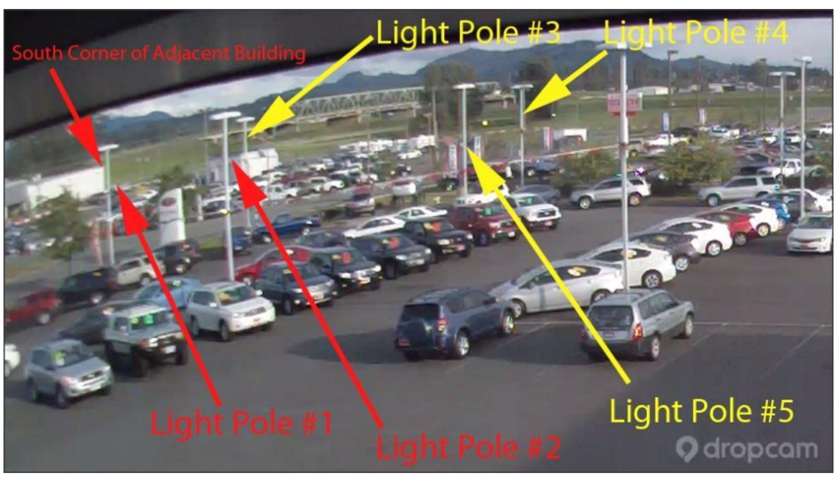

Image 4.9: A screenshot of the accident video with five light poles identified.

Five light poles were identified and then translated to a mapping source. These points were labeled #1 through #5 for future reference. With each identified light's position determined on the geographic mapping source, a line of perspective can be drawn from the camera's estimated location through each identified point.

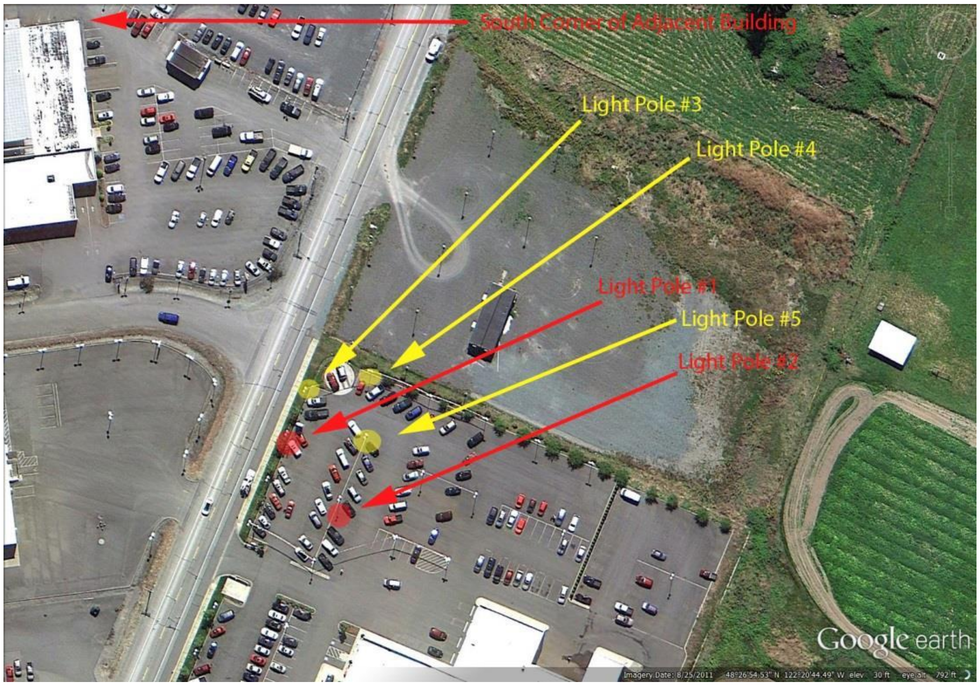

Figure 4.10: A screenshot from Google Earth with two light poles identified and translated onto a geographic reference base.

