3D LASER SCANNING
FACTUAL REPORT

Train Over-speed, Struck Passenger Waiting Area
Hoboken, NJ

DCA16MR011
(14 Pages)

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

3D LASER SCANNING FACTUAL REPORT

A. ACCIDENT

Type:	**Train over-speed; struck passenger-waiting area**
Date and Time:	**February 3, 2015 at 6:26p.m. EST**
Location:	**Hoboken, NJ**
Vehicle #1:	**New Jersey Transit Train No. 1614**
Fatalities:	**1**
NTSB #:	**DCA16MR011**

B. 3D LASER SCANNING GROUP

Kristin Poland, Ph.D. Group Chairman
NTSB Office of Research and Engineering
490 L'Enfant Plaza SW, Washington, D.C. 20594

Robert Squire
NTSB Office of Highway Safety
490 L'Enfant Plaza SW, Washington, D.C. 20594

Bill English
NTSB Office of Aviation Safety
490 L'Enfant Plaza SW, Washington, D.C. 20594

C. SUMMARY

Three-dimensional (3D) laser scanners and photogrammetry from a drone were used to record the 3D data of crash-related objects including the damage to the Hoboken terminal near the area of final rest, the lead cab car, and an exemplar rail car. The laser scanners 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 investigation, the train at final rest and an exemplar rail car were examined and scanned using two FARO Focus 3D X330 laser scanners. [1,2] The scanners were used in unison to increase efficiency. At final rest, the exterior of the cab car and a portion of car 2 were scanned in their final rest position. Additional rail cars were captured due to the range of the scanner. In addition, both the interior and exterior of an exemplar rail car (No. 6058) were scanned. Finally, after recovery, the interior and exterior of the lead cab car were scanned to further document the damage. A total of 81 individual scans were performed during this investigation.

In addition, a drone was flown to document the accident location. The drone is a DJI Inspire 1.[3] Onboard the drone is integrated a camera and a global positioning system (GPS). The GPS is integral to the drone flight controller and is a combination GPS/GLONASS receiver.

1. Rail Cars at Final Rest

Prior to the removal of the station canopy, the lead cab car and the second rail car were scanned with a total of 10 exterior scans on October 1, 2016. Images from the point cloud created by the scanner documenting these cars at final rest are shown in Figure 1 through Figure 4.

Figure 1: An image from the 3D laser scanner point cloud showing left side of the lead cab car. The direction of train travel was from the right side of the image toward the left side of the image.

[1] The FARO Focus X330 laser scanner has an advertised scan range of 330 meters.
[2] FARO quotes a systematic measurement error (one sigma) of ±2 mm (±0.079 in) at ranges of 10 m (33 ft) and 25 m (82 ft). FARO quotes a random error (one sigma) of less than ±2.2 mm (±0.087 in) in a fest-fit plane at ranges of 10 m (33 ft) and 25 m (82 ft), 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.
[3] Acquired by the NTSB in September 2016.

