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Using an Unmanned Aerial Vehicle to Produce Accurate Grade Crossing Profile Data

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14. ABSTRACT
The U.S. Department of Transportation (DOT) John A. Volpe National Transportation Systems Center (Volpe), under the direction of DOT's Federal Railroad Administration (FRA), Office of Research, Development and Technology, studied the use of unmanned aerial vehicles (UAVs) to produce accurate 3-dimensional models of high-profile highway-rail grade crossings. Volpe found that photogrammetry with ground control points can produce models with similar accuracy to those produce using LiDAR at a much lower cost. Volpe determined the process needed to achieve a simple measurement of ground clearance for these crossings and makes recommendations to FRA for pursuing this capability, and to work with FHWA to provide better information to drivers of low-clearance vehicles.

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Highway-rail, grade crossing, humped crossing, photogrammetry, LiDAR

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION

Inches	0			1			2			3			4			5	
Centimeters	0	1	2		3	4	5	6	7		8	9	10	11	12		13

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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The authors would also like to thank Eric Sherrock and his colleagues at ENSCO for sharing their experience in LiDAR technology, as well as Tripp Shannon and his team at DroneUp in Virginia Beach, VA for their hard work and insight in the features and challenges in drone technology, photogrammetry, and in LiDAR point cloud creation.

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Executive Summary

The John A. Volpe National Transportation Systems Center (Volpe) was tasked by the Federal Railroad Administration (FRA) Office of Research, Development and Technology to evaluate the feasibility of inspecting grade crossings by using photogrammetry or light detection and ranging (LiDAR) devices mounted on UAVs to develop accurate 3-dimensional models of high-profile highway-rail grade crossings.

The American Railway Engineering and Maintenance-of-Way Association has guidance for new or reconstructed grade crossings. This guidance, adopted by the American Association of State Highway and Transportation Officials, recommends that the surface of the highway be not more than 75 millimeters (3 inches) higher or lower than the top of the nearest rail at a point 7.5 meters (30 feet) from the rail, unless track superelevation dictates otherwise.[1] Beyond this, there is currently no formula or threshold for determining if a highway-rail grade crossing presents a risk for low ground clearance vehicles, or if it should be posted as such. The actual risk for vehicles to become stuck on tracks has more to do with the rate of change in the roadway grade than its magnitude, so accurate 3-dimensional models of crossings are needed in order to properly assess the risk.

Volpe researchers produced photogrammetry models at several grade crossings and discovered several challenges that resulted in model anomalies. Volpe contracted with a consultant to learn techniques for minimizing anomalies and to determine whether or not airborne LiDAR might be a better solution.

The analysis showed that accurate models can be produced using UAV photogrammetry, with even greater accuracy achieved through the use of ground control points. However, while equally accurate models can be produced using UAV LiDAR, significantly more work (and cost) is involved in processing the LiDAR data.

To make the most effective use of these models, the next steps would consist in the development of a software tool for analyzing them to determine the amount of ground clearance vehicles need to traverse each crossing. FRA could then add the ground clearance figures to its grade crossing inventory database, and work with the Federal Highway Administration to add ground clearance postings to Manual on Uniform Traffic Control Devices-compliant warning signs at high profile crossings.

[1] Obtained from the Federal Highway Administration Railroad-Highway Grade Crossing Handbook on November 18, 2019: https://safety.fhwa.dot.gov/hsip/xings/com_roaduser/07010/sec04c.cfm

1. Introduction

The John A. Volpe National Transportation Systems Center (Volpe) provides technical support to the Federal Railroad Administration (FRA) on all aspects of grade crossing safety and trespass prevention research. This support includes key research associated with all aspects of railroad rights-of-way (ROWs), including the highway-rail intersections (HRIs) and trespass issues.

At many highway-rail grade crossings, the tracks are at a significantly higher elevation than the roadway that approaches them, resulting in a high profile, or "hump." These crossings are significant hazards for vehicles with long wheelbases and low ground clearance. Motorcoach buses and lowboy trailers are the vehicles most likely to become "hung up" at these crossings.

