A Method for Creating Photograph Textured Planes and Camera Positions in HVE Simulations

Brad R. Shults
Ponderosa Associates

ABSTRACT

A method for creating photograph backgrounds in HVE is presented. This method is useful for comparing simulation results to accident photographs evidencing the scene. Through the use of survey equipment, photogrammetry software, and CAD software, a user may calculate the photograph plane and respective camera position in three-dimensional space of a particular photograph. A process for determining the three-dimensional camera position and photograph plane center is presented. A process for creating the photograph texture for HVE is presented. After presenting the above processes, an example crash from the 2011 ARC-CSI Crash Conference is presented. Additionally, a case study photograph background is presented. Finally, results are discussed and recommendations for future work are presented.

INTRODUCTION

The purpose of presenting this procedure is to define a relatively quick and effective method for creating a realistic scene without going to the extent of creating time intensive scene surfaces, textures, and rendering outputs that are often created with more robust animation programs from HVE simulation outputs. From survey measurements, or in some cases 2D traces from an aerial, an HVE user can solve for properties important to accurately placing a photograph background plane and viewing camera. This allows the user to compare evidence predicted in an HVE simulation (whether it be a EDSMAC4, SIMON, or another HVE simulation program) against the evidence observed in an accident photograph. In addition, this method allows the user to create an accident specific background. This allows involved parties to reference familiar landmarks and more easily describe the accident. The method presented in this paper may be applied to an accident site photograph, scene inspection photograph, or even a street view image from publicly available databases.

PROCEDURE

Before describing the specific procedure developed for placing a photograph background plane and camera position into an HVE scene, it is important to realize that other software packages and methods can be used to meet the same end. The procedure developed in this paper is the most streamlined method this author has been able to develop with survey equipment, PhotoModeler, 3D Studio Max, AutoCAD, and HVE. If a reader does not have all of these programs at their disposal, other programs or methods can be substituted to reach the same end. At a bare minimum, a user could implement this method with a camera, measuring tape, and HVE.

The general procedure steps are as follows:

1) Collect Measurements: Measure the accident scene.
2) Photogrammetry: Determine the camera location and photograph plane coordinates via photogrammetry.
3) Export to CAD: Export the photograph plane to a CAD program containing the scene data planned for HVE simulations.
4) Scale Photo Plane: Scale the photograph plane from the camera location such that the photograph plane extends beyond all scene data. This will make for cleaner simulation images during video creations.
5) Create a Square Aspect Ratio: Create a square plane around the extents of the photograph plane. This helps to maintain the photograph detail in an HVE texture.

6) Save as a JPEG: Create a square plane containing the centered photograph as a JPEG. This JPEG should be saved to the user's HVE > supportFiles > images > environments > EnvTextures – folder.
7) Texturing in HVE: Texture the square plane with the saved JPEG. Sometimes the JPEG will require mirroring and/or rotation due to sign conventions within a specific scene.
8) Enter Camera Setup Properties: Within a simulation event, create a "camera setup" view with the "Look At" properties being the photo plane center created when the photograph was scaled over the extents of scene data. Enter the "View from" properties from the photogrammetry work performed to solve for the camera position.

The previous procedure step explanations were over simplified to aid the general understanding of the process. Once the general process is understood, it is anticipated that the reader can use other programs and methods to meet the same end of placing a photograph plane and camera position into an HVE simulation study. A more detailed explanation of these steps will now be presented.

Procedure Step 1 – Collect Measurements

The accident scene needs to be measured and have several recognizable reference points available in the same photograph that a user wishes to create as a background for HVE simulations. For flat scenes with a high clarity aerial, it is often possible to solve for a camera's positions from an aerial trace of features on the roadway. Skip lines, road edges, joint lines, building bases, and other examples will often allow a user to roughly determine a camera position. Higher accuracy in calculating the camera position is obtained when using three-dimensional survey data, especially when the scene is contoured and elevation changes are significant.

Figure 1 depicts an example accident photograph. This photograph is a staged collision from the 2011 ARC-CSI Crash Conference in Las Vegas, Nevada. Select survey points are green dots circled in red. These points are a good example of adequate spread. In general, when using photogrammetry to determine a camera position and photograph plane, the more angular separation between points (e.g. spread on a single photograph image) the better the accuracy in triangulating the camera position. At the end of the process this creates a better alignment with the photograph background to the HVE simulation scene.

The circled reference points are used by a photogrammetry software package to determine the three-dimensional location and focal length of the camera used to take the photograph. It is beyond the scope of this paper to present the details and methodology of photogrammetry; however, the basic relation between survey measurements, photogrammetry, and HVE photograph properties will be described to a level such that one familiar with photogrammetry methods, CAD, and HVE will be able to recreate and understand the process of defining the camera's location and the photo plane's center. Ultimately, this process allows the user to enter calculated three-dimensional coordinates in HVE for a camera's "View from" and "Look at" input cells.

Figure 1 – Photogrammetry Control Points
Note: Larger figures are presented in the Appendix

Procedure Step 2 - Photogrammetry

Now that the X, Y, and Z distance relations between several points in the photograph are known, photogrammetry may be performed to determine the camera and photograph plane relationship.

Figure 2 depicts the PhotoModeler photogrammetry results for the cameras and photograph planes. Survey data is magenta. The camera positions are represented by blue camera symbols (containing X, Y, Z coordinates). Two cameras and photograph planes were solved for in this example. The resulting simulation views are presented in greater detail in the Results section.

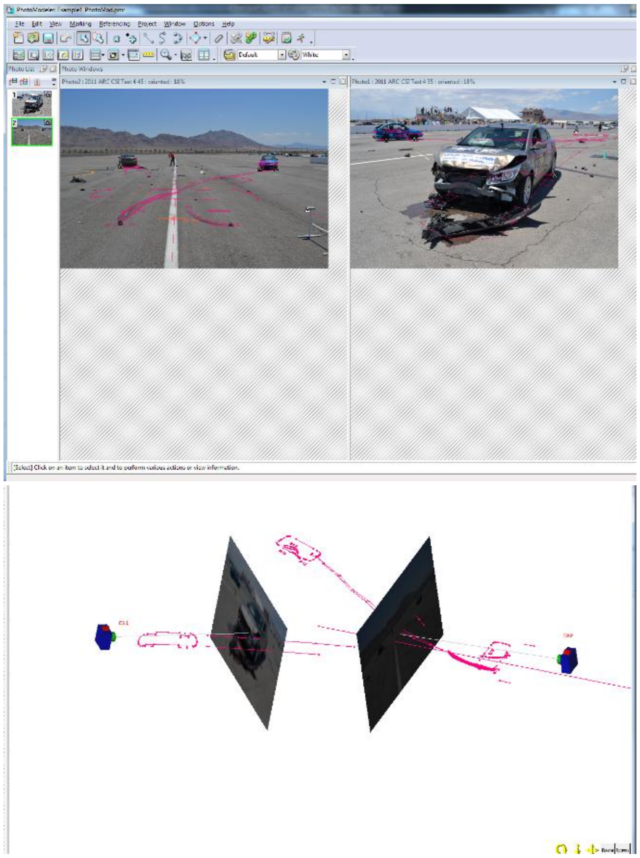

Figure 2 – Photogrammetry Results

Procedure Step 3 – Export to CAD

The camera and photo plane positions have been defined via photogrammetry. The results should now be exported into a CAD program so the photograph planes can be prepared for HVE representation. PhotoModeler's export option "Max Script .ms" allows this information to be exported such that the photograph planes can be prepared in CAD for representation in HVE. Figure 3 illustrates the results of opening the .ms export in 3D Studio Max.

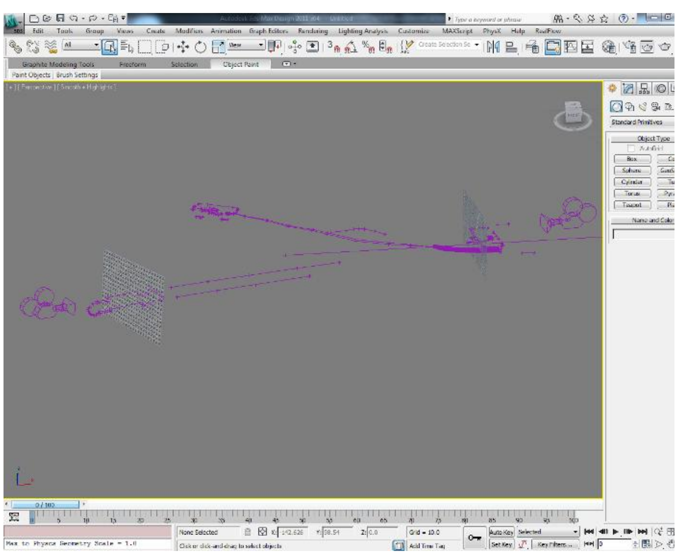

Figure 3 – Max Script Results in 3DS

After opening the exported .ms file in 3D Studio Max, the next step is to export the scene to a CAD program such as AutoCAD. Exporting from 3DS as an AutoCAD file (DWG or DXF) is this author's preferred method. Again, different users will have different preferences to reach the same end. The results of the export are presented in Figure 4 (the photograph planes are highlighted by blue coloring while the magenta colored data represents the survey data from the crash testing).

