Vehicle Trajectory Following Steering Disconnect Investigated by Application of HVE-VSM Steering DOF Capability

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ABSTRACT

A single vehicle run-off-the-road accident occurred on a major highway in Sonora State, Mexico. It was daylight and the road was dry. The accident initially was attributed to tire failure, but subsequent investigation indicated no tire damage.

Approximately one year after the accident the driver of the Dodge pickup, a citizen of the US living in Southern California, received a recall notice from the manufacturer indicating a possible steering column separation problem.

A lawsuit was filed against the manufacturer, claming the loss of control was due to steering column separation. The car had been destroyed in Mexico before the lawsuit was filed.

The Defense claimed that the path followed by the car was inconsistent with steering column separation and only could have been achieved with steering input. Therefore, the loss of control was due to inattentive driving and inappropriate steer input by the driver.

The recently-introduced steer degree of feedom (DOF) capability of VSM was used to investigate the claims of both the plaintiff and the defense.

INTRODUCTION

This single vehicle accident occurred on Mexico Highway 15 near Obregon, in Sonora State. The accident was investigated by the Mexican Federal Police. The diagram from the police report is shown in Figure One. No measurements of the tire marks were included, and the tire mark indications were made with a rubber stamp.

In the deposition of the police officer, the only distance estimate he made was the length of the tire marks labeled “B”, which he recalled (nearly two years later)

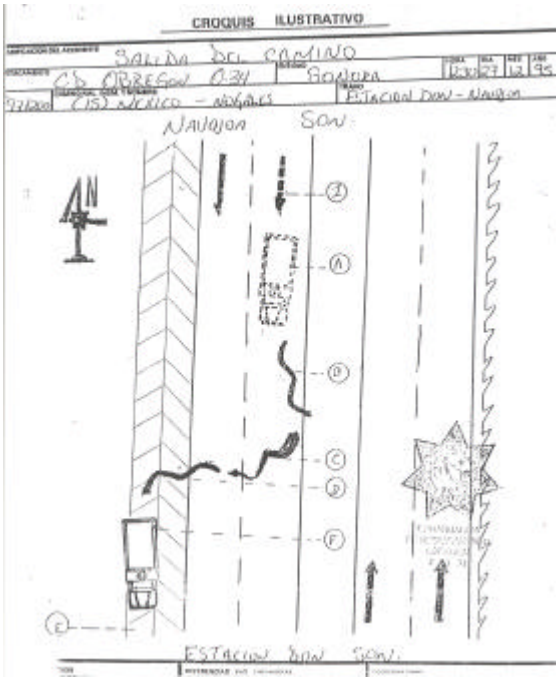


Figure One

were about twenty meters long and were “zig-zag” marks. He did not recall whether each tire mark indication stood for one or more marks.

Significant aspects of the tire marks were that they first went to the left, to the edge of the grass median, and then turned to the right to cross the lanes and exit the road on the right. The final rest of the vehicle was parallel to the road, as shown, but down a rather severe bank into an arroyo.

Many months after the accident, the investigating police officer was taken to the site of the accident where he described generally the location and path of the marks and the resting area of the vehicle. Figures two, three and four show the general area.

Figure Two

Figure Three

Figure Four

The vehicle involved was a 1995 Dodge Ram pickup, two-wheel drive. At the time of the accident it had about 25,000 miles on it.

In his depopsition the officer stated that he checked the tires and, although the two front tires were flat, he found no damage to any tires. He also stated he did not check the steering, so he could not testify if the steering column was or was not intact. The vehicle was destroyed before there was any further examination of it.

CHRYSLER CORPORATION

Recall Notification

No. 709

January, 1997

To: All Dodge Truck Dealers

Subject: Safety Recall #709 – Steering Shaft

Models: 1994 and 1995 Model Year Dodge Ram (BR) Trucks

If the collapsible steering column shaft internal retainers break, the lower column shaft may separate from the upper column shaft and cause a loss of steering control. To prevent this condition, a sleeve must be installed on the intermediate steering shaft to limit movement of the lower column shaft.

IMPORTANT: Some of the involved vehicles may be in dealer used vehicle inventory. Dealers should complete this recall service on these vehicles before retail delivery. Dealers should also perform this recall on vehicles in for service as determined by using DIAL System Function 70.

Details of this service action are explained in the following sections.

Service Procedure Videotape

No videotape of the service procedure for this recall will be provided.

Dealer Notification & Vehicle List

Involved dealers: Each dealer to whom involved vehicles were invoiced (or the current dealer at the same street address) will receive a copy of this dealer recall notification letter and a list of the involved vehicles by first class mail.

