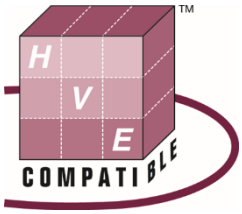


HVE-WP-2017-2

# Simulation of a Four-Car Collision Using SIMON/DyMESH

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# Simulation of a Four-Car Collision Using SIMON/DyMESH

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## ABSTRACT

This paper describes the reconstruction of a four-car collision using the SIMON 3D vehicle dynamics model and the DyMESH 3D crush damage model that are part of the HVE suite. The collision included an underride impact between two of the vehicles so that 2D methods of reconstruction were not viable in this study. The use of HVE's "Show Skidmarks" option is also discussed in this study.

## INTRODUCTION

The accident in this study involved four vehicles and three impacts and occurred at the intersection of a U.S. highway and a local road. Vehicle 1 was a gold 1999 Dodge Intrepid. Vehicle 2 was a black 1999 Ford Escort. Vehicle 3 was a green 2003 Mazda Protégé. Vehicle 4 was a gray 2006 Honda Civic.

The first impact occurred when the Ford Escort, which was traveling westbound on the highway, impacted the rear end of the Honda Civic. The Civic was initially stopped and facing west in the highway's westbound travel lane and was preparing to turn south onto a local road.

As a result of the first impact, the Civic was pushed into the highway eastbound travel lane where it had a frontal impact with the Mazda Protégé, which was initially traveling eastbound in that lane. This was the second impact.

After the first impact, the Escort continued westbound past the Civic and Protégé and yawed into the eastbound lanes of the highway, where it was subsequently impacted on its front passenger door by the front of the Dodge Intrepid, which was traveling eastbound on the highway. This was the third impact. It was daylight, clear, and dry at the time of the accident.

## DATA COLLECTION

Site data was collected from post-accident photographs, laser scans of the site, and from *Google Earth Pro* images. One of the *Google Earth Pro* images of the site was taken about 20 days after the accident so that tire marks from the accident were visible in the image. Vehicle final rest positions were determined from both post-accident measurements made by investigating police officers, and from the post-accident photographs using photogrammetry (see Figure 1).

None of the vehicles were available for inspection for this study. Consequently, all vehicle crush dimensions were determined from post-accident photographs using photogrammetry (see Figures 2, 3, and 4).

Witness statements and testimony were used to provide initial estimates of vehicle actions and speeds.