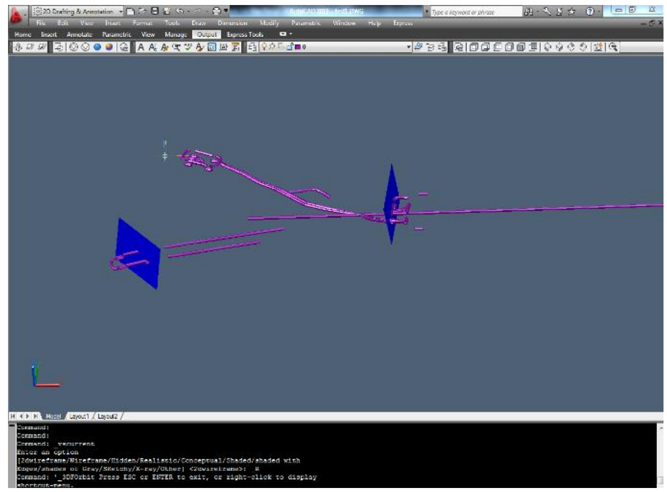

Figure 4 – Photo Planes in AutoCAD

Procedure Step 4 – Scale Photo Plane

Once the photo planes have been imported into AutoCAD, the next step is to scale the photographs beyond the extent of scene geometry data. To do this the user needs to place a point for the solved camera location. The three-dimensional camera points are available from the results of photogrammetry. The camera point will be used as the base scale point for the respective photograph plane. This scaling process will improve the appearance of the HVE simulation work and will allow the user to compare the photograph perspective matchup with the scene geometry data. Figure 5 depicts the scaling process.

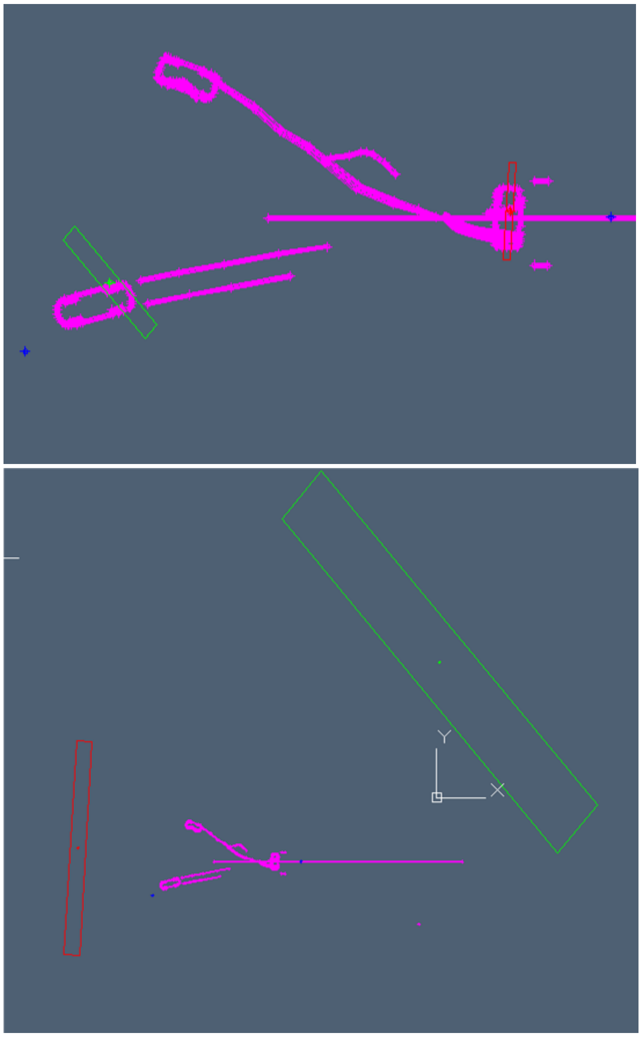

Figure 5 – Scaling Photo Planes in AutoCAD Beyond the Extent of Survey Data

Note: The top figure is before scaling and the bottom figure is after scaling. Scaling is performed at the blue camera points.

Procedure Step 5 – Create a Square Aspect Ratio

Next, the photograph planes need to have an overall square plane surrounding the extents of the photograph area. This is helpful for maintaining the aspect ratio and perspective of the photograph when HVE texturing is applied to the plane. It is helpful to keep the rectangular photograph plane outline as a sizing guide for texturing work within HVE. It is also helpful to have a square plane larger and over extending the longest aspect ratio of the photograph plane. This allows users to check that all of the photograph imagery has been textured into HVE and assure that nothing has been "cropped out" during the texturing process. Figure 6 illustrates the results of adding a square texture plane to the center of the photograph plane. The square planes are light blue in color.

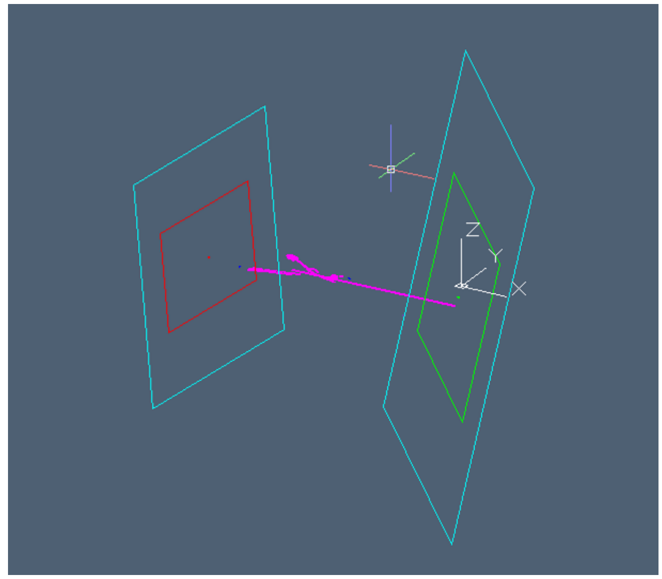

Figure 6 – Creating Square Planes in AutoCAD

Procedure Step 6 – Save as a JPEG

Now square JPEGs need to be created for the HVE textures. A simple method is plotting square images with AutoCAD's plot to JPEG feature. Figure 7 depicts the square regions that are plotted (5,000 by 5,000 pixels is a good JPEG plot size) and saved to JPEGs for future textures. These JPEGs should be saved to the user's HVE > supportFiles > images > environments > EnvTextures – folder.

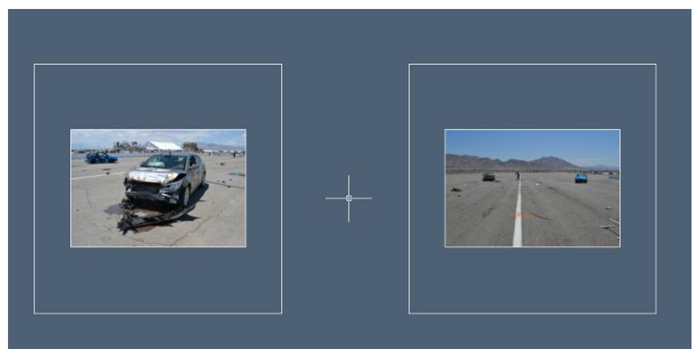

Figure 7 – AutoCAD JPEG Plotting Setup

Procedure Step 7 – Texturing in HVE

The scene can now be imported into HVE and the photograph planes textured with the JPEG images. It is helpful to have each photograph plane a unique color when importing from a CAD program. HVE separates objects by color in the scene's geometry during import. This will allow a user to individually select, control, and manipulate each photograph plane independently from one another. The process for applying the textures is the same as applying any texture in HVE. Simply use the 3-D Edit > Launch 3-D Editor and then adjust material colors and material textures. Often times it is best to change the photograph plane colors from their original color to all white with minimal shine/gloss.

Photograph planes can also be made transparent to improve camera views when creating a video from the simulations. The results of texturing the photograph planes are presented in Figure 8.

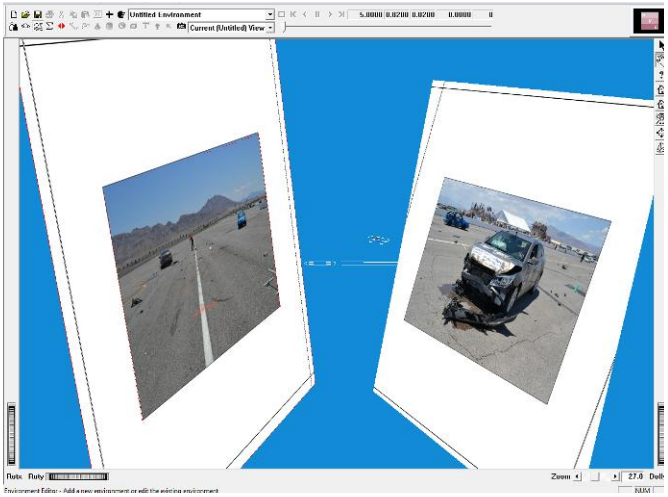

Figure 8 – JPEGs Applied as HVE Textures in Simulation Scene

<u>Procedure Step 8 – Enter Camera Setup Properties</u>

The last step is to create cameras with properties that match the results of previous photogrammetry and CAD workup. The photogrammetry work should provide the user with the camera location. Recall that HVE uses SAE sign convention standards. Depending on the software used for buildup work, this will often require the user to flip the sign results for y and z coordinates about the x-axis. The camera setup should view from the solved for photogrammetry camera coordinates and look at the center of the photograph plane after it was scaled beyond the survey data in the CAD work. From this point on, regular simulation work may be performed and the results compared against a photograph background may be examined. In addition, video output can be created and more realism is achieved. Various transparency settings allow a user to highlight various evidence and surfaces. Transparency settings also will allow a user to remove photograph planes from view so that traditional simulation work may be carried out. This is especially useful if a particular scene and simulation have several views a user wishes to analyze or present. Figures 9 and 10 illustrate the ARC-CSI Crash vehicles approaching their areas of rest during HVE simulation studies.