Knowing the estimated camera position, Point “C”, lines of sight were then drawn to create a series of rays. These two rays, Ray C1 and Ray C2, extend from Point C through each light pole #1 and #2. The rays were then extended to cross the Interstate 5 so a point to point distance on the Interstate’s southbound outer most lane could be calculated using only the existing camera perspective.

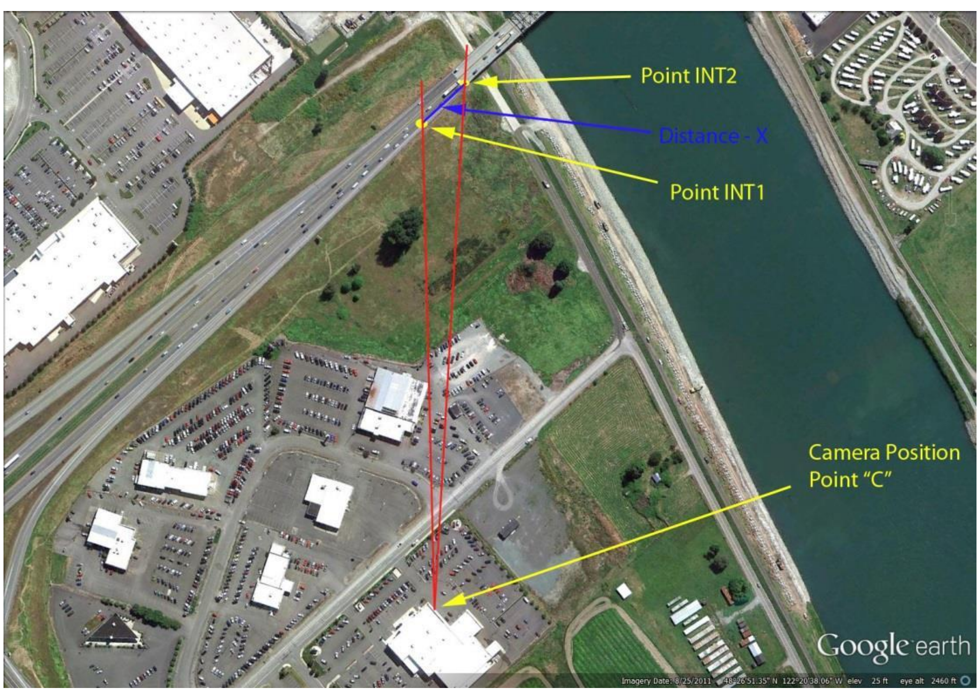

Figure 4.11: The two rays extending from Point C through each street light.

The screenshot with the generated geometric reference was then recreated in the original mapping software.

Figure 4.12: The geometric properties of the landmark translation exercise recreated in the mapping software so measurements can be obtained.

Measuring the distance on the center of Interstate 5's outermost southbound lane that intersects ray C1 and C2 is possible by utilizing a distance measurement tool on the mapping software. Two points INT1 and INT2 were created using this method. The distance is outputted and was found to be 236 feet. The measurement will later be used to calculate the average groundspeed of the accident combination unit between points INT1 and INT2.

The time in which it took the Accident Combination Unit to move between each of these geometric reference points was then determined. To accomplish this, Light Pole #1 and #2 were imagined as virtual checkpoints that were assumed to extend perpendicularly from the parking lot's surface. From the camera's perspective, Light Pole #1 and #2 create a vertical line which intersects the southbound lanes of Interstate 5 in the background. It is then possible to utilize these two positions as a checkpoint so a time measurement can be made as the Accident Combination Unit travels between Light Pole #1 and #2.

Image 4.13: Vertical lines from light pole positions1 and 2 are used to indicate when the Accident Combination Unit crossed each segment from point INT1 to INT2 on the centerline of the outermost lane of Interstate 5 southbound. Here, the Accident Combination Unit is seen at point INT1, a checkpoint using Light Pole #1 as a reference position. The indicated video time is 34 seconds and 11 frames.

