3D LASER SCANNING GROUP CHAIRMAN
Factual Report

Train Derailment
Philadelphia, PA

DCA15MR010
(17 Pages)

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF RESEARCH AND ENGINEERING
WASHINGTON, D.C. 20594

3D LASER SCANNING FACTUAL REPORT

A. CRASH INFORMATION

Type:	**Train derailment**
Date and Time:	**May 12, 2015 at 9:21p.m. EDT**
Location:	**Philadelphia, PA**
Vehicle #2:	**Amtrak Passenger Train #188**
Fatalities:	**8**
NTSB #:	**DCA15MR010**

B. SUMMARY

For a summary of the accident, please refer to the *Crash Summary* report in the docket for this investigation.

C. 3D LASER SCANNING GROUP

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A. 3D LASER SCANNING

A three-dimensional (3D) laser scanner was used to record the 3D data of crash-related objects including the topography and the train at final rest. The scanner cannot capture objects that are out of its line of sight. As a result, special targets were used to link together multiple scans from various vantage points.

In this crash, the final rest positions of passenger Cars 1 and 2, the locomotive, passenger Car 2, passenger Car 3, and a sister passenger car were examined and scanned using both a FARO Focus 3D X120 and a FARO Focus 3D X330 laser scanner. The scanners were used in unison to increase efficiency. [1,2]

Some of the scanning activity was conducted post-recovery and scans conducted after the vehicles were moved may not represent the condition of the locomotive and passenger cars immediately after the accident. Passenger Cars 1 and 2 were scanned in their final rest positions after vehicle extrication and may also not represent the exact condition of those cars at final rest.[3] A total of 97 individual scans were performed during this investigation. Measurements were taken from the point cloud data, which is a product of the 3D laser scanner.[4]

1. Passenger Cars 1 and 2

Passenger Cars 1 and 2 were documented in their final rest positions with a total of 18 exterior scans. Portions of Cars 3, 4, and 5 were also captured from these 18 scans. Images from the point cloud created by the scanner documenting these cars at final rest are shown in Figure 1 and Figure 2. An overhead view of the point cloud is shown in Figure 3.

[1] The FARO Focus X120 laser scanner has an advertised scan range of 100 meters.
[2] The FARO Focus X330 laser scanner has an advertised scan range of 330 meters.
[3] Vehicle extrication refers to the procedure used to remove a vehicle from around an occupant after a crash has occurred.
[4] FARO quotes a systematic measurement error (one sigma) of ±2 mm (±0.079 in) at ranges of 10 m (33 feet) and 25 m (82 feet). FARO quotes a random error (one sigma) of less than ±2.2 mm (±0.087 inches) in a best-fit plane at ranges of 10 m (33 feet) and 25 m (82 feet), with a target reflectivity of either 10 % or 90 %. Additional uncertainty in dimensional data may result from the manual choice of points to represent a specific object from the entire 3D point cloud.

Figure 1. An image from the 3D laser scanner point cloud showing passenger Car 1 in its final rest position after vehicle extrication.

Figure 2. An image from the 3D laser scanner point cloud showing the passenger Car 2 on the left and a portion of passenger Car 1. The underside of passenger Car 3 can be seen in the background.