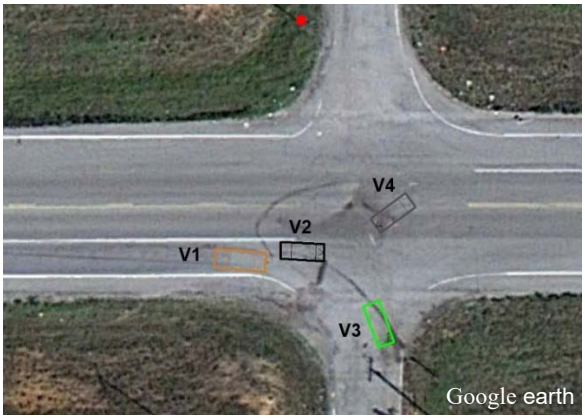


**Figure 1-Vehicle FR Positions & Tire marks**

**Figure 2-Ford Escort Photogrammetry**

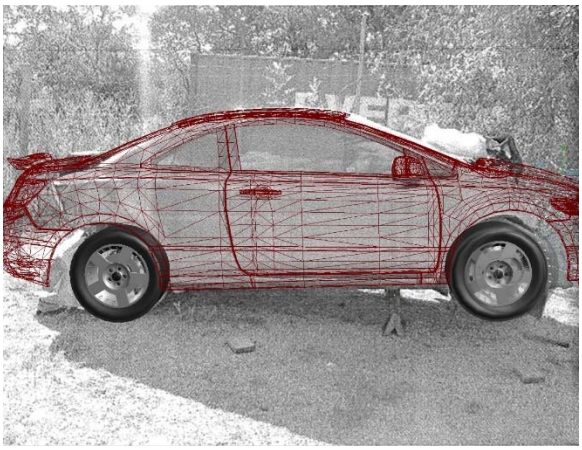

**Figure 3-Honda Civic Photogrammetry**

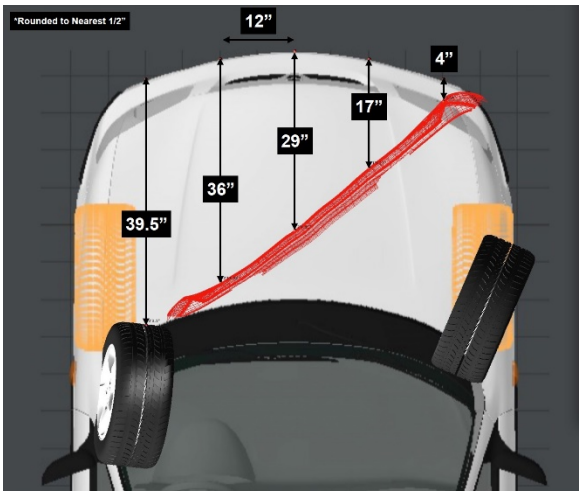


**Figure 4-Mazda Protégé Photogrammetry**

ANALYSIS

Given the relatively uncomplicated nature of the accident site, the environment was built in HVE using the program's native drafting tools. Three of the vehicles were taken from the HVE vehicle library with some modification to some variables using data from the *Experts AutoStats* vehicle database. The fourth vehicle, the Ford Escort, was built separately and imported into HVE.

A review of the post-accident photographs of the Ford Escort and Honda Civic showed that the front of the Escort underrode the rear end of the Civic during the first impact. Given the 3D nature of this impact and the damage, it was decided to use SIMON/DyMESH to simulate the collision to ensure that all vehicle motion and crush damage were simulated as accurately as possible.

Multiple simulations of the collision were run in HVE SIMON/DyMESH to get a best-fit solution using the vehicle final rest positions, the tire marks on the roadway, and the vehicle crush damage. The HVE "Show Skidmarks" option was also selected to compare with the actual tire marks and arrive at a solution.

The first and second impacts had to be simulated within the same HVE event because these two impacts initiated only 0.62-second apart with the Escort and Civic still engaged when the second impact between the Civic and the Mazda Protégé occurred (See Figure 5). This point underscores the value of HVE in simulating a collision of this complexity as more traditional reconstruction methods (i.e. "pencil and paper" calculations) would not have been able to reliably handle the overlapping impacts.

**Figure 5-Overlapping Impacts**

Regarding the analysis of the specific impacts, the first impact involving the Escort and Civic was focused on first. The benefit of using this approach was that the Escort impact speed could be solved independent, for the most part, of the other two impacts. Only a relatively narrow range of Escort impact speeds produced an underride damage pattern consistent with the actual damage to the Escort and Civic (see Figures 6 and 7) and produced the post-impact movements, positions, and tire marks consistent with the site evidence.

An Escort impact speed of 45 mph provided the best fit solution for the first impact. Escort speeds much above 45 mph resulted in a rollover of the Civic, something that did not happen. However, the fact that SIMON/DyMESH can and did predict a rollover at higher speeds in this case was helpful as it established an upper threshold for the Escort impact speed. Escort speeds much below 45 mph resulted in post-impact damage patterns and motion paths that were not consistent with the evidence.

**Figure 6-Honda Civic Crush (Actual)**

**Figure 7-Honda Civic Crush (HVE SIMON/DyMESH)**

As a result of the first impact, the Civic was accelerated to a speed of 17 mph and yawing counterclockwise when it reached its position for the second impact. Various speeds for the Mazda Protégé were simulated for the second impact, with an impact speed of 64 mph for the Protégé again providing a best fit solution with the damage patterns, tire mark evidence, and vehicle post-impact positions.

As a result of the first two collisions, the Civic yawed about 360 degrees to its final rest position. After the first collision, the Escort continued west and yawed counter-clockwise into the eastbound lanes where it was struck on its front passenger door by the Dodge Intrepid at an impact speed of about 20 mph. Figure 8a-d shows the collision sequence for all three impacts. Figures 9 and 10 show a comparison of the actual tire marks and those generated by HVE.