Image 4.14: Vertical lines from light pole positions1 and 2 are used to indicate when the Accident Combination Unit crossed each segment from point INT1 to INT2 on the centerline of the outermost lane of Interstate 5 southbound. Here, the Accident Combination Unit is seen at point INT2, a checkpoint using Light

Pole #2 as a reference position. The indicated video time is 37 seconds and 02 frames.

The ACU is shown moving frame by frame through the image in reference to the vertical lines created by Light Poles #1 and #2. The time it takes for the ACU's cab to move between each perspective line was then recorded. This time is displayed by the video editing software as a combination of whole seconds and a carryover frame count, an integer value which counts the number of frames from each subsequent integer second. All times in this report are referred to in SSMM, where the SS is the value in seconds and FF is the value in carryover frames. In the nonlinear video editing software, the unique frame rate of 25.92 fps is accounted for, however, it is displayed in a 30 FPS frame counter. Values for this report then become recorded as a 30 FPS time base, and the equation for the time duration of a singular frame at 30 FPS in the equation above was utilized. Using a distance over time calculation a speed of 60 mph was obtained after rounding to significant figures. The equation and results are summarized in section 4.5.

A tractor trailer overtaking the ACU is visible in the left most lane of the southbound side of Interstate 5 in the vicinity of the Interstate 5 bridge. Though partially obscured, the speed of the overtaking tractor trailer was also obtained as the cab is visible at points INT1 and INT2. Images of the overtaking tractor trailer at INT1 and INT2 are shown below in Image 4.12 and 4.13 respectively. The equation resulted in a speed of 64 mph being obtained after rounding to significant figures.

Image 4.15: Vertical lines from light pole positions1 and 2 are used to indicate when the overtaking tractor trailer crossed each segment from point INT1 to INT2 on the centerline of the innermost lane of Interstate 5 southbound. Here, the

overtaking tractor trailer is seen at point INT1, a checkpoint using Light Pole #1 as a reference position. The indicated video time is 34 seconds and 25 frames.

Image 4.16: Vertical lines from light pole positions1 and 2 are used to indicate when the overtaking tractor trailer crossed each segment from point INT1 to INT2 on the centerline of the innermost lane of Interstate 5 southbound. Here, the overtaking tractor trailer is seen at point INT1, a checkpoint using Light Pole #1 as a reference position. The indicated video time is 37 seconds and 11 frames.

4.5. Equations and Results

The Dropcam video was then analyzed frame by frame to determine the exact time it takes the vehicles of interest to cross each vertical light pole position which correlate to imaginary points INT1 and INT2. Using the front end of each vehicle's structure, a frame reference was taken at each of the perspective lines as the vehicles moved through the image. As the front end of each vehicle passed each light pole position, the time in whole seconds and number of carryover frames were recorded. The measurement of time in whole seconds and carryover frames were converted to a total time value in the 4^{th} column of the spreadsheet, T_t. Using the mapping software, the distance between the two imaginary points, INT1 and INT2, was measured and entered. The time between two measured points is now known, allowing the vehicle's groundspeed to be calculated. The results are shown in the table below.

Vehicle	Time - S (sec)	Carryover Frames - Ts (Frames)	Total Time - Tt (sec)	Distance - d (ft)	Groundspeed - Gs (mph)	Gs - Rounded (mph)
ACU	2	21	2.70	236	59.60	60
Tractor Trailer	2	16	2.53	236	63.52	64

Table 4.1: A table showing the time, the measured distance and the calculated groundspeed for the vehicles between points INT1 and INT2.

<u>Equations:</u>

Time: S – The integer number of seconds displayed by the video editing program
Carryover Frames: T_s – The number of frames carried over from the integer second
Total Frames: T_f – The total number of frames counted between perspective lines
Total Time: T_t – The additive combination of Time (S) and Carryover Frames (T_s) in seconds
Distance: d – The distance along the runway's centerline between perspective lines.
Groundspeed: G_s – The aircraft's calculated speed along the runway centerline.