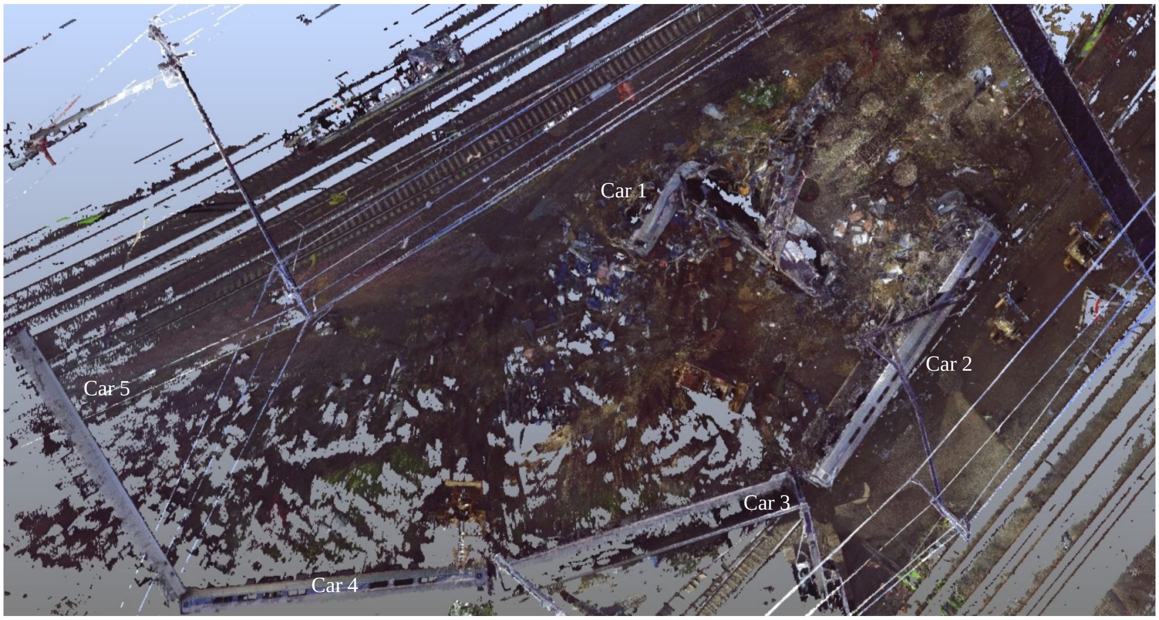

Figure 3. An overhead image from the 3D laser scanner point cloud showing passenger Cars 1, 2, 3, 4, and 5.

The condition of the rail car windows in Car 2 was examined from the 3D laser scan data. Images showing the condition of the windows for Car 2 are show in Figure 4 through Figure 6.[5]

Figure 4. An image from the scanner showing the roof and left side of Car 2 in its final rest position. The direction of travel is marked on the image.

[5] The images from the scanner are shown in a planar view, which results in a curvature due to the 360 degree scan laid onto a two-dimensional image.

Figure 5. An image from the scanner showing the right side of Car 2, near the coupling to Car 1, in its final rest position. The direction of travel is marked on the image.

Figure 6. An image from the scanner showing the right side of Car 2, near the coupling to Car 3, in its final rest position. The direction of travel is marked on the image.

2. Locomotive

The locomotive was documented with a total of 18 scans. Two of the 18 scans were performed from the locomotive roof. Three were interior scans focusing on the engineer cabs.[6] Images from the point cloud created by the scanner documenting the locomotive are shown in Figure 7 and Figure 8. Views of the locomotive roof are shown in Figure 9 and Figure 10. Measurements of the damage along the right side of the locomotive are shown in Figure 11.

Figure 7. An image from the 3D laser scanner point cloud showing the front right of the locomotive.

Figure 8. An image from the 3D laser scanner point cloud showing the front left of the locomotive.

[6] There are engineer cabs at both ends of the locomotive.

Figure 9. An image from the scanner showing the locomotive roof looking toward the engineer's cab, toward the direction of travel.

Figure 10. An image from the scanner showing the locomotive roof looking away from the direction of travel.

Figure 11. Measurements documenting the damage on the right side of the locomotive. The front of the locomotive is on the right side of the image. (From left to right, the dimensions are 3.9 feet, 4.0 feet, and 4.1 feet.)

3. Passenger Car 2

Passenger Car 2 was also documented post-recovery with a total of 18 scans. Images from the point cloud created by the scanner showing both the B- and A-ends of passenger Car 2 are shown in Figure 12, Figure 13, and Figure 14.[7]

[7] According to the consist (see the Survival Factor's Group Chairman's Report), the lead end for the locomotive, Car 3, Car 4 and Car 7 was the A-end. For Cars 1, 2, 5, and 6, the lead end was the B-end.

Figure 12. An image from the 3D laser scanner point cloud showing the B-end of passenger Car 2.

Figure 13. An image from the 3D laser scanner point cloud showing the B-end of passenger Car 2 from the other side.

Figure 14. An image from the 3D laser scanner point cloud showing the A-end of passenger Car 2.

4. Passenger Car 3

Passenger Car 3 was also documented post-recovery with a total of 25 scans. Of the 25 scans, 9 scans documented the interior. Images from the point cloud created by the scanner showing both the A- and B-ends of passenger Car 3 are shown in Figure 15, Figure 16, and Figure 17.

Figure 15. An image from the 3D laser scanner point cloud showing the B-end of passenger Car 3.

Figure 16. An image from the 3D laser scanner point cloud showing the B-end of passenger Car 3 from the other side.

Figure 17. An image from the 3D laser scanner point cloud showing the A-end of passenger Car 3.

1. Sister Car - 82674

A sister passenger Car 82674 was documented with a total of 18 scans, 8 of which were interior scans. This car was a sister to passenger Car 1 but the interior configuration was slightly different since passenger Car 82674 was a coach car, not a business class car. Images from the point cloud created by the scanner showing both ends of the sister passenger car are shown in Figure 18 and Figure 19.

Figure 18. An image from the 3D laser scanner point cloud showing the B-end of passenger Car 82674.

Figure 19. An image from the 3D laser scanner point cloud showing the A-end of passenger Car 82674.

2. Wreckage survey with Trimble Geo7x GPS device

The group surveyed the locations of major portions of the train wreckage and other items of interest at the accident site with a Trimble Geo7x survey-quality Global Positioning System (GPS) device. At the accident location, the Geo7x reported a real-time accuracy of approximately 30 inches, and a "post-processed" (corrected) accuracy of as little as 4 inches.