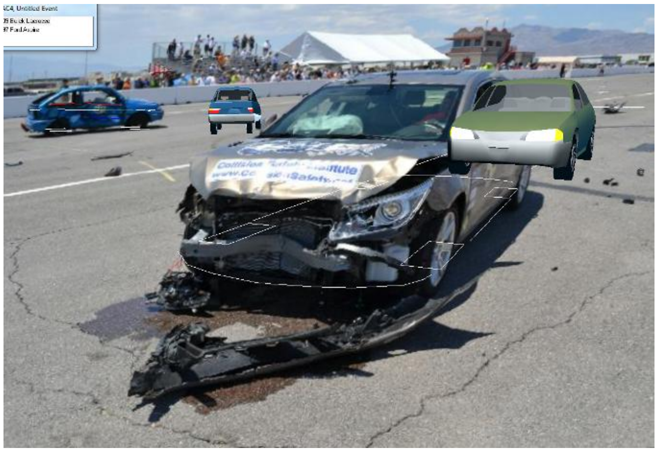

Figure 9 – HVE Simulation Study View #1

Figure 10 – HVE Simulation Study View #2

RESULTS: CASE STUDY EXAMPLES

The above procedure will now be applied for two examples. The first example will be familiar as it is the same 2011 ARC-CSI Crash Conference staged collision that was used to present the overall procedure of applying photograph backgrounds. The second example will be an altered case study example that was investigated by Ponderosa Associates.

The first example involves a 1997 Ford Aspire and 2011 Buick Lacrosse. This example is intended to highlight the capability of comparing a simulation predicted area of rest to the area of rest evidenced in an accident site photograph. Note that further work could be implemented to match simulation tire mark prediction to the tire marks witnessed in the accident site photograph. This would involve fine tuning many parameters such as road friction, tire friction settings, braking, tire damage, suspension, and other components. In this special case where we have complete accident scene video that can be directly compared to simulation video output, even more work could be done to closely replicate yaw rotation rates, crush deformation rates, and overall decelerations. The scope of this example is to simply highlight the utility of using photograph backgrounds within HVE to quickly compare the simulation results against the observed evidence. Appendix Figures 11 through 13 depict the results of this comparison.

The second example is a case that Ponderosa Associates has worked on. The collision and involved vehicles have been altered from the actual case; however, the background imagery, scene survey data, scene surfaces, and camera positions match actual casework results. The purpose of this example is to demonstrate the utility of adding a scene inspection photograph to create a photo-realistic background. Note that in this example no comparisons are made to areas of rest as this was a case where no quality accident site photographs were taken or provided. The utility of creating this background is to aid witnesses and parties involved in describing the accident. Landmark references such as dirt road turnouts, fences, buildings, and culverts are often referred to by involved parties. Also, critical issues such as available sightline and certain perspectives at a given location can be better expressed and judged by viewers. Adding a scene photo background can aid descriptions and improve the effectiveness of a simulation in conveying key concepts. Appendix Figures 14 through 18 depict the visual results of this hypothetical case.

CONCLUSIONS

By acquiring scene measurements, performing photogrammetry, and by using various software programs it has been shown that evidence photographs can be accurately incorporated into HVE simulation studies. These photographs aid a reconstructionist in matching critical evidence and presenting available sightlines. In addition, these photographs bring a real world aspect to the simulations in a relatively quick turnaround. Once a user has gained experience with the presented process, a simulation scene with a photograph background can often be created in one day. Although various animation programs might be more robust in offering various lighting conditions, driver perspectives, witness perspectives, and camera rigs, the procedure presented within this paper is a quick and simple way to achieve similar results without spending the time or resource required to render more complex animations from HVE simulation outputs.

The procedure presented in this paper does have shortcomings. In general, HVE textures seem to have increased perspective accuracy when the photograph is less tilted relative to the scene. Perspective matching has known issues from photogrammetry software work to exporting to various CAD programs. PhotoModeler has developed tools to minimize perspective matching errors. It is beyond the scope of this paper to fully address the software issues involved with perspective matching accuracy, yet it is important to be aware of the issue.

Finally, the method of applying a photograph background in an HVE simulation increases the utility of HVE. Unique applications exist that this author has been successful in applying the above outlined method. Such applications include cases involving bicycles, snow mobiles, tubing hills, ski slopes, and others. By applying this method with some creative CAD work, a user will find many perception-reaction cases may be examined in greater detail within HVE than they may have originally thought possible.

RECOMMENDATIONS FOR FUTURE WORK

As was briefly discussed earlier in this paper, two concepts should be further investigated.

The first concept is the relation between HVE texturing and the photograph plane's three-dimensional angular position. It is suspected that perspective matching error increases as the photograph plane tilt increases (i.e. when the photograph plane becomes less orthogonal to the scene's horizon). Roll and yaw angles of the photograph plane also seem to influence the perspective matching quality. It is suspected that the processing technique that HVE software uses for texturing, which requires square imaging to maintain clarity, is the main issue for losing clarity of a photograph's perspective match to scene data as the photograph plane becomes less orthogonal. Deriving a method of quantifying the reduced perspective matching to the relation of the photograph's plane angle would be an interesting and valuable study.

Secondly, if possible, the overall procedure should be streamlined to include less legwork, file management, and required software programs. Ideally, a user would be able to perform photogrammetry and enter parameters into a sub program that automatically textures and surfaces photograph planes according to the controlling variables. Such variables include photogrammetry results, extent of scene data, and aspect ratios of evidence photographs.

AUTHOR CONTACT DETAILS

Questions, concerns, or comments may be sent to bshults@ponderosa-assoc.com.