For determining Total Time (T_t) in seconds:

$$S + \left(\frac{1sec}{Ts}\right) = Tt$$

For determining Groundspeed (G_s) in Miles Per Hour (mph):

$$Gs = \left(\frac{d}{Tt}\right)$$

$$Gs = \left(\frac{d}{Tt}\right)\left(\frac{3600sec}{1hour}\right)\left(\frac{1\,mile}{5280feet}\right)$$

5. Uncertainty and Assumptions

A number of assumptions had to be made to conduct this study, which led to varying amounts of uncertainty in the calculations. The primary challenge is accounting for the unique frame rate of the Dropcam's recording. The manufacturer of the equipment explains that the frame rate output from the Dropcam is dependent upon the amount of light available to expose the image to a proper level and the amount of motion present in the image's field of view. When imported into a non-linear video editing software suite, video metadata shows a particular frame rate in which the video was recorded. In the file provided for this study, it is uncertain if that frame rate applies throughout the entire duration of the recording. Without knowing the linearity of the recording's frame rate, the resultant speed of objects in the recording cannot be verified completely. For this study, the frame rate shown in the metadata is assumed to apply for the entire duration of the provided recording.

Additionally, when a non-standard recording rate is input to a traditional non-linear video editing software program, only limited options are available for playback and output of the video file. All times noted in this study were output from the video editing software's source window. In this case the source window displays the imported video on a 30 frame per second timeline. It is assumed for this study that the 25.92 FPS source is displayed in a 30 FPS timeline and that no telecining[7] is present. The times used for this report were then based off a 30 FPS timeline with the assumption that time and position could be noted accurately while not being affected by telecining.

Difficulties were also presented when trying to identify the position of the camera in the accident video file that was used to conduct the study. The location of the camera was approximated utilizing photographs provided by the car dealership. Changing the camera location will alter the resultant speeds calculated in this report. Values for a camera location error were not quantified.

To calculate the distance traveled, a line was drawn between the two imaginary points INT1 and INT2 described in Figure 4.8 and Figure 4.9. A distance was measured using Google Earth in the center of the lane of travel. An assumption was made that the vehicles were traveling along the center portion of the lane in which they were stated to be traveling.

Pixel to distance ratio can also provide an area for inaccuracy. To examine this, the number of pixels spanning the distance between the two light poles must first be measured. This value is measured to be 256 pixels. Without accounting for the camera's skew to the roadway, divide 236 feet by 256 pixels, which results approximately 0.92 feet per pixel.

Since the identification of the ACU and Tractor Trailer's location on the roadway in relation to Light poles #1 and 2 is at the control of the user, the error in identifying the exact frame at which each event occurred was examined. For a simple error study, an error of +/- 2 frames was examined for each identification point. A minimum speed value was obtained by adding a frame error to the location of INT points 1 and 2. A maximum speed was obtained by subtracting a frame error to the identification locations. This error effectively changes the time it took the vehicle to travel the 236 feet between the two points and thus changes the speed calculation results. Table 4.2 shows the unrounded and rounded calculations that take into account significant figures.

Error	Vehicle	Time - S (sec)	Carryover Frames - Ts (Frames)	Total Time - Tt (sec)	Distance - d (ft)	Groundspeed - Gs (mph)	Gs - Rounded (mph)
Min.	ACU	2	25	2.83	236	56.79	57
Min.	Tractor Trailer	2	20	2.67	236	60.34	60
Max.	ACU	2	17	2.57	236	62.69	63
Max.	Tractor Trailer	2	12	2.40	236	67.05	67

Table 4.2: A table showing the unrounded and unrounded calculations for the frame identification error study.

The results of the frame identification error study yield a difference of roughly +/- 3 mph from the initial calculations.

The thickness of the light poles and their relative close distance to the camera when compared to the region examined in this report is another source

[7] Telecining – The process of encoding video media from one time code format to another, wherein complex methods are used to make individual frames appear in synchronization.

of uncertainty. Since the light poles which create the identification points are not located next to the roadway, ambiguity is introduced in the distance calculation for the studied region. Using Google Earth, the distance measured is essentially related to the thickness of the poles and the thickness of the calibration lines (rays) drawn to measure the region.