In 2017, there were 2,123 train accidents/incidents at railroad crossings, resulting in 309 fatalities.[2] Of these, 160 accidents involved trucks or buses "stuck" or "stopped" on the tracks. While the data doesn't specifically clarify, it is likely that in many of these incidents, the trucks or buses lacked sufficient ground clearance to traverse the hump in the crossing, causing the vehicle to become stuck, or hung up. One incident where a tour bus in Biloxi, MS became stuck on a humped crossing resulted in the deaths of four bus passengers and injuries to 38 others.[3]

The FRA Office of Research, Development and Technology (RD&T) tasked Volpe with evaluating the viability of using an unmanned aerial vehicle (UAV, or "drone") to produce accurate profile models of humped crossings. Hopefully, if this can be accomplished with minimal time and expense, crossings with dangerously high humps can be more effectively marked, providing drivers of low-profile vehicles with meaningful warnings that inform them if they are at risk of getting hung up if they cross.

1.1 Background

Figure 1 shows an example of a humped crossing with posted signage in Suffolk, VA (Crossing ID 467411X). Currently, there is no standard for what constitutes a high-profile, or "humped" crossing. American Railway Engineering and Maintenance-of-Way Association guidance for new or reconstructed grade crossings, which has been adopted by the American Association of State Highway and Transportation Officials, recommend that the surface of the highway be not more than 75 millimeters (3 inches) higher or lower than the top of the nearest rail at a point 7.5 meters (30 feet) from the rail, unless track superelevation dictates otherwise. The Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, published by the Federal Highway Administration (FHWA), states that a low ground clearance (W10-5) sign should be posted "if the highway profile conditions are sufficiently abrupt to create a hang-up situation for long wheelbase vehicles or for trailers with low ground clearance." [4] As a result, the State and

[2] Obtained from the FRA Office of Safety Analysis website on September 27, 2019: https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/on_the_fly_download.aspx

[3] Jansen, Bart, "Fatal train collision with bus resulted from unsafe, humped road crossing, NTSB says." *USA Today*, August 7, 2018.

[4] Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition, Federal Highway Administration, p. 763: https://mutcd.fhwa.dot.gov/pdfs/2009r1r2/mutcd2009r1r2edition.pdf

local governments responsible for posting roadway safety signs must rely on historical incident data, pay for what might be an expensive civil engineering study, or merely determine the risk based on visual estimation. The resulting condition is one where some warning signs are present at crossings where there is very little risk of hang up, while many crossings with high hang-up potential have no warning signs.

Figure 1 – Humped crossing in Suffolk, VA (Crossing ID 467411X)

Beyond this, there is currently no meaningful measure of what constitutes a low ground clearance condition. Every vehicle is different, with the risk of hang up being a combination of the vehicle's wheelbase, ground clearance and the differential calculus of the curvature of the hump. It is this last factor, which historically has been a challenging metric to capture, that this study aims to simplify.

1.1.1 Past Research

For several years, FRA has been sponsoring research on the use of a LiDAR-based scanner affixed to a railcar to capture point cloud data for the crossings it traverses. According to the National Oceanic and Atmospheric Administration, LiDAR, which stands for light detection and ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.[5] While this approach has produced many accurate grade crossing profiles, there are many challenges to this approach. To be effective, the LiDAR railcar must be on the end of the train, and vehicles cannot be stopped near the tracks in the approach lanes of the crossings. Furthermore, FRA has limited control over which crossings the LiDAR car travels across, and producing each clean LiDAR point cloud requires extensive labor in back-end processing.

Volpe learned about the operation and potential uses of UAV technology when it tested a Matrice 200 as a trespass detection system in Brunswick, ME in 2019. Volpe saw the evolving photogrammetry industry and recognized that drones, combined with specialized software, could produce accurate point clouds at lower cost and with less effort than LiDAR systems. Through the Brunswick project, Volpe has a license for the Pix4D software that was used in that effort.

1.2 Objectives

Volpe sought to determine the viability of using a UAV to capture imagery that can yield accurate point cloud models of humped railroad crossings. In addition, Volpe aimed to determine the pros and cons of photogrammetry (using photographs to produce point cloud data) versus those of airborne LiDAR.