Appendix Figures

Figure 1 – Photogrammetry Control Points

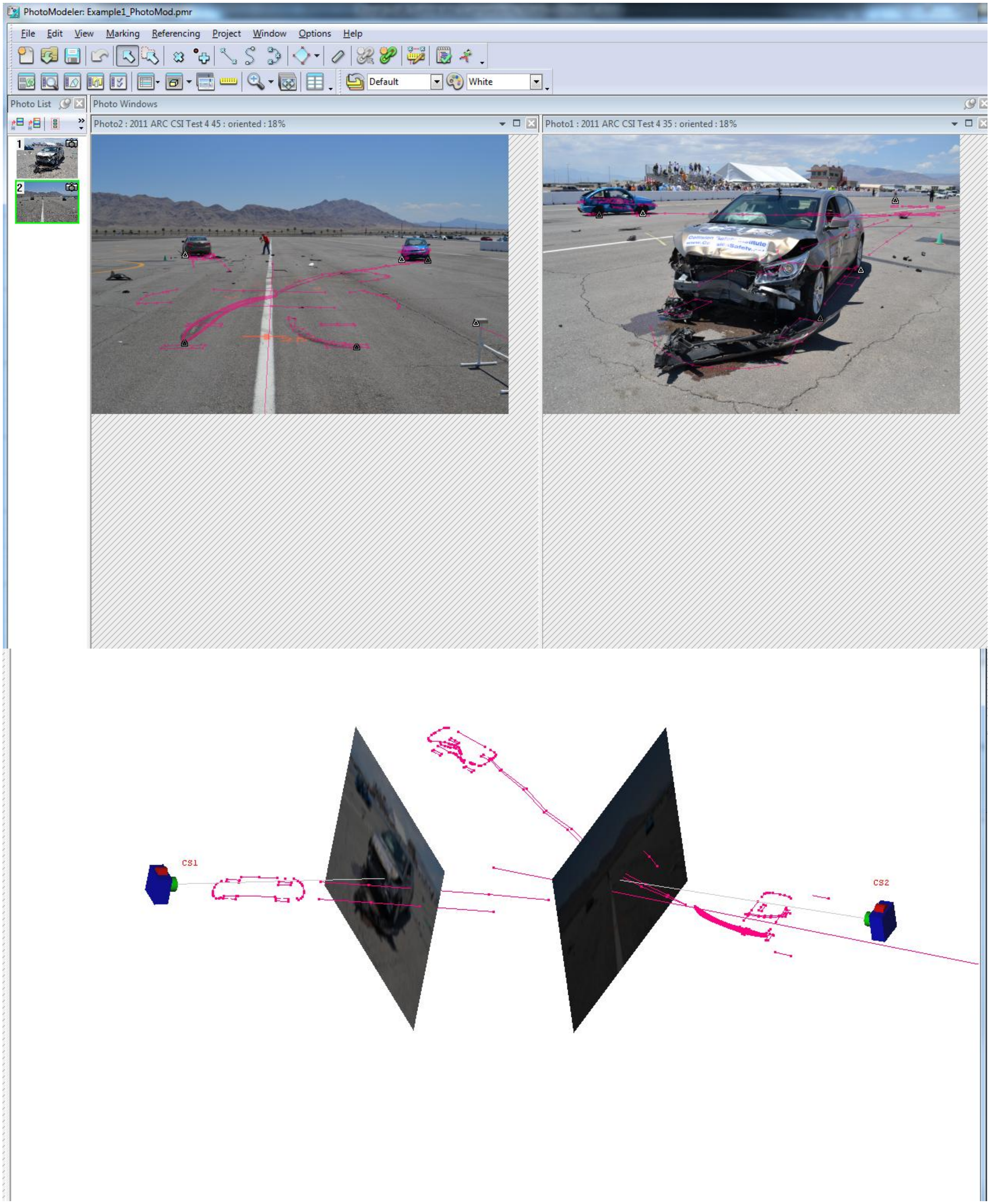

Figure 2 – Photogrammetry Results

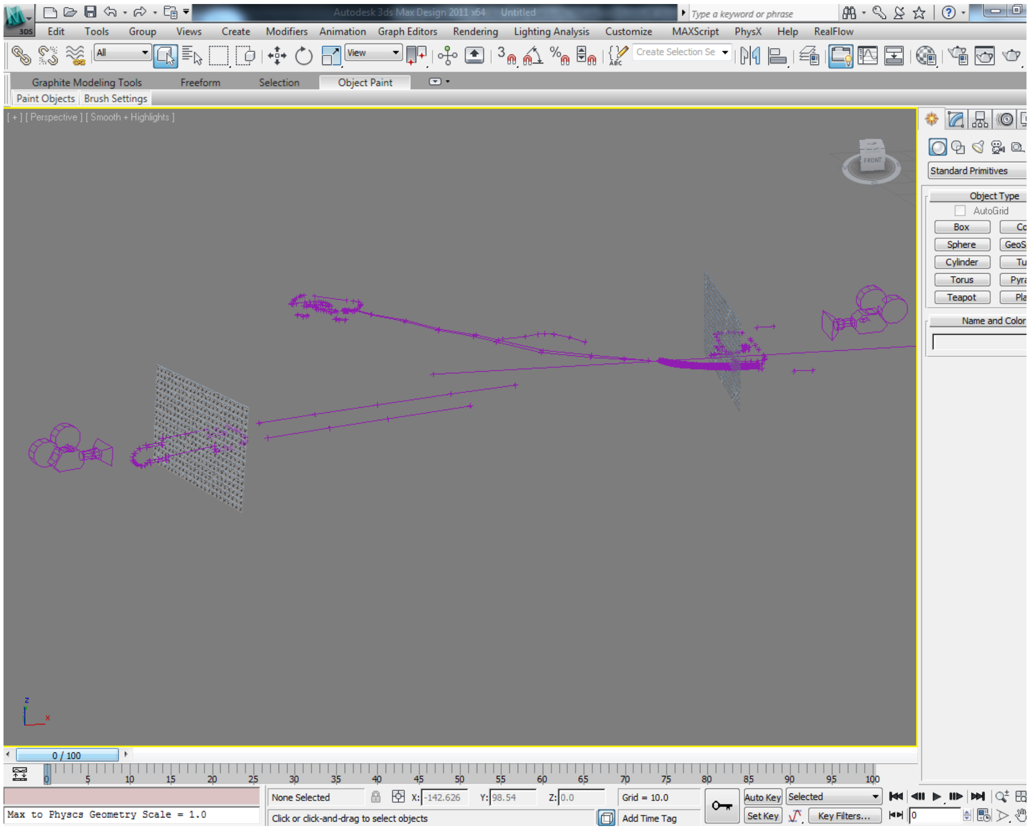

Figure 3 – Max Script Results in 3DS

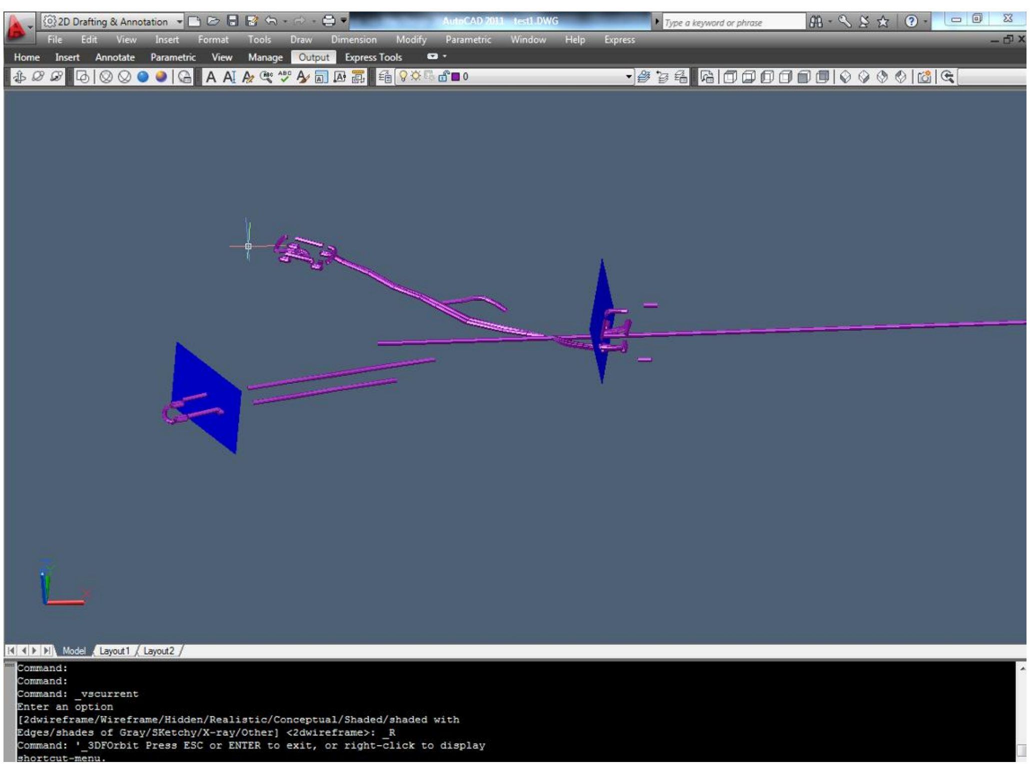

Figure 4 – Photo Planes in AutoCAD

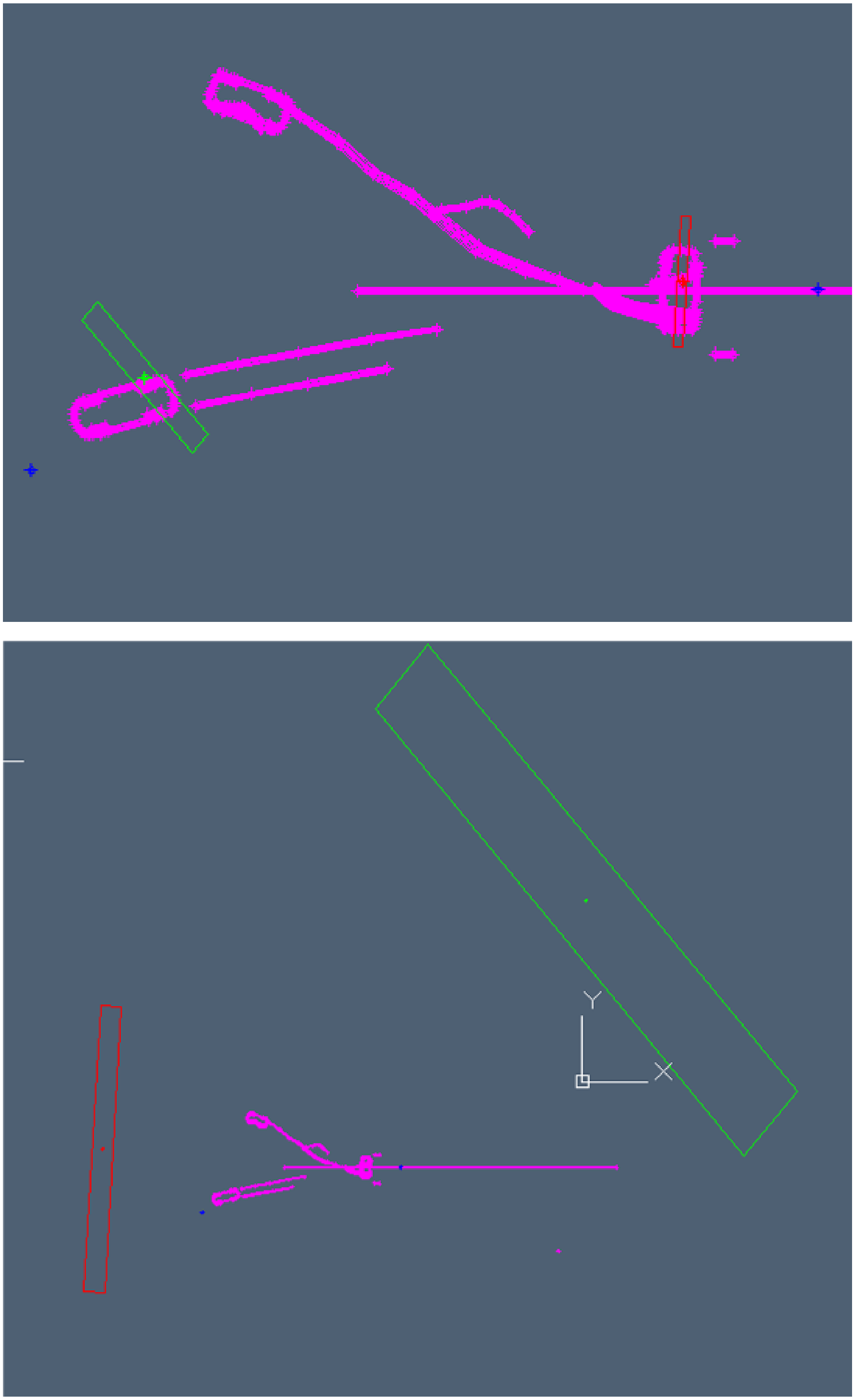

Figure 5 – Scaling Photo Planes in AutoCAD Beyond the Extent of Survey Data

Note: The top figure is before scaling and the bottom figure is after scaling. Scaling is performed at the blue camera points.