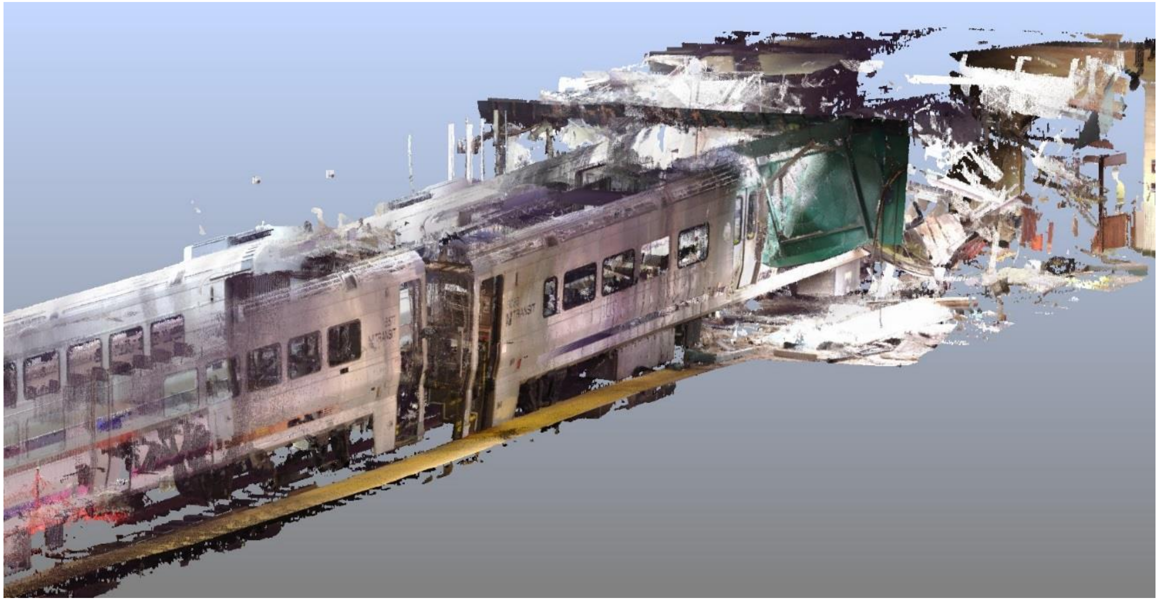


Figure 2: An image from the 3D laser scanner point cloud showing the right side of the cab car and a portion of car 2. The direction of train travel was from the left side of the image toward the right side of the image.

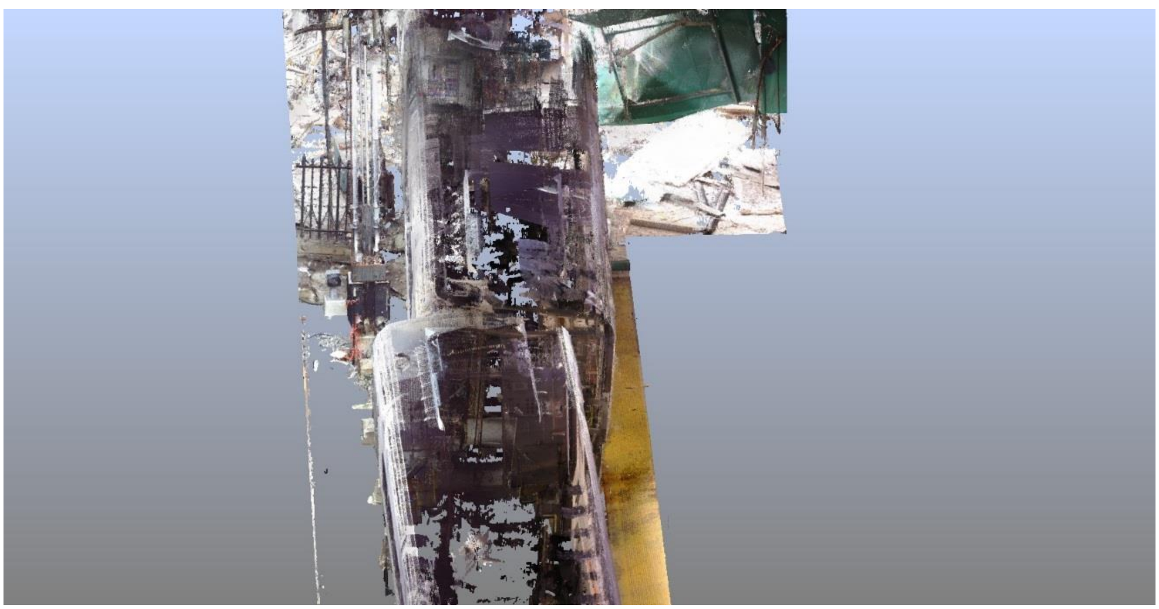


Figure 3: An image from the 3D laser scanner point cloud showing the orientation of the cab car (top of image) relative to car 2 (bottom of image).

Figure 4: An image from the 3D laser scanner point cloud showing an overhead view of the orientation of the cab car relative to car 2 and car 3. The direction of train travel was from the left side of the image toward the right side of the image.

2. Exemplar Cab Car - 6058

An exemplar cab car was documented with a total of 38 scans on October 2, 2016. Twenty-one of those scans were exterior scans. The additional 17 scans were performed to document the interior. Point cloud images of the cab car exterior created by the scanner are shown in Figure 5 through Figure 8. Direction of travel is based on the position of the F-end of the car, which designates the front end.

Figure 5: An image from the 3D laser scanner point cloud showing F-end and right side of exemplar cab car 6058.

Figure 6: An image from the 3D laser scanner point cloud showing F-end and left side of exemplar cab car 6058.