1.3 Overall Approach

Volpe researched photogrammetry requirements and determined an ideal UAV for this project was the DJI Mavic 2 Pro. It's small, lightweight, and features a Hasselblad 20 megapixel camera. Volpe purchased the UAV, smart controller, hard transport case, and landing pad. During testing, Volpe discovered that Pix4D did not support the smart controller, so its autonomous photogrammetry capture program would not function on it. As a result, Volpe purchased a discontinued standard Mavic 2 controller so it could test the autonomous capture feature.

To better understand the pros and cons of both photogrammetry and LiDAR, Volpe issued a contract to a consultant, DroneUp, of Virginia Beach, VA, to produce point clouds of a humped crossing using both technologies. Through this approach, Volpe did not need to purchase its own aerial LiDAR system, plus it could gain the insights of experts in both technologies regarding the capture and back-end processing challenges.

1.4 Scope

This study investigated the viability of using drone photogrammetry to capture accurate point cloud data of high profile railroad crossings that present a hang-up risk to low ground clearance vehicles. It also aimed to explore the strengths and shortcomings of aerial LiDAR as compared to photogrammetry. Finally, this study examined how best to use this information to improve safety at high-profile railroad crossings.

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[5] From the NOAA article "What is LiDAR?" (https://oceanservice.noaa.gov/facts/lidar.html), retrieved October 4, 2019.

1.5 Organization of the Report

This report is organized as follows:

- Section 2 describes the research in UAV photogrammetry, the strengths and weaknesses of airborne LiDAR for point cloud modeling, and the analysis of the data collected during testing.
- Section 3 provides the conclusions.
- Section 4 lists the references used in this report

2. Research and Analysis

Volpe researchers examined two approaches for using a UAV for modeling grade crossings: Photogrammetry and LiDAR. This section describes these studies, and provides an analysis of the how the models can be used to provide safety enhancements.

2.1 Photogrammetry

Photogrammetry is a process for creating 3-dimensional models from a series of interrelated photographs. While this is not a new process, the recent emergence of inexpensive, high-quality UAVs, coupled with the development of modern modeling software tools, has resulted in a new capability for creating highly accurate models with relatively little time and effort. This report details the equipment and procedures Volpe used to create models of humped grade crossings and how these can be used to improve safety at these crossings.

2.1.1 Unmanned Aerial Vehicle

Volpe conducted market research to identify the UAV best-suited for this project. Volpe concluded that the DJI Mavic 2 Pro was the best available option in terms of size, price and capability. Its small, 20-megapixel Hasselblad camera provides rich photographic detail that can create highly detailed photogrammetry models. The Mavic 2 Pro with a smart controller was purchased for $1,899. It is shown in Figure 2 at a grade crossing in Gloucester, MA (Crossing ID 053927W).

Figure 2 – DJI Mavic 2 Pro at humped crossing in Gloucester, MA (Crossing ID 053927W)

Volpe also purchased a hard case and landing pad for the drone, along with spare memory chips and other accessories, totaling approximately $200. Registering the drone with the Federal Aviation Administration (FAA) cost $5. During testing, Volpe discovered that Pix4D did not support the DJI smart controller, so its autonomous image capture program would not work. Volpe purchased a standard Mavic 2 controller for $325, which uses an iPhone as a processor and display, and on which the Pix4D image capture application worked well. Two Volpe researchers with FAA remote pilot certification operated the UAV during this project.

2.1.2 Photogrammetry Software

Volpe had an existing perpetual license for Pix4D software from a previous project in Brunswick, ME using UAVs to perform trespasser detection. This software takes drone imagery and, with the help of the GPS data captured with the images, creates 3-dimensional models from detailed point clouds.

Pix4D can use any imagery to create point clouds, including videos and photos taken from cell phones. However, best results are achieved when individual images are captured with the DJI drone because these also capture the GPS data for each picture, which helps the software associate the images with one another.

Pix4D requires significant processing power. Because of this, Volpe set up a dedicated computer with an Intel® Core™ i7 1.9GHz processor, a 2TB solid-state drive and 32GB RAM. Even with this configuration, researchers found that Pix4D took 5–6 hours to produce models from 300–400 aerial images.