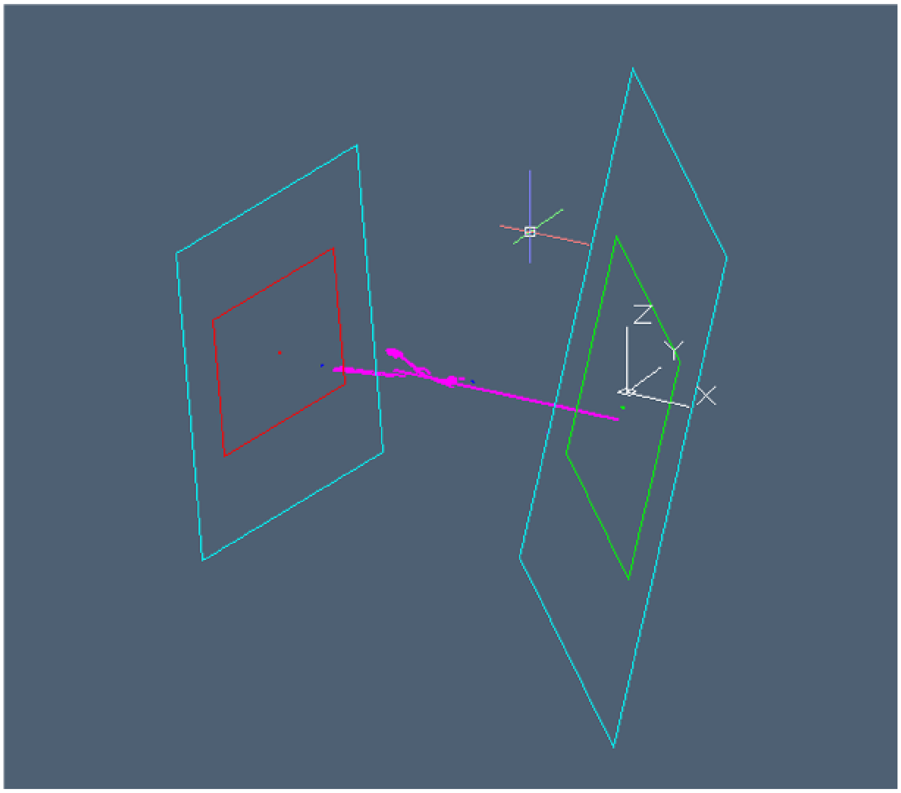

Figure 6 – Creating Square Planes in AutoCAD

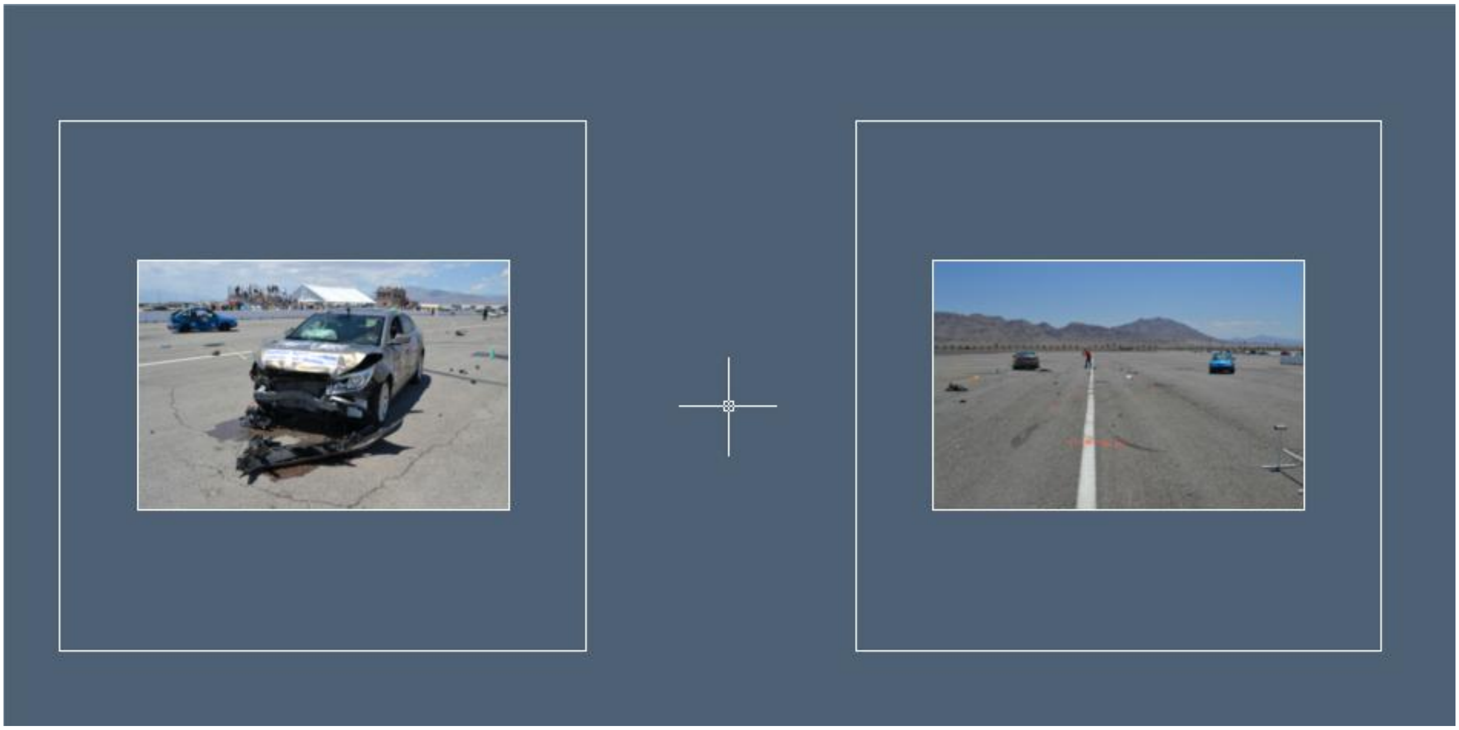

Figure 7 – AutoCAD JPEG Plotting Setup

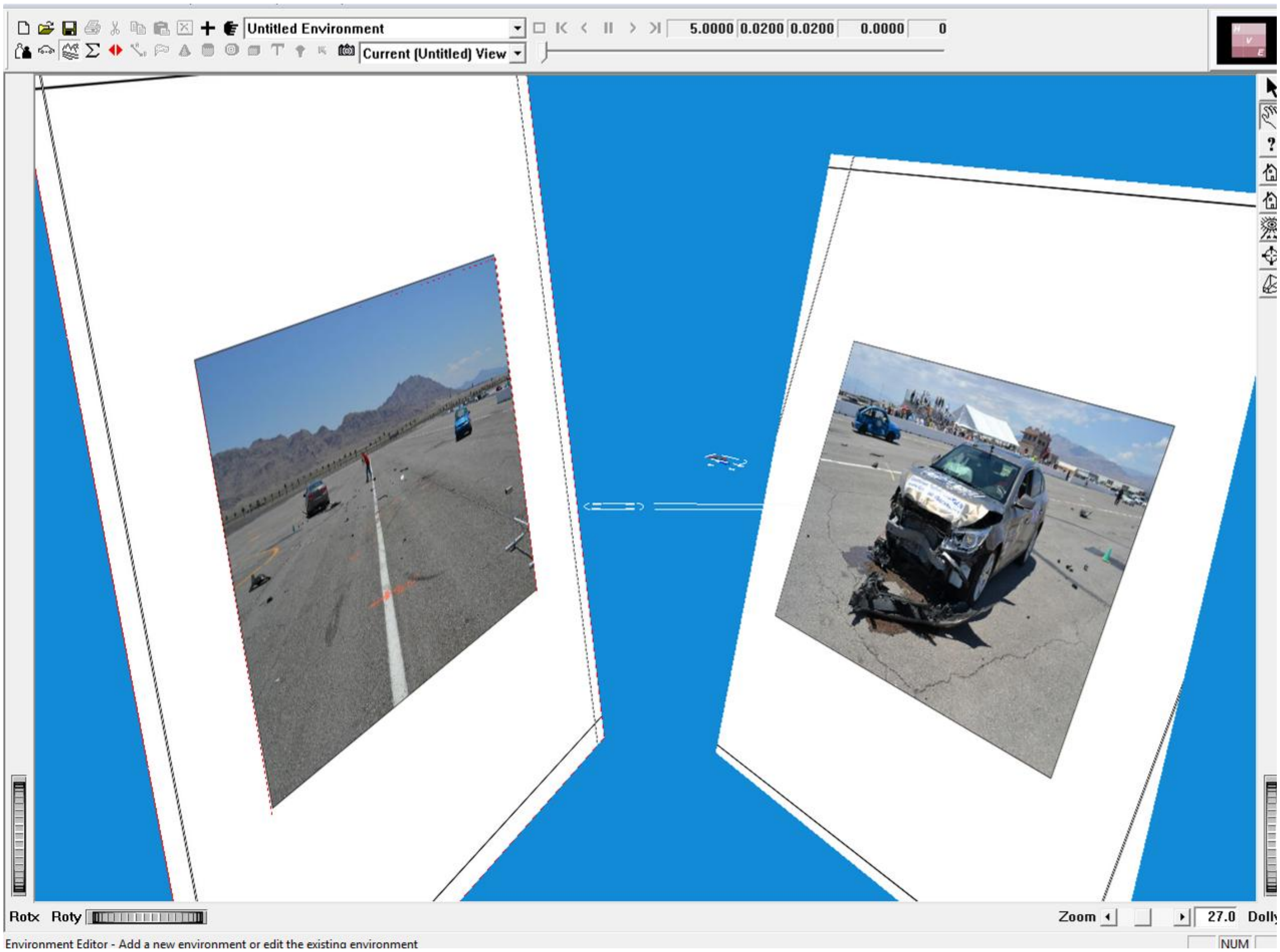

Figure 8 – JPEGs Applied as HVE Textures in Simulation Scene

Figure 9 –HVE Simulation Study View #1

Figure 10 – HVE Simulation Study View #2