The Vehicle List is arranged in Vehicle Identification Number (VIN) sequence. Owners known to Chrysler are also listed. The lists are for dealer reference in arranging for service of involved vehicles.

All other dealers: Each Dodge Truck dealer who does not receive a Vehicle List will receive a copy of this dealer recall notification letter by first class mail.

DIAL System Functions 53, 70 and VIP

All involved vehicles will be entered to DIAL System Functions 53, 70 and VIP at the time of recall implementation for dealer inquiry as needed.

CHRYSLER-0025

Figure Five

THE RECALL

Chrysler Corporation issued Recall Notification No. 709 in January of 1997. The Recall indicated that if certain shaft internal retainers failed, the lower steering column could separate from the upper column, resulting in a total loss of steering control. This detail was part of the column collapse provision. A field fix involved placing a

plastic sleeve around part of the intermediate shaft (a part of the upper column), to prevent it from dropping into the lower column if the retainers failed. The first page of the Recall is shown in Figure Five and column diagrams are shown in Figures Six and Seven.

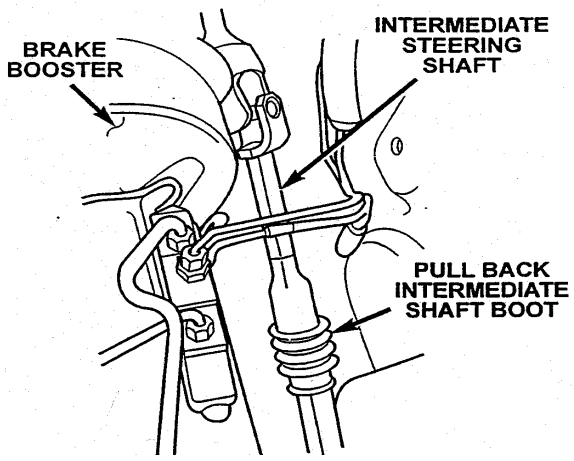


Figure Six

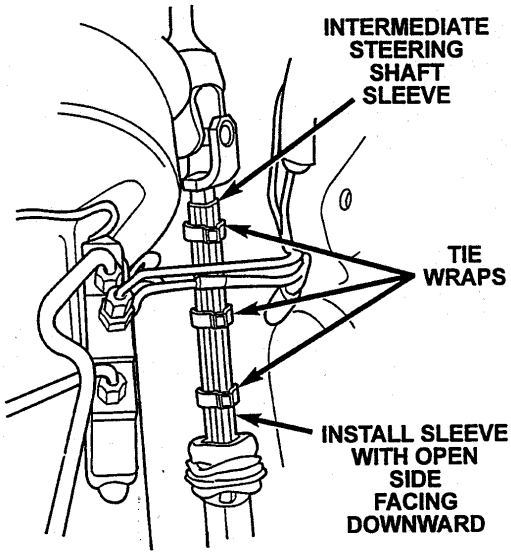


Figure Seven

The important fact of this potential failure was that it was neither intermittent nor partial; if it occurred, it was immediate and total. This allowed its simulation by the HVE-VSM steering DOF model.

THE ISSUE

The primary technical contention was whether the path of the vehicle (even as poorly defined as it was) could be achieved with a separated steering column, or whether (as the defense contended) it would require steering input by the driver through the steering wheel.

The essential characteristics of the path were: (1) an initial movement to the left, probably encroaching into the grass median with the left-side wheels, (2) following that, a rather sharp turn to the right, departing the road surface on the right side, but (3) with some turning back to the left so that the attitude of the vehicle at rest was essentially parallel to the road.

THE SIMULATION

With some considerable difficulty, an acceptable topographic map was obtained through a licensed Mexican surveyor. The terrain was constructed in the HVE 3-D Editor point by point. An overhead view of a portion of the terrain is shown in Figure Eight.