To achieve greater accuracy, there are several manual steps that can be taken. One is to establish manual tie points (MTPs) – specific points in multiple images that can help the software tie images together. This time-consuming step is especially important when incorporating images taken from different perspectives or from different cameras. Other techniques for improving accuracy involve laying a tape measure of known length on the ground and measuring the height of vertical poles within the scene so they can be manually scaled within Pix4D.

Another tool for achieving improved accuracy is the use of ground control points (GCPs). A survey team places targets on the ground within the scene then employs a total station system, a highly accurate surveying device that uses differential GPS to provide very accurate position data for each GCP. Total station systems range from $5,000 to $18,000, depending on the level of accuracy and autonomy desired.

Figure 3 shows a Pix4D point cloud along with the cameras that captured each image used to produce it. This test site was a humped crossing on Stanwood Avenue in Gloucester, MA (Crossing ID 053927W). The circular pattern of the cameras resulted from using the Hyperlapse application installed on the smart controller. This application flies the drone and captures the images autonomously.

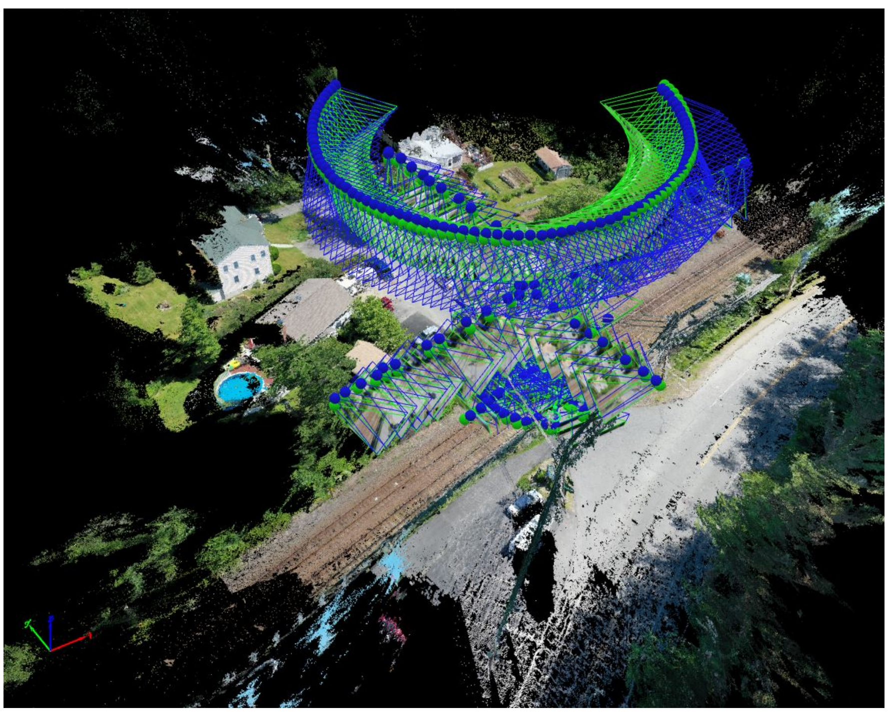


Figure 3 – Point cloud and camera positions from Gloucester test site

In processing the Gloucester test data, Volpe discovered several challenges in producing a 3-dimensional model. Power lines (often present at grade crossings) cause anomalies in the models, as Pix4D tends to interpret them as edges of a surface. While these wires are located well above the roadway (which is the subject of our modeling) they are nonetheless something researchers did not want included in the model. Figure 4 shows a still image of the 3-dimensional model produced by Pix4D showing the artifact above the tracks. Through this test, Volpe learned of the need to “clean up” point cloud data in the Pix4D back-end processing. While there are several techniques, the simplest proved to be one where additional photographs were taken at ground level which showed the wires. These images could be included in the Pix4D project and then used as screening images to delete large areas of the sky where the artifacts were present.

Figure 4 – Frame capture of a 3-dimensional rendering showing anomalies caused by overhead wires

The Volpe team found that UAV photogrammetry could produce accurate grade crossing models, but there were also challenges involved. Volpe then sought to investigate if airborne LiDAR was a better solution for this task.