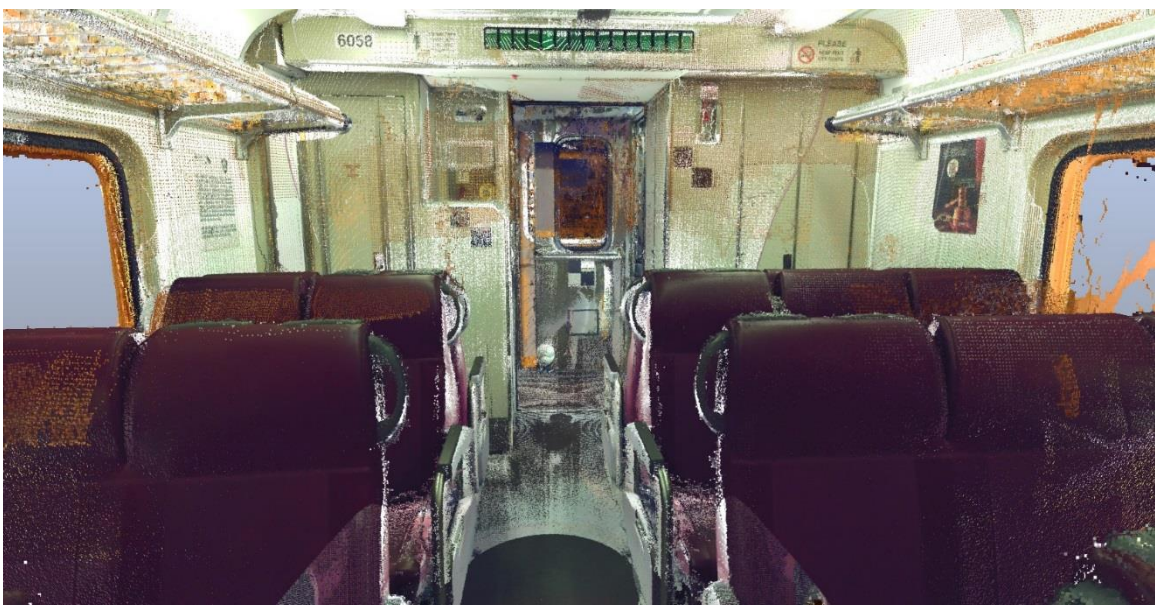


Figure 7: An image from the 3D laser scanner point cloud showing the interior of exemplar cab car 6058.

Figure 8: An image from the 3D laser scanner point cloud showing the cab and control console of exemplar cab car 6058.

3. Accident Cab Car - 6036

Thirty-three scans documented the accident lead cab car after recovery on November 10, 2016. Twenty-six of those scans were exterior scans. Four of those exterior scans were from an elevated position to capture an I-beam that penetrated the roof of the car. The intruding I-beam was part of the support for the roof of the terminal, and the I-beam intrusion was accompanied by other roof structure and materials. Seven additional scans documented the interior in regions that were accessible.[4] Figure 9 and Figure 10 show the point cloud images of the cab car exterior, which were created by the scanner.

Figure 9: An image from the 3D laser scanner point cloud showing the left side of lead cab car 6036. (The F-end is on the left side of the image.)

Figure 10: An image from the 3D laser scanner point cloud showing the right side of lead cab car 6036. (The F-end is on the right side of the image.)

[4] Damage to the lead cab car and the lack of support for the I-beam embedded in the car prevented access to some regions of the car.

Interior scans were limited due to the amount of intrusion and debris in the forward end of the cab car and the structural instability of the I-beam in the ceiling and passenger cabin region. Planar images from the laser scanner showing the intrusion into the forward passenger compartment are shown in Figure 11 through Figure 13. (Planar views create images similar to those created with a fish-eye lens with straight lines shown as curves. The planar view allows display of a greater visual angle.)