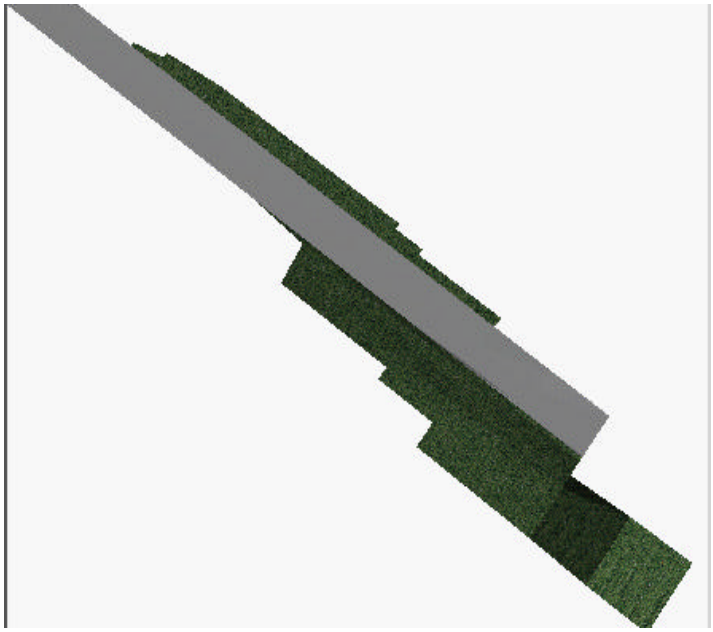


Figure Eight

A vehicle model was produced by EDC and is shown in Figure Nine. All mechanical properties were checked independently against manufacturer's specifications.

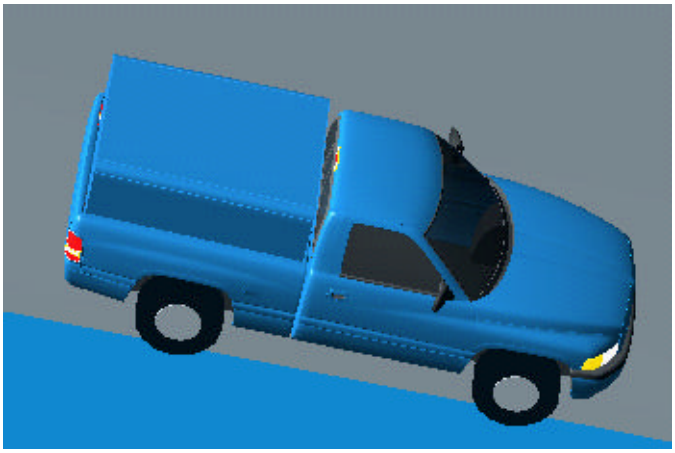


Figure Nine

With the steering DOF calculation mode activated, runs were made with various initial speeds, starting positions, and braking patterns. It became evident that (1) initially the vehicle would drift to the left, due to the super-elevation of the number one, or left, lane, (2) brake application while the left-side tires were on the grass of the median (with an assumed, low friction coefficient compared to that of the road surface) would cause a clockwise yaw back onto the road, and (3) release of the brakes while on the road would allow the front wheels to align with the

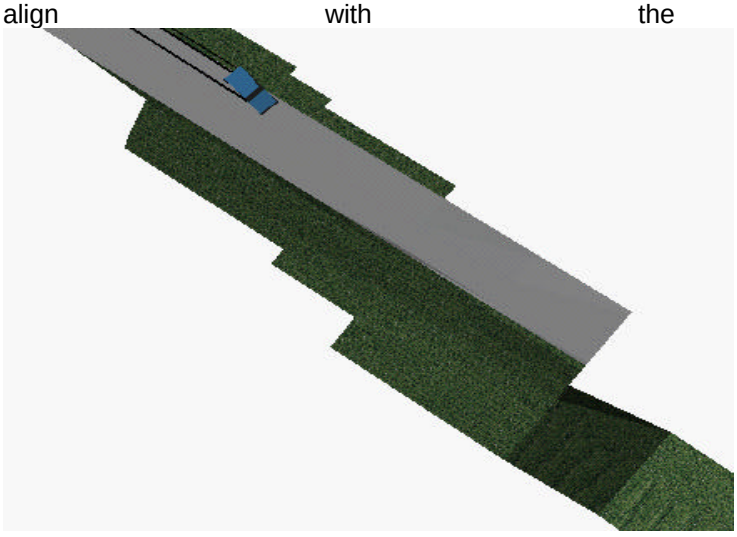


Figure Ten: t = 3.3 sec.

body velocity vector, slowing the clockwise yaw and tending to straighten the vehicle path. Varying braking patterns would allow varying paths to be followed, including one that matched well the available accident data.

None of these vehicle responses is particularly unexpected, of course, but the demonstration of the entire pattern of response was useful.

Figures ten through fourteen show one solution.