2.2 LiDAR

Creating point cloud models using LiDAR scanners has been an accepted practice among mapping and surveying professionals for several years. More recently, small, lightweight LiDAR sensors have been developed for use on UAVs.

Volpe issued a contract to DroneUp of Virginia Beach to help answer that question. DroneUp provides commercial UAV services using both photogrammetry and LiDAR, so they were hired to model a nearby humped crossing using both technologies.

The modeling was conducted on August 6, 2019 at the Lake Meade Drive grade crossing in Suffolk, VA (Crossing ID 467411X). This crossing, previously shown in Figure 1, has a substantial hump and was marked with low ground clearance (W10-5) signs. DroneUp used a DJI Matrice 600 with a Velodyne Puck 16 LiDAR system for the LiDAR scanning, and a DJI Phantom 4 Pro V2 with a 20-megapixel camera for the photogrammetry work. The LiDAR scanning system is shown in Figure 5.

Figure 5 – DroneUp's DJI Matrice 600 with Velodyne LiDAR system

DroneUp informed the research team that there is substantial setup time involved in the LiDAR equipment prior to flight. The differential GPS system requires up to an hour to lock in on satellites and provide the level of positional accuracy required by the LiDAR scanner.

2.3 Analysis

The determination of whether a vehicle can travel over a humped crossing without becoming stuck is a function of the vehicle's ground clearance, wheelbase, and the rate of change of the curvature of the hump. For simplicity, this study used a 30-foot wheelbase as a worst-case scenario, since most lowboy trailers and motorcoach buses have wheel bases between 24 and 30 feet. While there are some low vehicles with longer wheelbases, these are rare and their drivers are likely aware that they pose an unusually high risk of hang up.

In Figure 6 below, the high-risk hang-up points of a humped grade crossing are illustrated in cross-section. Note that it's not the height of the hump that is important, it's the rate of change of the curve. Areas with sharp "peaks," which may or may not occur near the highest point of the hump, yield the highest hang-up risk. Each red line segment shown in the figure represents 30 feet in length, and the locations with the most severe convex curvature are shown as perpendicular measurements. If the highest of these measurements exceeds the vehicle's ground clearance, it will strike the ground and be at risk of becoming stuck.

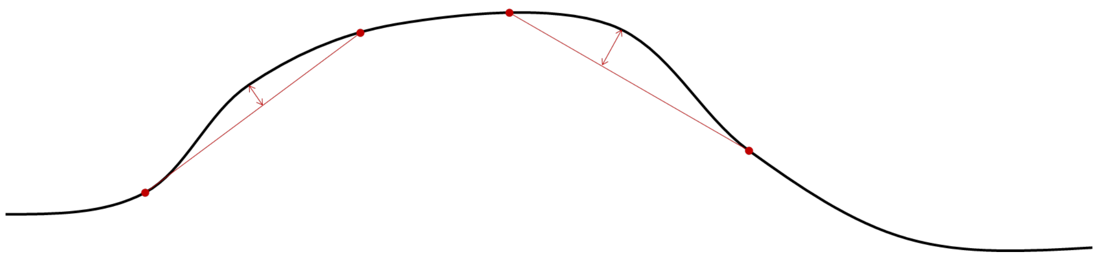
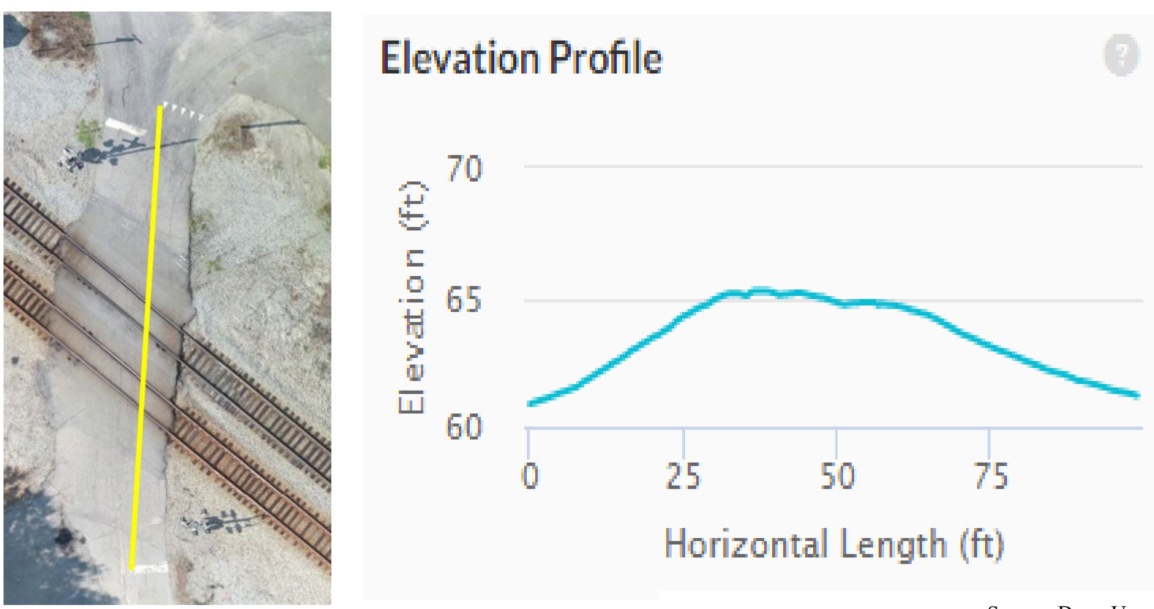