Because the camera is pointed towards the south and is not perpendicular to the roadway, pixel to distance measurements will vary as the objects in the field of view are placed further away from the camera toward the Interstate 5 bridge. As objects are placed further away from the camera toward the bridge, distance to pixel ratio increases, this results in greater inaccuracy in speed as the vehicles move closer to the bridge.

The effect that barrel distortion has on this type of study was also examined. Since the total distance is known across the measured portion of the image plane that spans the region of interest, it was determined that barrel distortion had no effect on any of the vehicles speed calculations.

Finally, since the most accurate way to resolve the vehicles' positions in reference to the light poles are by one frame, the chances of a vehicle falling exactly on a reference point when time is recorded is unlikely. For this study, the times recorded as the vehicles cross the light poles are assumed to be within the width of a pixel, recognizing possible errors as related to the rough distance/pixel ratio as discussed above and how slight variations in distance can alter the results.

6. Distance/Position Study Discussion

The calculated results of the study, including the maximum possible error discussed above, yielded groundspeeds that are consistent with highway traffic speeds in the vicinity of the Interstate 5 bridge. The calculated speeds from this study, including the possible accuracy error from the uncertainty and assumption discussion, are close to the posted speed limit of 60 mph and contain an error of at least +/- 3 mph.

7. Video Enhancement:

<u>"1224@20130523185509.mpg" - Patrol Car Video</u>

The patrol car video was exported as a series of still images for each frame of video in .JPEG[8] format. These stills were exported at the original video resolution of 720 by 480 pixels. To save time and hard drive space only a portion of the video was exported as stills. The export starts at 05:00;00 into the patrol car video. The still export sequencing begins at frame "0" at the baseline time of 05:00;00 and increases in integer increments for each frame at the native recording rate of 29.97 fps. In the vicinity of Exit 231, the pilot vehicle, the Accident Combination Unit, a maroon cabbed tractor trailer and a green cabbed tractor trailer are visible.

In an attempt to clarify these images, a variety of filters in an imagine enhancement software suite were used in combination to better define each vehicle. Sharpening filters were used in combination with blur effects to achieve an improved result. The video was also attempted to become de-interlaced, as alternating lines of video were merged to help clarify particular objects. The results are shown in the attached images below. The particular vehicle is referred in the image description.

Image 7.17: Frame number 511 in a raw exported .JPEG format from the patrol car video. The pilot vehicle is shown obscured behind a vehicle traveling in the fast lane.

[8] JPEG – Joint Photographic Experts Group – A commonly used method/format of compression for a digital image.

Image 7.18: Frame number 515 in a raw exported .JPEG format from the patrol car video. The pilot vehicle is shown at the edge of the frame.

Image 7.19: An enhanced image of the pilot vehicle in frame number 515 enlarged and enhanced with a scale transformation effect a sharpening function and a motion blur filter.

Image 7.20: Frame number 530 in a raw exported .JPEG format from the patrol car video showing the sign for Exit 231 northbound on Interstate 5.

Image 7.21: An enhanced image of frame number 530 enlarged and enhanced with a scale transformation effect and a sharpening filter. The sign for Exit 231 is shown.

Image 7.22: Frame number 574 in a raw exported .JPEG format from the patrol car video. The accident combination unit is shown.

Image 7.23: An enhanced image of frame number 574 enlarged with a scale transformation effect and clarified with a -90 degree blur effect to help de-interlace the image. A sharpening filter was later applied.

Image 7.24: Frame number 689 in a raw exported .JPEG format from the patrol car video. The maroon cabbed tractor trailer is shown.

Image 7.25: An enhanced image of the maroon cabbed tractor trailer in frame number 689 enlarged with a scale transformation effect and clarified with a -90 degree blur filter to de-interlace the image. A sharpening filter was later applied.

Image 7.26: Frame number 762 in a raw exported .JPEG format from the patrol car video. The green cabbed tractor trailer is shown.

Image 7.27: An enhanced image of the green cabbed tractor trailer in frame number 762 enlarged with a scaled transformation effect, sharpening filter and vertical motion blur effect applied.