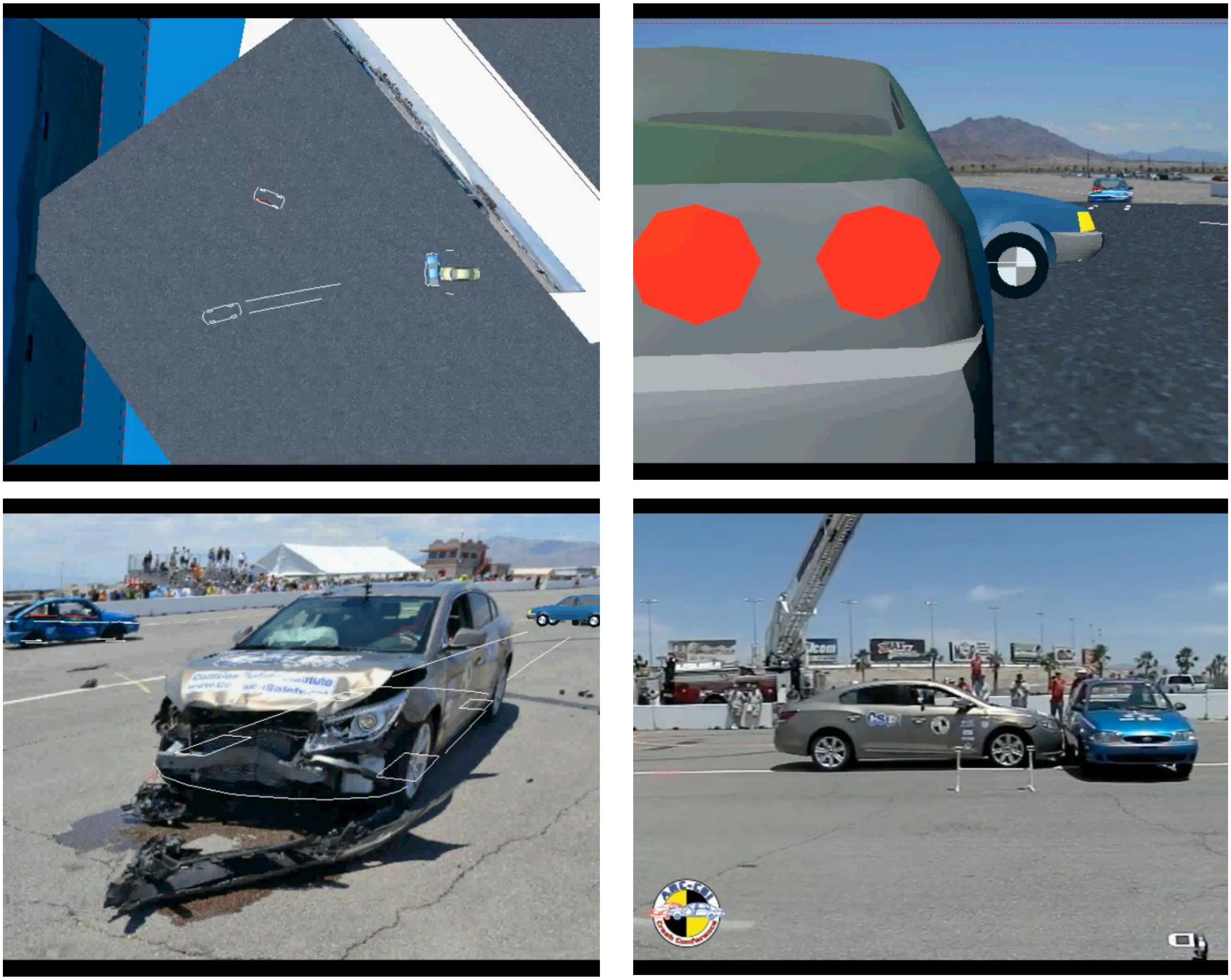

Figure 11 – 2011 ARC/CSI Crash Test and HVE Simulation Comparisons at Impact

Figure 12 – 2011 ARC/CSI Crash Test and HVE Simulation Comparisons at Midpoint Post Impact Travel

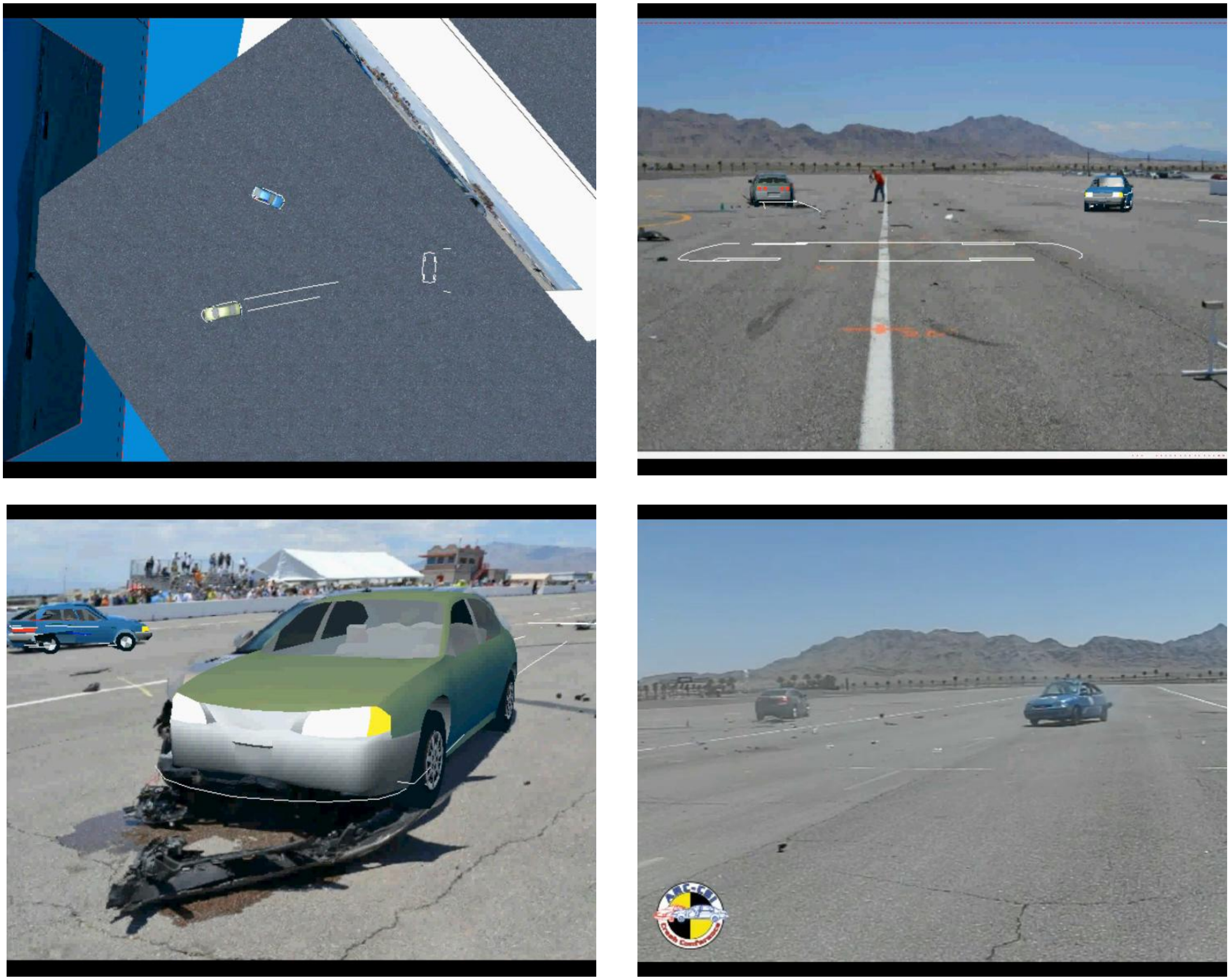

Figure 13 – 2011 ARC/CSI Crash Test and HVE Simulation Comparisons at Areas of Rest