Figure 6 – Illustration of the hang-up points of a humped grade crossing

Following the DroneUp photogrammetry and LiDAR flights at the grade crossing in Suffolk, Volpe met with the DroneUp team at their offices in Virginia Beach. In short, both LiDAR and photogrammetry produced accurate models of the grade crossing. Below are the key findings:

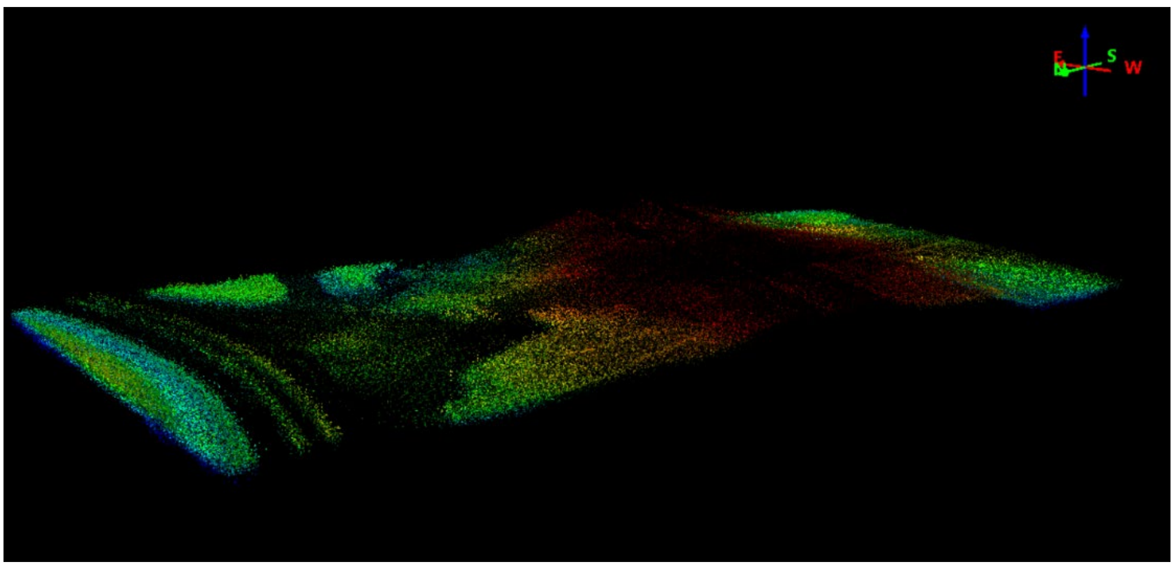
- Because there currently is no software tool to aid in the calculation of the perpendicular peaks shown in Figure 6, DroneUp instead focused on calculating the peak height of the cross-section of the grade crossing across its entire 97-foot length from stop bar to yield point, as shown in Figure 7. The maximum difference in elevation across its length was calculated by DroneUp as follows:
    - LiDAR: 4.46 feet
    - Photogrammetry without GCPs: 4.4 feet
    - Photogrammetry with GCPs: 4.46 feet