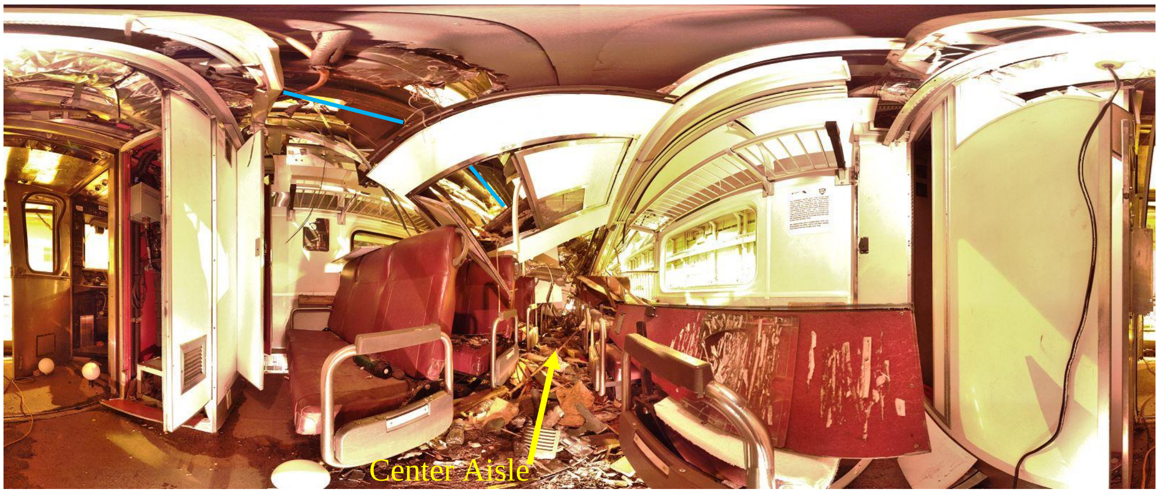


Figure 11: A planar image from the 3D laser scanner showing the forward passenger compartment. The scanner is located near the first row of passenger seats in the center aisle and is looking rearward. The yellow arrow marks the center aisle and two blue lines denote the intruding I-beam. The train operator's cab is shown on the far left of the image.

Figure 12: A planar image from the 3D laser scanner showing the rear passenger compartment and the intrusion forward of the center vestibule. The view is looking forward in the direction of train travel.

Figure 13: A planar image from the 3D laser scanner showing the center vestibule of the lead cab car and the damage from the intruding I-beam. The view is looking forward in the direction of train travel. The black arrow marks the center aisle.

Figure 14 shows the overall dimensions of the lead cab car and the general position of the exterior damage and Figure 15 shows an overhead view of the lead cab car with the intruding I-beam highlighted. The I-beam punctured a hole in the roof to a location about 9.34 m back from the front of the car, with the punctured part of the roof being pushed down or back into the car by the end of the I-beam. The I-beam extended into the car about 13 m as measured from the front of the cab car. Slices through the point cloud highlight the intrusion into the front portion of the lead cab car. Figure 16 is an overlay of the accident lead cab car and an exemplar cab car (in pink). A yellow line highlights the top flange of the intruding I-beam and the 8° angle of the I-beam relative to the horizontal. Cross sectional slices were also taken starting at the front of the cab car and moving aft toward the center vestibule to further highlight the intrusion of the I-beam. The slices document the debris that was deposited in the lead cab car from the glass panels and concrete in the station canopy along with debris from the damaged cab car roof and ceiling. The slice locations and thickness were chosen to best visualize the point cloud cross sections. The locations of these cross sections are shown in Figure 17. Figure 18 shows an overlay of a single cross section from the accident cab car and the exemplar cab car at the same position. Further, Video 1 shows the series of these cross sections starting at the front of the lead cab car and continuing through to the center vestibule.

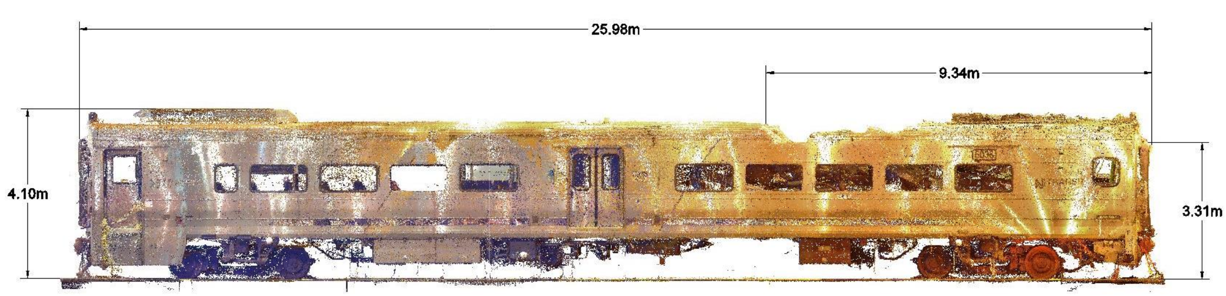


Figure 14: An image from the 3D laser scanner point cloud showing the overall dimensions (in meters) of lead cab car 6036 and the general region of exterior damage. (The F-end is on the right side of the image.)