Post-processed accuracy is achieved by correcting the recorded GPS positions using correction data corresponding to the time and place of the measurements, as provided by a nearby "base station." The base station used in the present case was the "PAPH" Continuously Operating Reference Station (CORS) located in North Philadelphia, at latitude / longitude coordinates 40° 00' 47.34854" N, 075° 10' 34.78766" W.

The overall accuracy of the Geo7x is affected by the proximity of structures to the GPS antenna. Hence, while at a distance from any structure the GPS usually reported an estimated post-processed accuracy of 4 inches, this accuracy would deteriorate (to as much as 3 ft.) when the antenna was close to a structure (for example, the side of a train car).

Data is collected with the Geo7x using the Trimble *TerraSync* software running on the device. *TerraSync* denotes items to be surveyed as "features," and allows for three different types of features: point features (consisting of 1 GPS position), line features (a curve through space defined by two or more GPS positions), and area features (a closed polygon defined by 3 or more GPS positions). Users can create custom features built upon these three basic types, and associate particular attributes to those features (such as labels, photographs, height or other numerical data). These custom features and their attributes are defined in a "data dictionary" for the device. In the present case, the "NTSB_Oct2014" data dictionary was used, and data collected into the custom feature types listed in Table 1 (note that the "Custom Feature Type" names in Table 1 do not necessarily describe the items surveyed using the corresponding custom feature).

Table 1: Custom *TerraSync* feature types used in this survey.

Custom Feature Type	**Base Feature Type**	**Attributes**
Impact Point	Point	Comment (name label) 1 Photograph Height (not used in this survey) Date & Time
Pole	Point	Comment (name label) 1 Photograph Height (not used in this survey) Date & Time
Fence	Line	Comment (name label) 1 Photograph User-input length (not used in this survey. *Note:* Trimble software automatically computes line length based on the recorded GPS positions) Height (not used in this survey) Date & Time
Main Wreckage	Area	Comment (name label) 1 Photograph Date & Time

The actual on-scene features surveyed for this accident are listed in Table 2. The "68% accuracies" listed in Table 2 are those reported by the Trimble *GPS Pathfinder Office* software used to post-process the data collected with the Geo7x. Note that the *GPS Pathfinder Office* software runs on a Windows-based laptop, as opposed to the *TerraSync* software, which runs on the Geo7x device itself. The "68% accuracies" values indicate that there is a 68% chance that the actual position of the feature is within the accuracy listed (for example, a value of 0.2 ft. would mean that there is a 68% chance that the feature is within 0.2 ft. of the stated position).

Additional information about the features collected with the Geo7x (for example, satellite status, dilution of precision values, mean sea level elevations, etc.) can be queried from the *GPS Pathfinder Office* software. The position data for each feature can also be exported from the *GPS Pathfinder Office* software into various formats, including ASCII text, and *Google Earth* .kml format.

A screenshot of *Google Earth* with the .kmz file opened and information about a feature displayed is shown in Figure 20.

Table 2: Features collected with the Geo7x device in this survey.