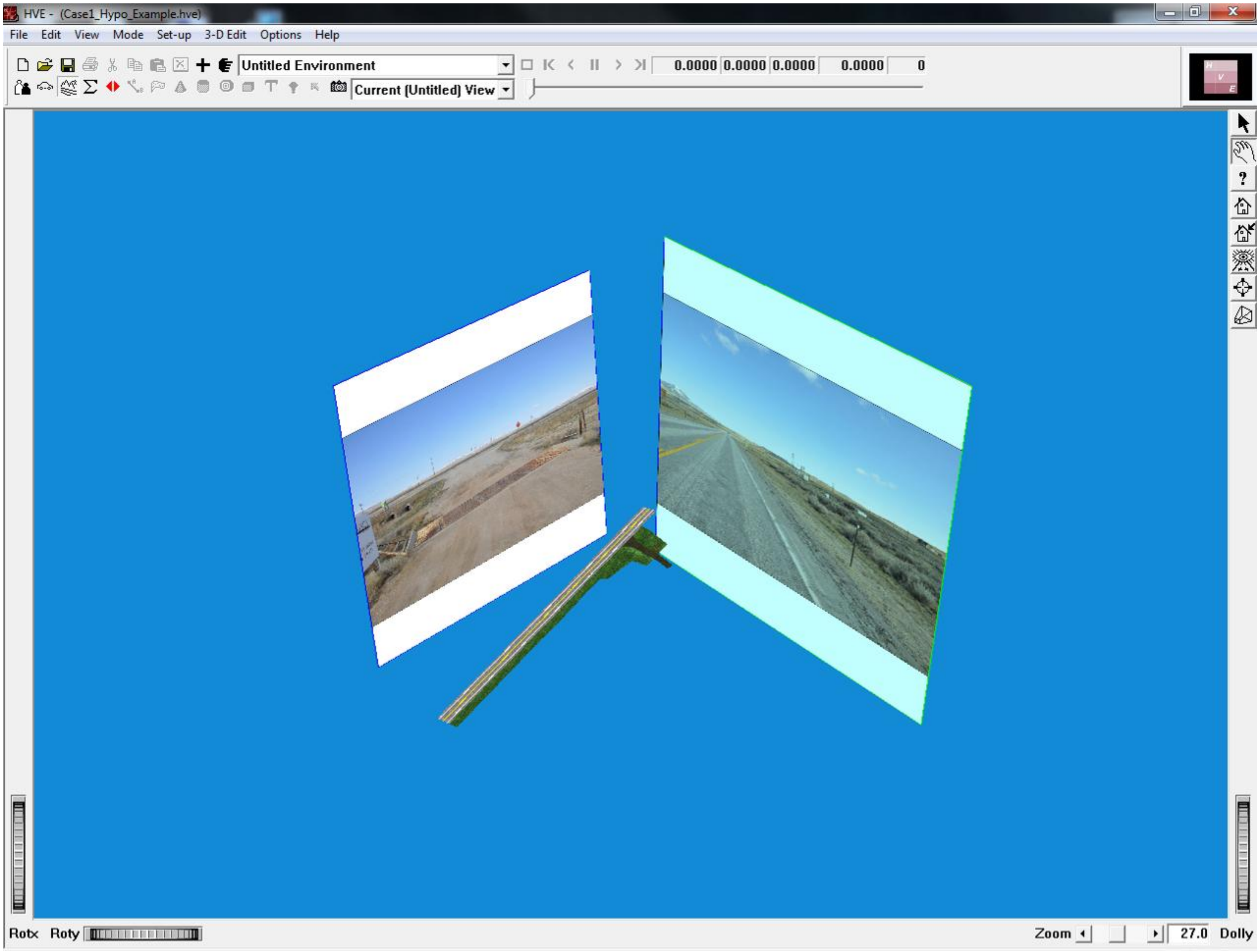

Figure 14 – Hypothetical Case Example, Isometric Environment View

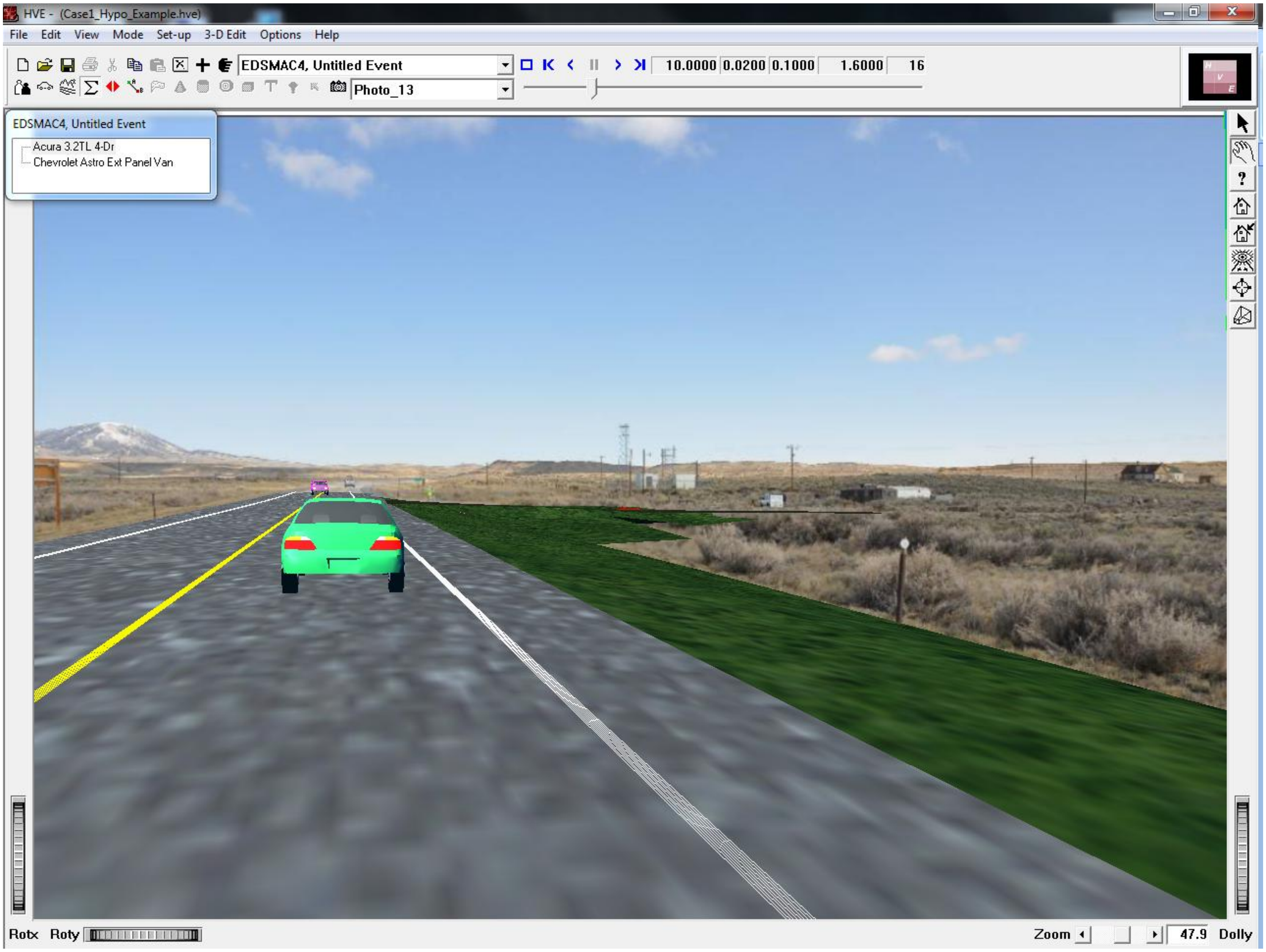

Figure 15 – Hypothetical Case Example, View from Photograph 1 with Solid Environment Surfaces