Source: DroneUp

Figure 7 – Cross section of the Lake Meade Drive grade crossing (Crossing ID 467411X)

- In addition to the extra pre-flight time required to set up the LiDAR's differential GPS system, it takes significantly more skilled labor to process the LiDAR data than the photogrammetry data. DroneUp later told Volpe it took approximately 4 days in point cloud editing to fully process the LiDAR data, while the photogrammetry data was processed almost completely autonomously in about 4 hours. The biggest reason for this difference is that LiDAR data cannot be viewed and oriented visually, and the tools for processing it are not as automated. Photogrammetry data, which is comprised of photographs, is much easier to visualize and tools such as Pix4D are largely automated. Often, LiDAR analysts will overlay GPS-pinned photographs to aid in orientation.
- DroneUp produced 3-dimensional renderings of the crossing using LiDAR and photogrammetry. A screen capture of the LiDAR rendering is shown in Figure 8, and a screen capture of the photogrammetry rendering is shown in Figure 9. While these renderings are helpful in recognizing anomalies that can result from incorrect or incomplete point cloud processing, they do not aid in calculating the hang-up risk.



Source: DroneUp

Figure 8 – Screen capture of a 3D model of Lake Meade Drive crossing using LiDAR

Source: DroneUp

Figure 9 – 3-dimensional rendering of Lake Meade Drive crossing using photogrammetry

3. Conclusions

While there are guidelines for constructing new highway-rail grade crossings aimed at preventing vehicles from becoming stuck on the tracks, there is currently no formula or threshold for determining if an existing crossing presents a risk for low ground clearance vehicles, or if it should be posted as such. It is left to States and municipalities to determine the risk through whatever means they choose.

Both photogrammetry and LiDAR data captured from drones are capable of producing highly accurate three-dimensional models of high profile grade crossings. However, LiDAR models require equipment that is much more expensive, and processing the data is far more labor-intensive than photogrammetry.

To make effective use of these models, Volpe recommends FRA pursue the development of a software tool that can analyze 3-dimensional models of grade crossings to produce a single number: the inches of ground clearance required for a vehicle with a 30-foot wheelbase to safely traverse a grade crossing. In much the same way drivers are warned of a low bridge by the posted height, Volpe suggests that drivers of trucks and buses should be warned of humped crossings by having the inches of required ground clearance posted. Photogrammetry offers a cost-effective way to model the crossing, but a software tool to analyze those models to produce this number does not yet exist.

Currently, there is a field in the FRA grade crossing inventory database to indicate if a crossing presents a hazard for low ground clearance vehicles. Volpe recommends adding a field to indicate the actual ground clearance (in inches) required for most vehicles to safely traverse the crossing.

Finally, Volpe recommends working with FHWA to amend the MUTCD to make posting the required clearance at high-profile crossings part of the standard notification to drivers.

4. References

Federal Railroad Administration. Office of Safety Analysis database.

Jansen, B. (2018, August 7). Fatal train collision with bus resulted from unsafe, humped road crossing, NTSB says. *USA Today*.

Federal Highway Administration. (2009). Manual on Uniform Traffic Control Devices for Streets and Highways, p. 763.

National Oceanic and Atmospheric Administration. What is LiDAR?

Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
AREMA	American Railway Engineering and Maintenance-of-Way Association
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
GB	Gigabyte
GCP	Ground Control Point
GPS	Global Positioning System
HRI	Highway-Rail Intersection
LiDAR	Light Detection and Ranging
MTPs	Manual Tie Points
MUTCD	Manual on Uniform Traffic Control Devices
NOAA	National Oceanic and Atmospheric Administration
RAM	Random Access Memory
RD&T	Railroad Development and Technology
ROW	Right-of-Way
TB	Terabyte
UAV	Unmanned Aerial Vehicle
U.S. DOT	U.S. Department of Transportation
Volpe	John A. Volpe National Transportation Systems