Feature #	Custom Feature Type	Comment (name label)	Photo taken?	68% accuracies	Description
1	Impact Point	derail point	yes	0.1 ft.	First evidence of chipped rail tie on track 2 (not point where train wheels first climbed the track)
2	Pole	pole 1	yes	0.4 ft.	Base of vertical beam supporting catenary frame and wires
3	Pole	pole 2	yes	0.8 ft.	Base of vertical beam supporting catenary frame and wires
4	Fence	Car 7	yes	0.7 ft. (worst) 0.3 ft. (average)	Back and right side edges of Car 7
5	Fence	Car 6 r side	yes	0.7 ft. (worst) 0.4 ft. (average)	Right side edge of Car 6
6	Fence	Car 5 r side	yes	3.2 ft. (worst) 1.7 ft. (average)	Right side edge of Car 5
7	Fence	Car 4 r side	yes	0.1 ft. (worst) 0.1 ft. (average)	Right side edge of Car 4
8	Fence	Car 3 r side	yes	0.1 ft. (worst) 0.1 ft. (average)	Right side edge of Car 3
9	Fence	Car 2 r side	yes	0.1 ft. (worst) 0.1 ft. (average)	Right side edge of Car 2
10	Pole	pole 3	yes	0.5 ft.	Base of vertical beam supporting catenary frame and wires
11	Pole	bridge post 1	yes	0.7 ft.	Base of vertical beam supporting bridge northeast of wreckage
12	Pole	bridge post 2	yes	0.3 ft.	Base of vertical beam supporting bridge northeast of wreckage
13	Pole	bridge post 3	yes	3.3 ft.	Base of vertical beam supporting bridge northeast of wreckage
14	Pole	bridge post 4	yes	0.1 ft.	Base of vertical beam supporting bridge northeast of wreckage
15	Main Wreckage	loco footprint	yes	0.1 ft. (worst) 0.1 ft. (average)	Outline of crater left by final resting place of locomotive
16	Main Wreckage	Car 1 outline	yes	0.3 ft. (worst) 0.3 ft. (average)	Outline of Car 1 wreckage area
17	Pole	pole 5*	yes	0.3 ft.	Base of vertical beam supporting catenary frame and wires
18	Pole	downed pole	yes	0.3 ft.	Base of vertical beam supporting catenary frame and wires, bent to ground between Cars 5 & 6
19	Pole	severed base	yes	0.3 ft.	Base of vertical beam supporting catenary frame and wires, beam cut from base
20	Fence	track line	no	3.8 ft. (worst) 0.6 ft. (average)	Center of track 2 northeast of Car 6
21	Fence	track line 2	yes	0.4 ft. (worst) 0.3 ft. (average)	Center of track 2 southwest of Car 6
22	Impact Point	beam rest	yes	0.3 ft.	End of catenary beam resting in tracks
23	Impact Point	Amtrak cp 3	yes	0.4 ft.	Amtrak Total Station survey control point #3
24	Impact Point	cp3 2	no	0.3 ft.	Repeat of Amtrak Total Station survey control point #3 for better precision
25	Impact Point	Amtrak cp 1 t1	yes	0.3 ft.	Amtrak Total Station survey control point #1 (named “t1”?)
26	Pole	pole ?	yes	0.3 ft.	Repeat of Feature #10
27	Pole	pole base ?	yes	0.3 ft.	Base of vertical beam supporting catenary frame and wires, beam sheared / severed at base

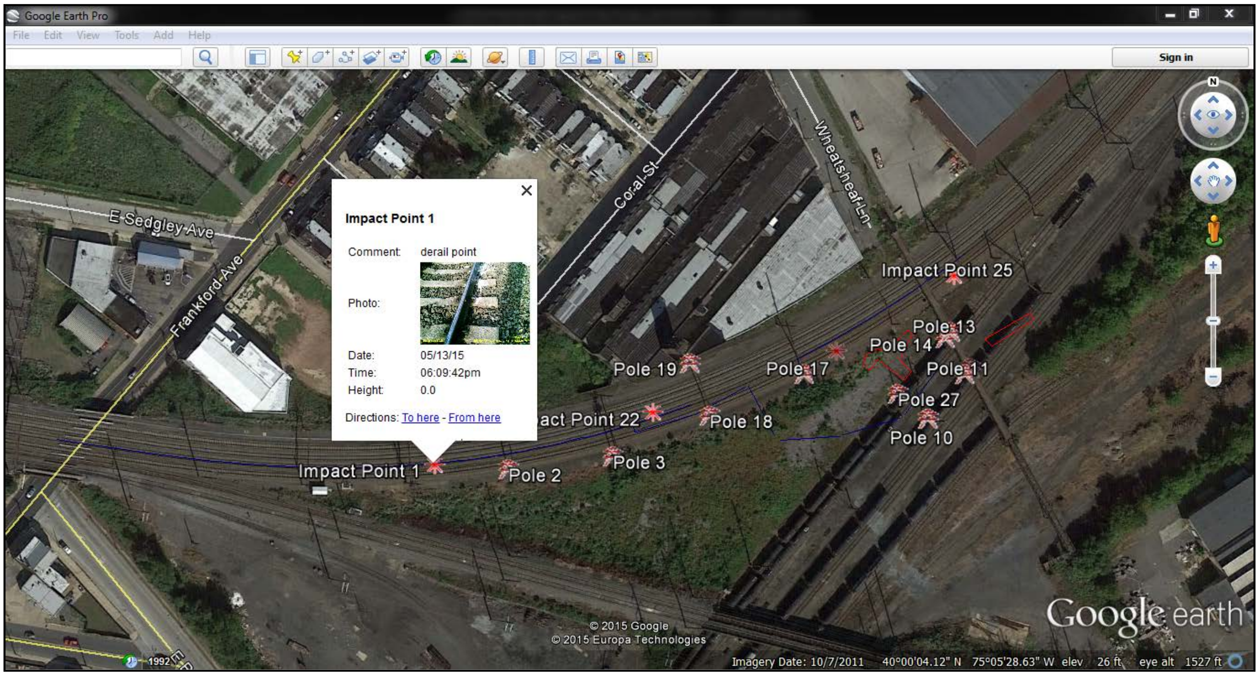

Figure 20**.** Screenshot of *Google Earth* with **NTSB3_AMTRAK1_1.kmz** file loaded, and survey feature #1 highlighted.