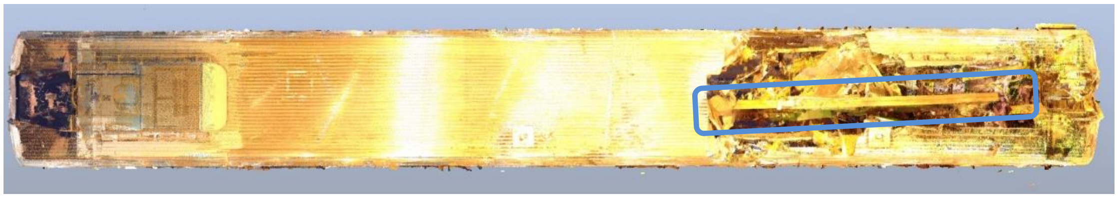


Figure 15: An image from the 3D laser scanner point cloud showing the top of lead cab car 6036. (The F-end is on the right side of the image.) The blue box highlights the intruding I-beam.

Figure 16: An overlay showing a slice through the center of the lead cab car's point cloud with an overlay of the exemplar cab car (in pink). The front of the rail car is on the right side and a yellow line highlights the I-beam that penetrated the passenger compartment. The overlay also displays the 8° angle of the I-beam with respect to the horizontal.

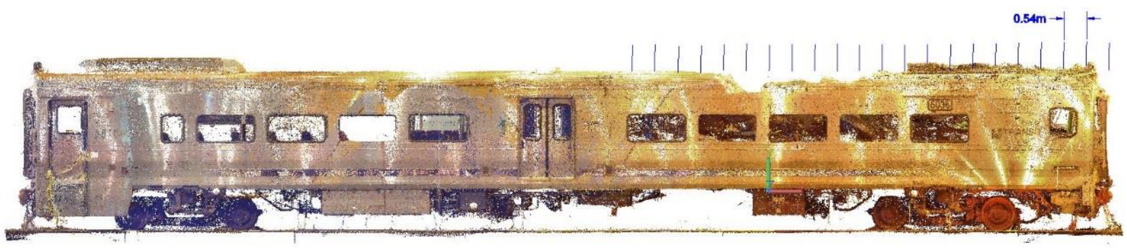


Figure 17: Vertical bars highlight the position of the cross section slices starting at the F-end of the lead cab car (right side of image). Each cross section slice is represents 0.54 meters.

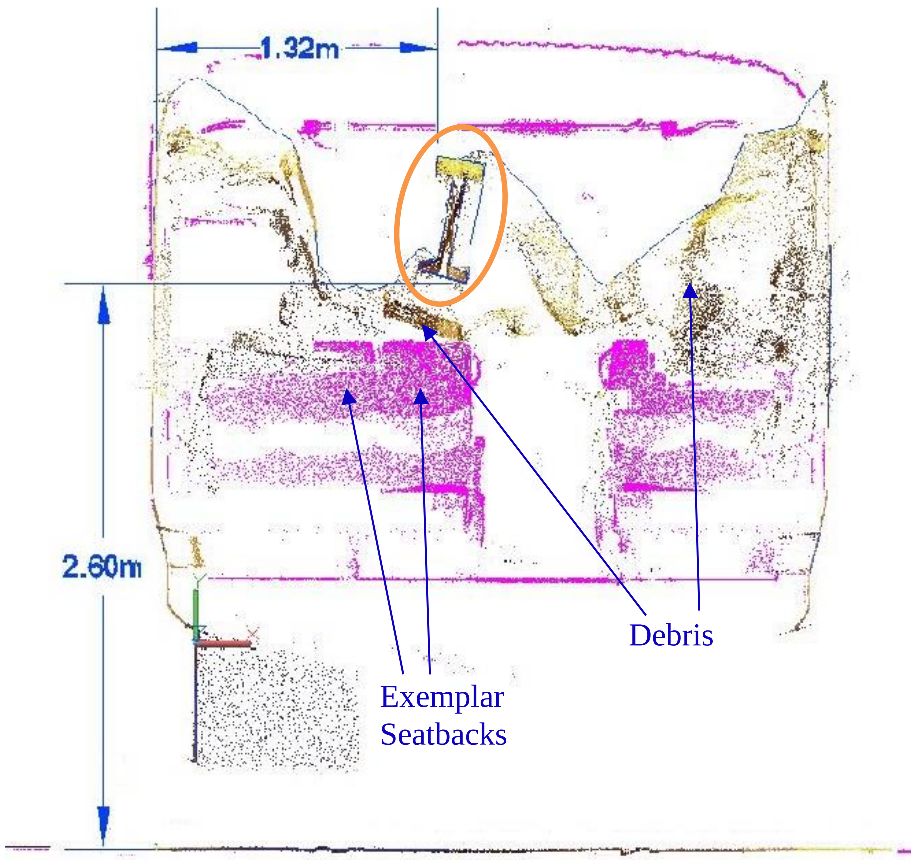
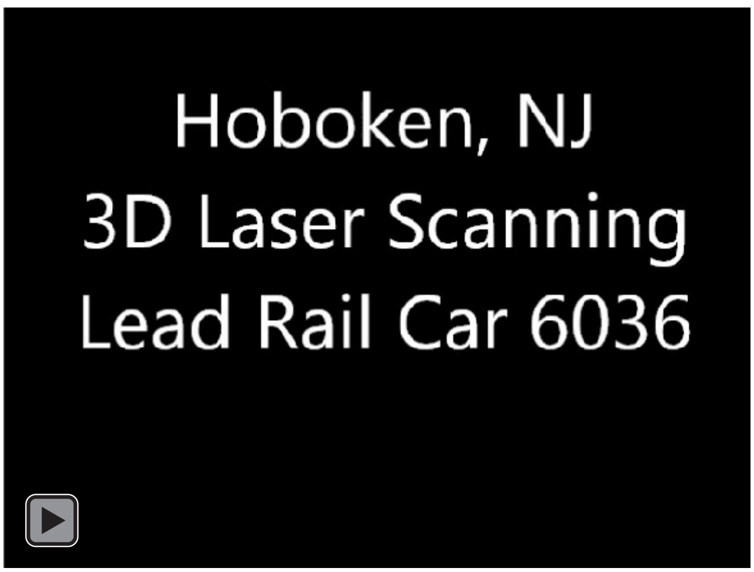