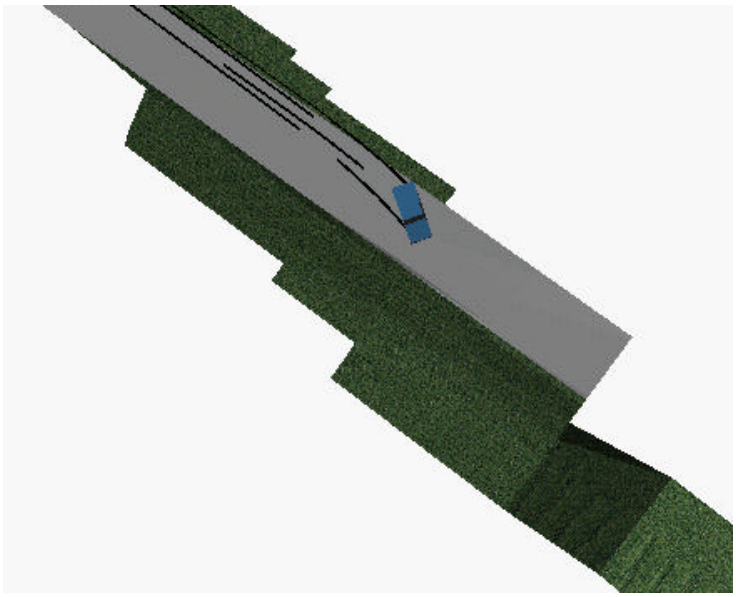


Figure Eleven: t = 4.7 sec.

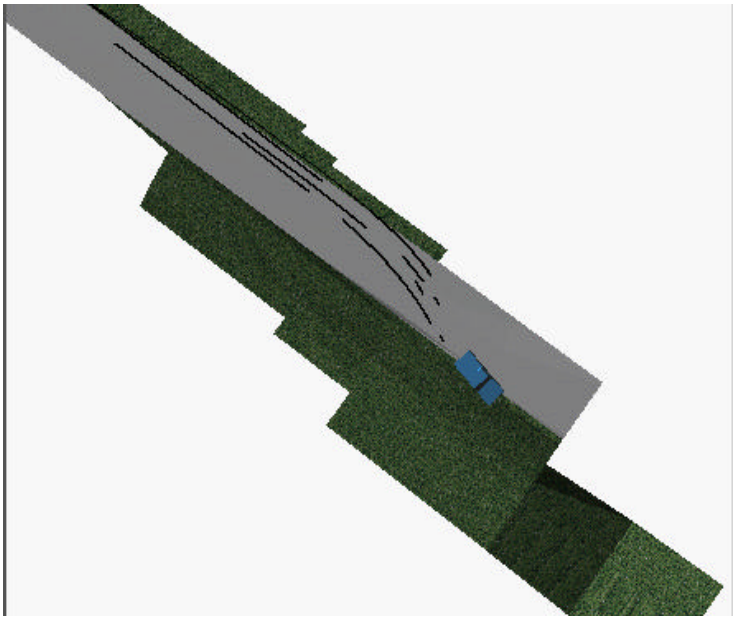


Figure Twelve: t = 6.4 sec.

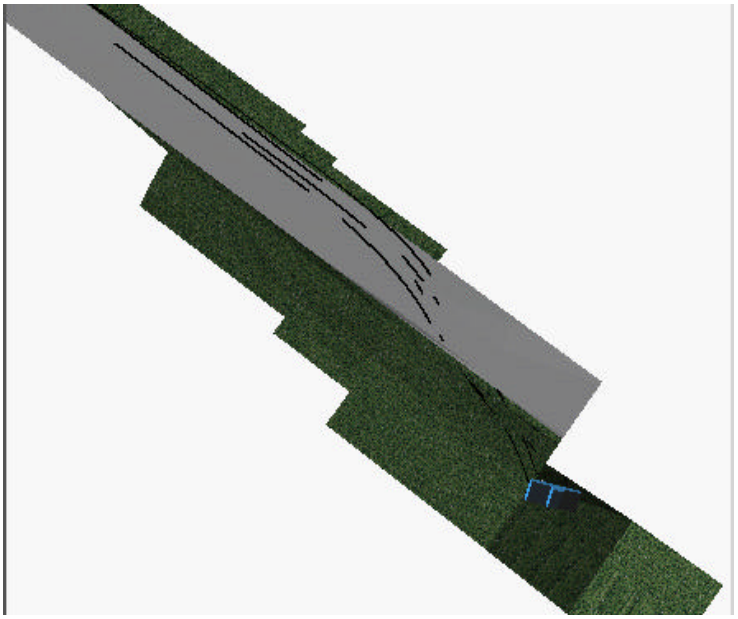


Figure Thirteen: t = 8.2 sec.