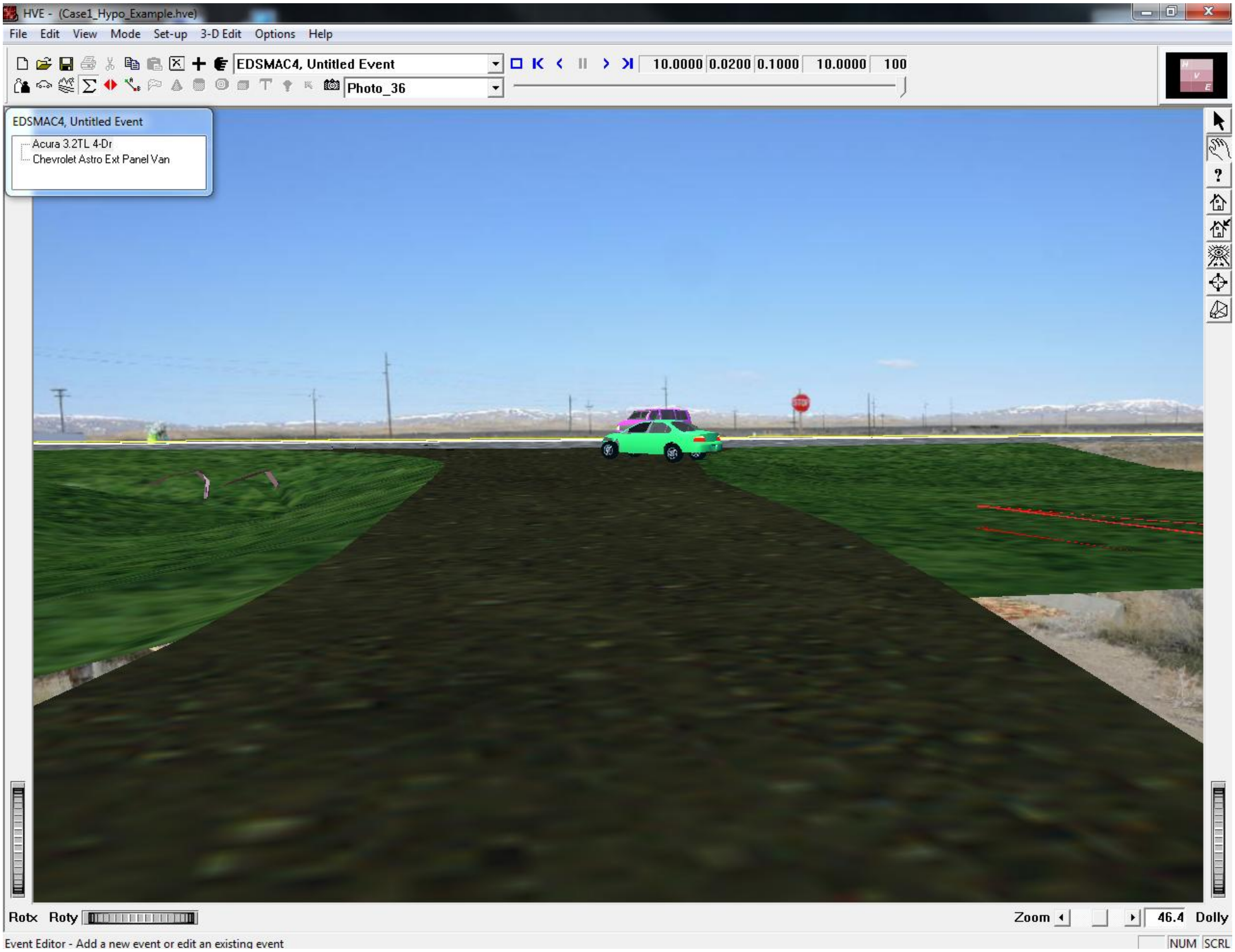

Figure 16 – Hypothetical Case Example, View from Photograph 2 with Solid Environment Surfaces

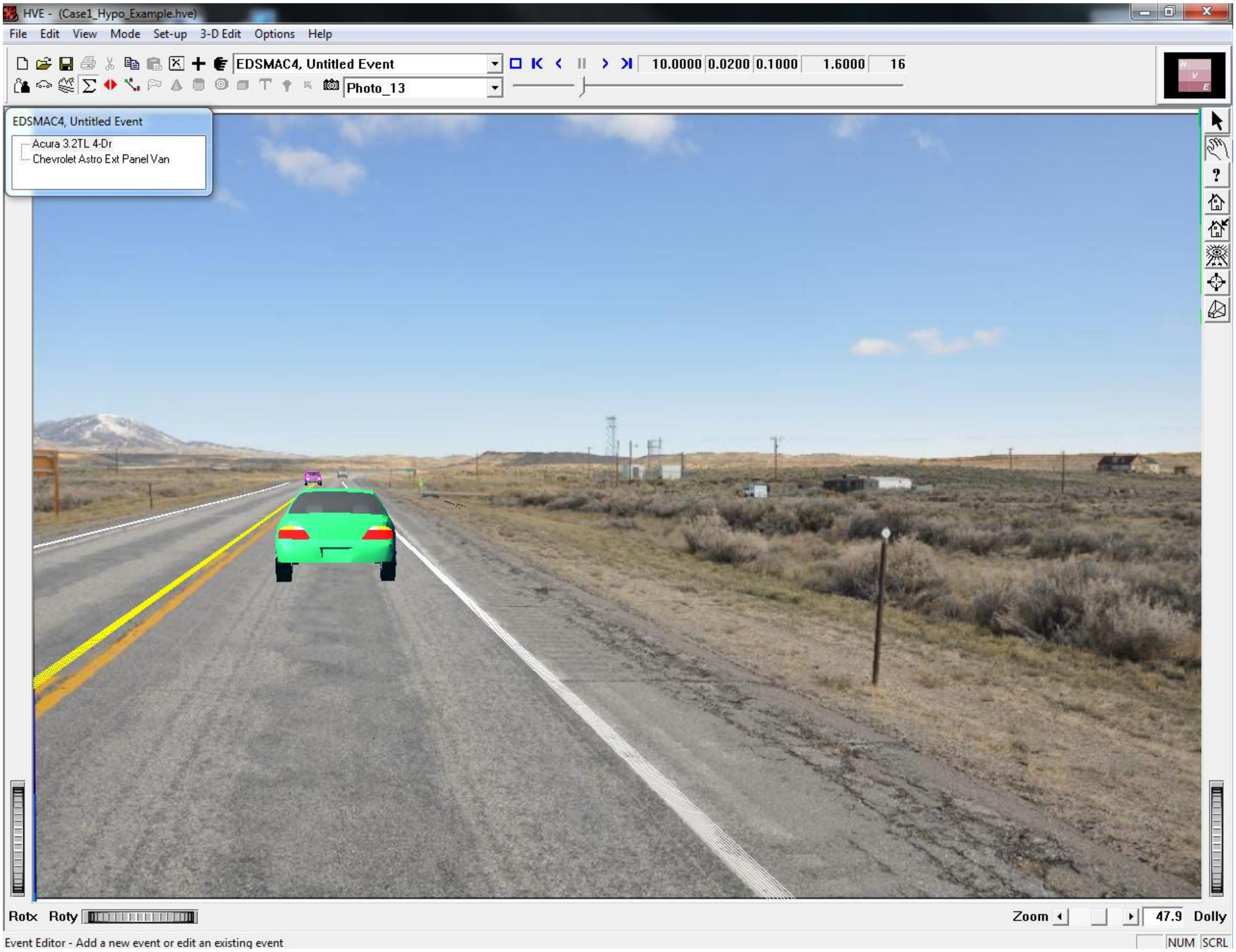

Figure 17 – Hypothetical Case Example, View from Photograph 1 with Transparent Environment Surfaces

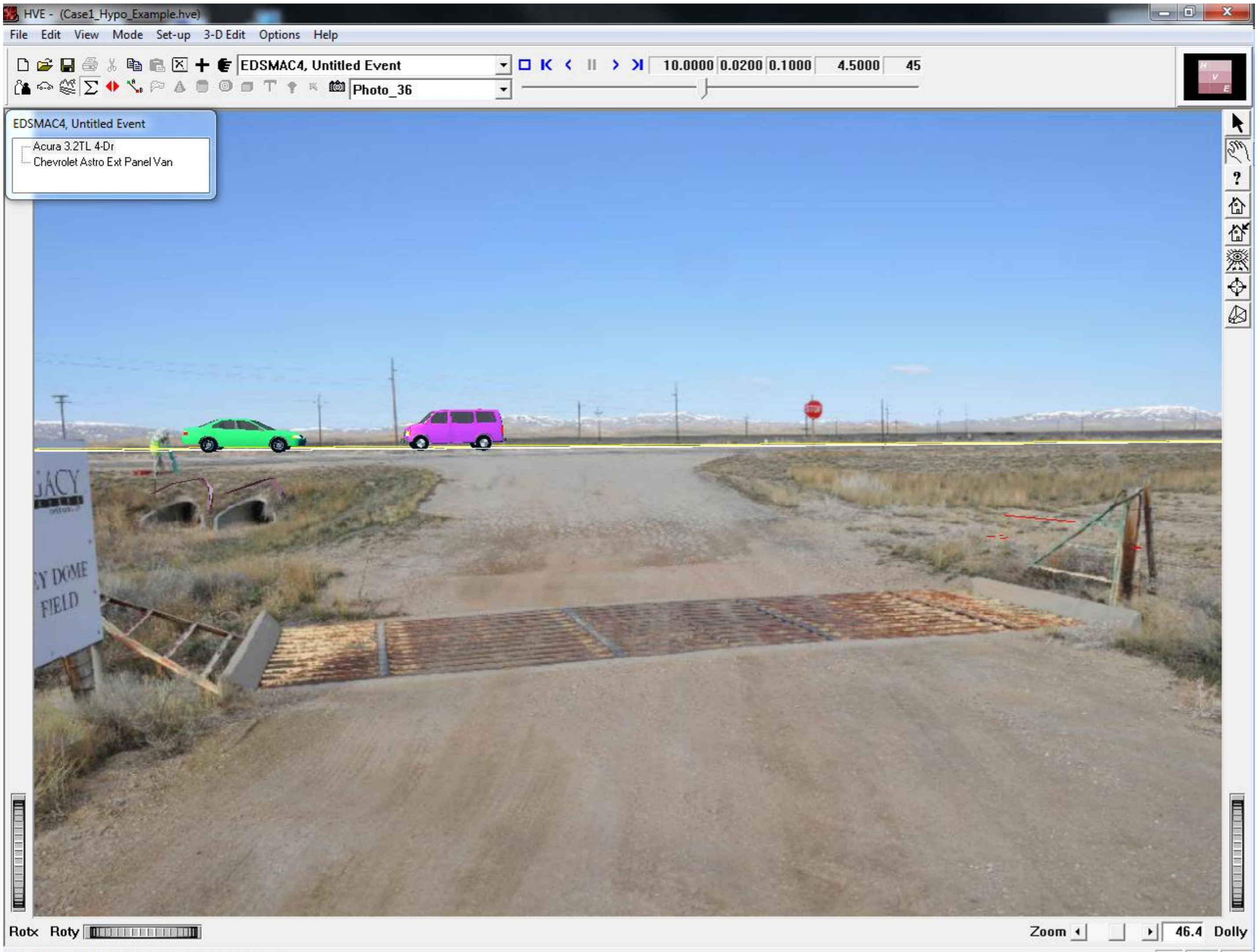

Figure 18 – Hypothetical Case Example, View from Photograph 2 with Transparent Environment Surfaces