Figure 18: An overlay showing a cross section of the lead cab car's point cloud (outlined in blue) with an overlay of the exemplar cab car (in pink). This cross section was approximately 8 meters from the front of the lead cab car. The dimensions show the location of the I-beam. An orange circle highlights the I-beam that penetrated the passenger compartment. Exemplar seatbacks and debris are also marked.



Video 1: This video depicts cross sections of the lead cab car starting from the front of the rail car through to the center vestibule.

4. Drone

The drone was flown from a rooftop of the Hoboken terminal adjacent to the final rest position of the train on October 1, 2016. During the flight, 109 images were taken of the damaged canopy and portions of the train that were visible underneath the canopy. Using the combination of photogrammetry and the GPS data, the software Pix4D was used to combine the drone imagery and create a 3D point cloud of the data.[5] The point cloud was meshed to create a 3D surface. A Google Earth image showing the area documented by the drone is shown in Figure 19. Images from the drone flyover and the 3D mesh are shown in Figure 20 through Figure 22. Video 2 shows the 3D surfaces created by the drone images and Pix4D.

The drone flight was limited due to high electrical current in the catenary wires, which affected the internal drone compass, disabling the safety mechanisms of flight. As a result, the drone was not flown along the approach track to the Hoboken terminal.

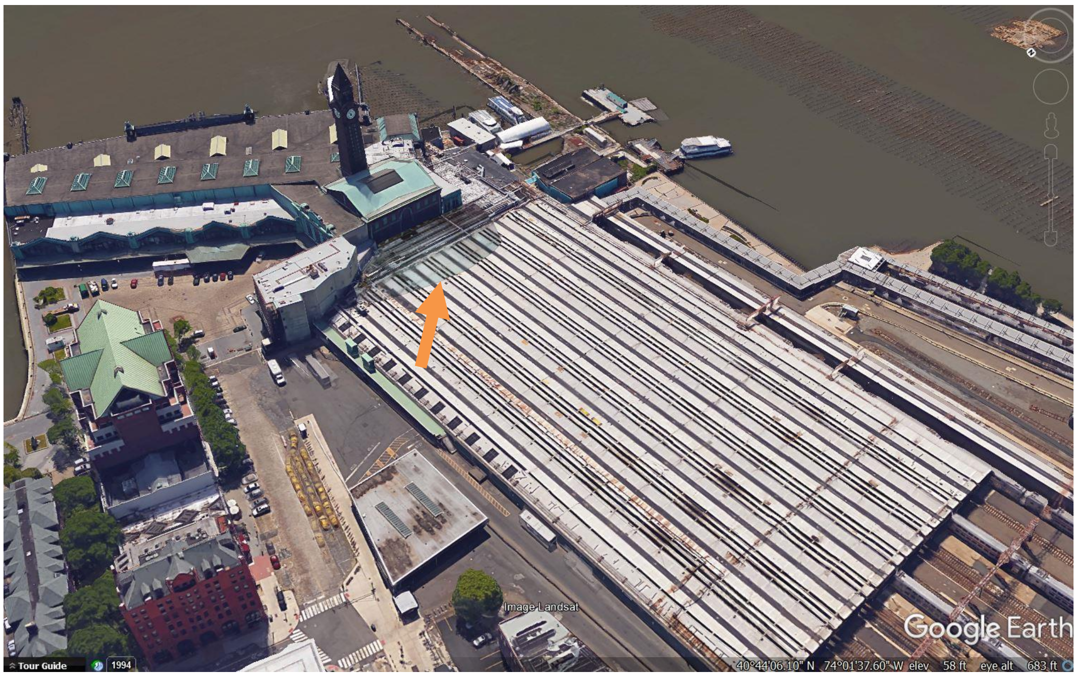


Figure 19: A Google Earth image overlaid with the orthomap of the drone documentation region is shown. The slightly darker region, highlighted by the orange arrow, near the Hoboken terminal is the region documented by the drone flyover.

[5] https://pix4d.com/ accessed on 2/16/2017.

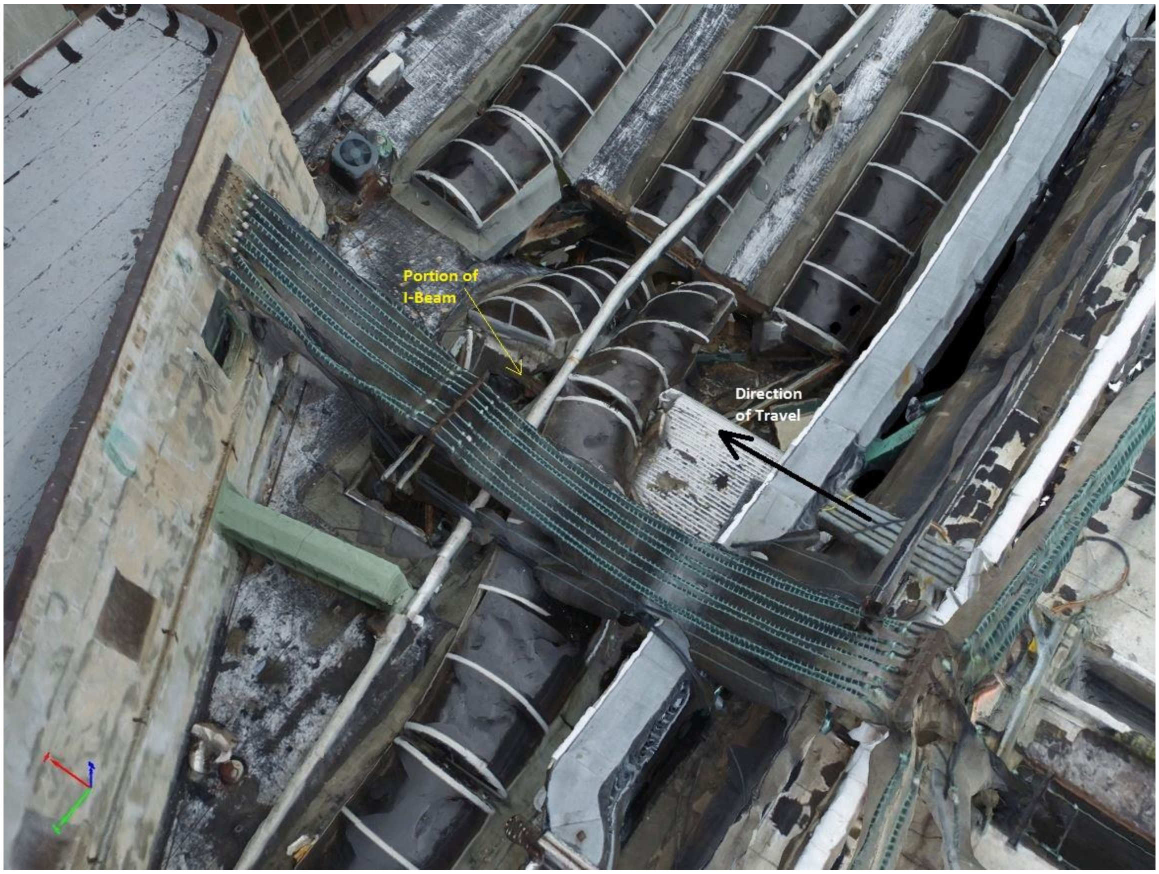


Figure 20: A photograph from the drone flyover showing the damaged canopy with glass panels and a portion of the train. The direction of train travel and a portion of the I-beam are labeled on the image.