## CONCLUSIONS

HVE with SIMON/DyMESH provided the necessary tools to reconstruct the collision particularly given the 3D nature of the underride collision between the Escort and Civic. The significant amount of tire mark evidence at the site provided much information about vehicle positions and dynamics so that the HVE "Show Skidmarks" option was also a valuable tool in converging on a reconstruction of the collision. The vehicle crush damage patterns determined from the photographs also matched well with those simulated by DyMESH.

## ACKNOWLEDGEMENTS

The author wishes to express his sincere thanks to Fearless Eye, Inc. in the Kansas City, MO area for their photogrammetry work in determining vehicle crush damage, to James Sneddon of Baker Sneddon Consulting in Schaumburg, IL for building the Ford Escort model for use in this study, and to the outstanding staff at Engineering Dynamics Corporation for their valuable assistance.

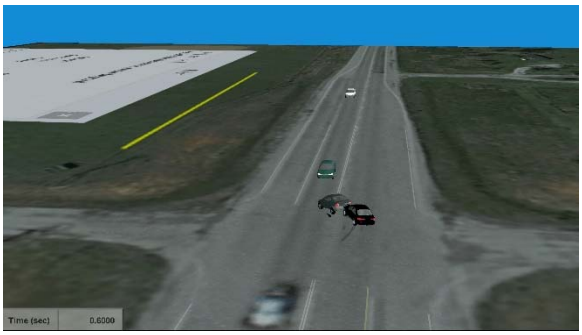


**Figure 8a-Simulation t=0.6000 sec**

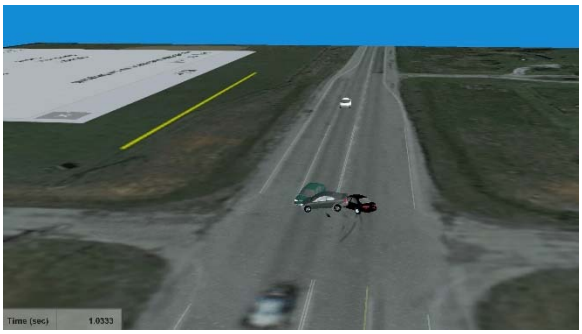


**Figure 8b-Simulation t=1.0333 sec**


**Figure 8c-Simulation t=2.8000 sec**

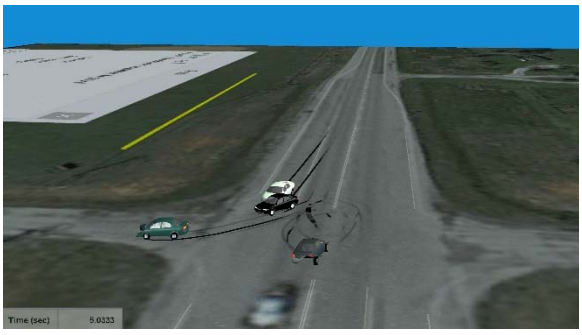


**Figure 8d-Simulation t=5.0333 sec**

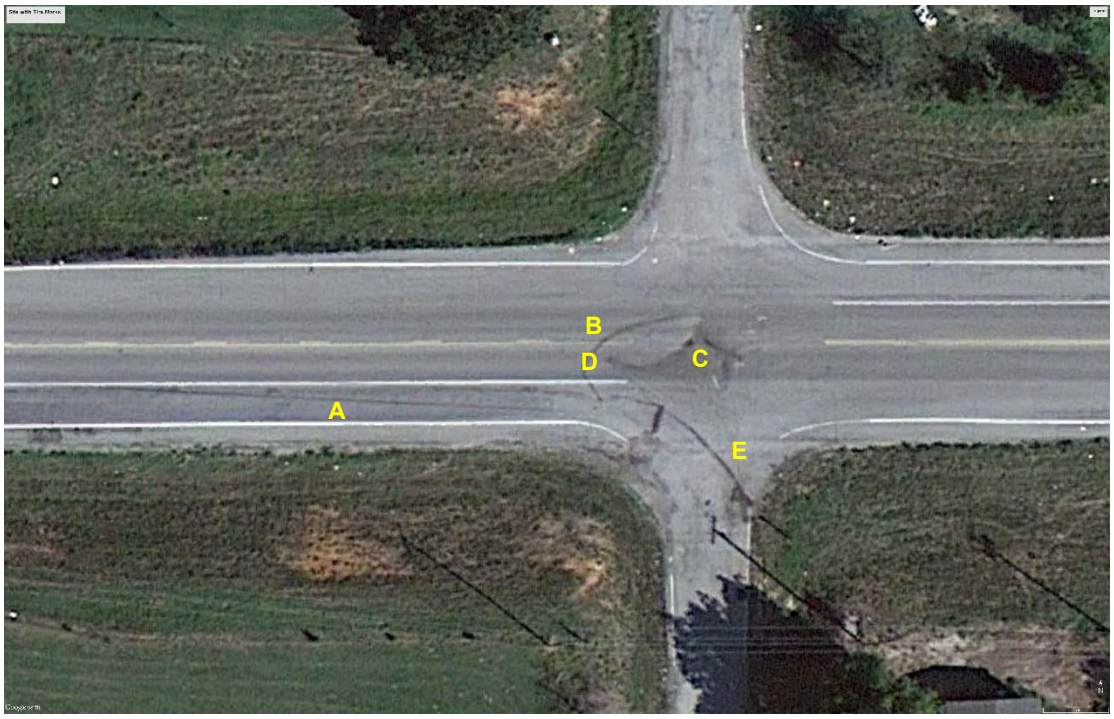


**Figure 9-Actual Tire marks**

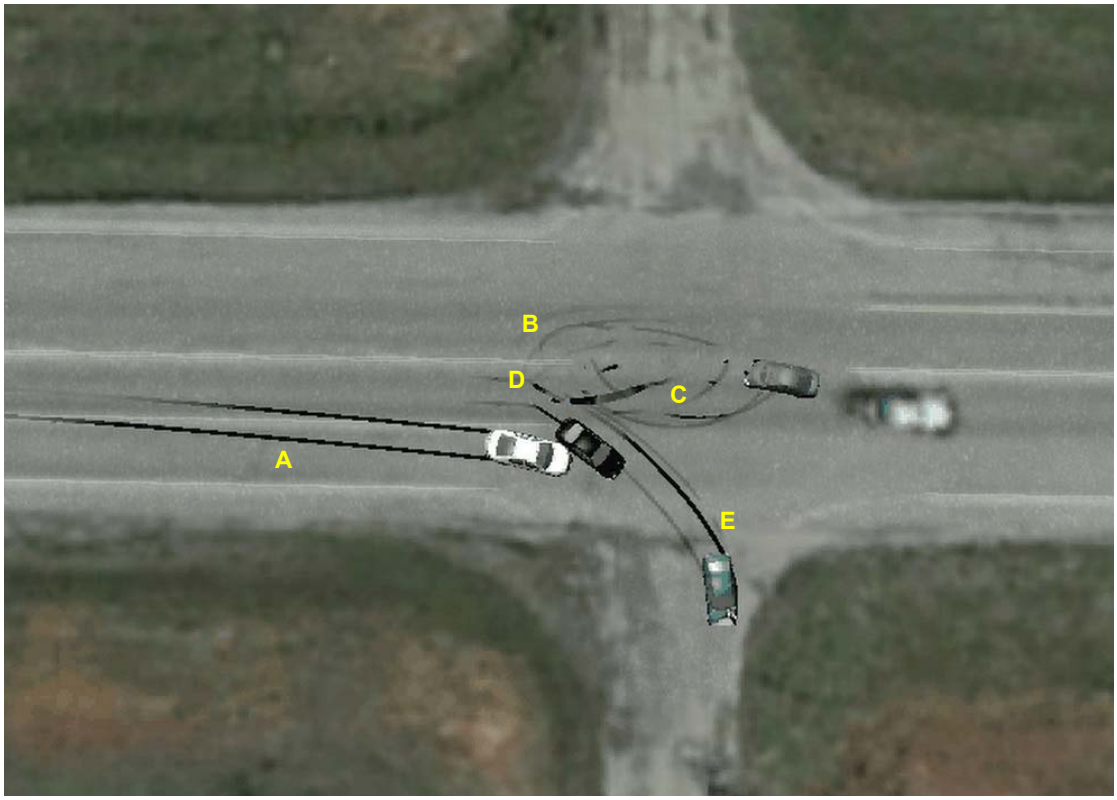


**Figure 10-HVE Tire marks**