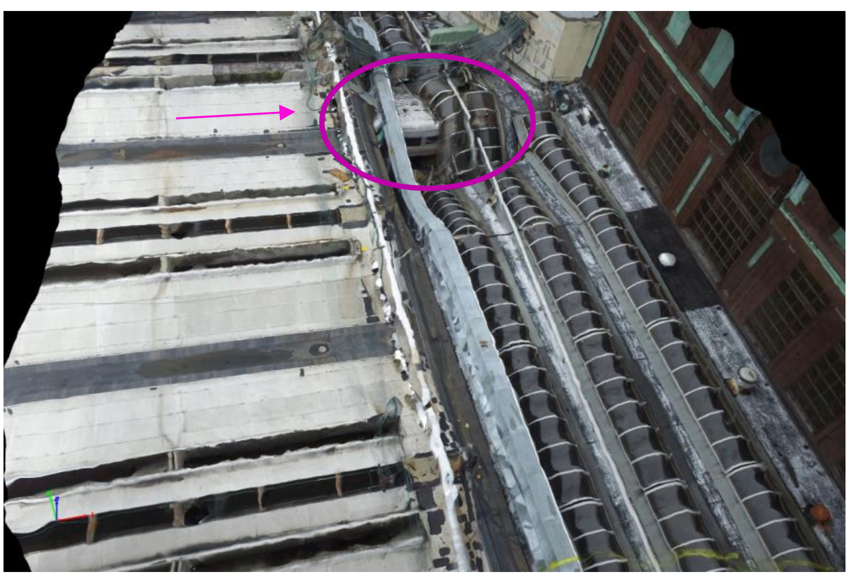


Figure 21: An image of the 3D mesh created from the drone flyover. The Hoboken terminal is on the right side of the image and the train shed is on the left side of the image. The pink circle shows the portion of the train that is visible and the pink arrow shows the direction of train travel.

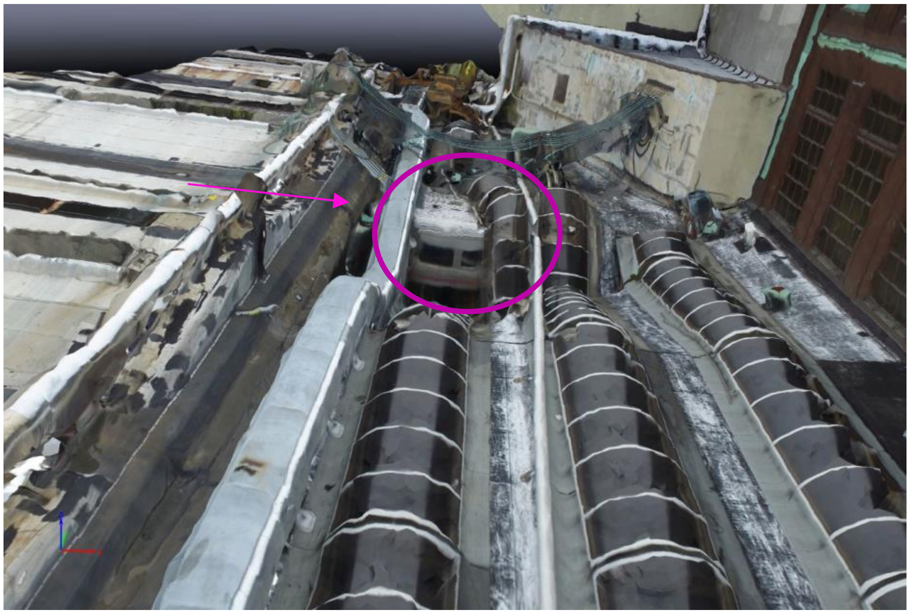


Figure 22: An image of the 3D mesh created from the drone flyover looking toward the north. The pink circle shows the portion of the train that is visible and the pink arrow shows the direction of train travel.

Video 2: This video depicts cross sections of the lead cab car starting from the front of the rail car through to the center vestibule.

END OF INFORMATION

Kristin Poland, Ph.D.
Senior Biomechanical Engineer