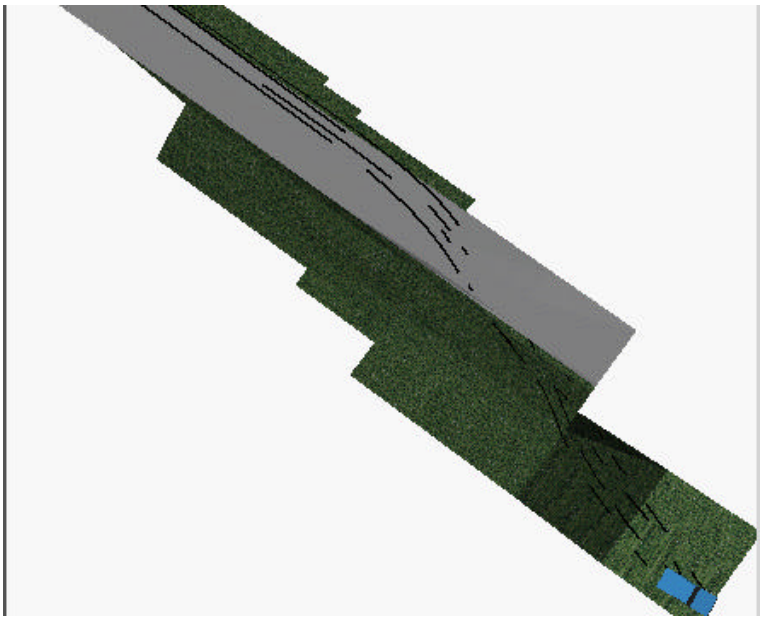
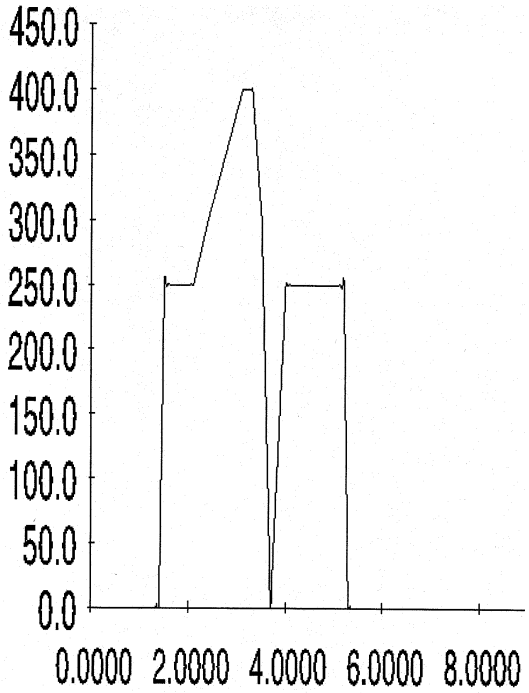


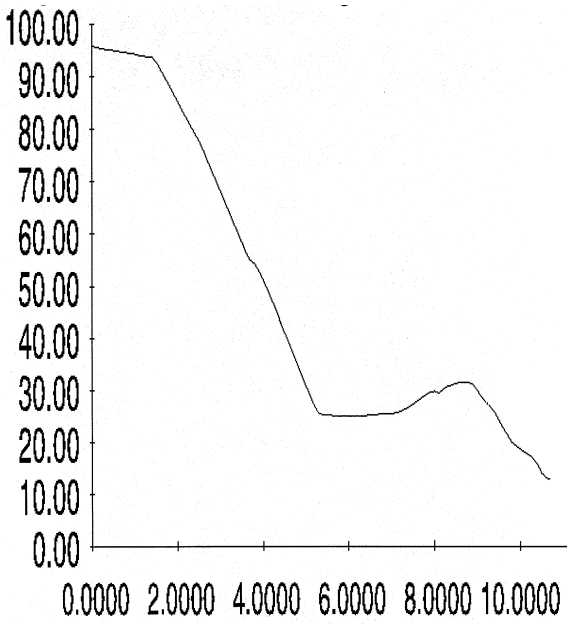
Figure Fourteen: t = 10.7 sec.

The braking pattern for this particular run is shown in Figure Fifteen. The vertical scale is Newtons of brake pedal force.



Seconds

Figure Fifteen



Seconds

Figure Sixteen

Speed versus time is shown in Figure Sixteen; the vertical scale is kilometers per hour.

Yaw (degrees) versus time is shown in Figure Seventeen.

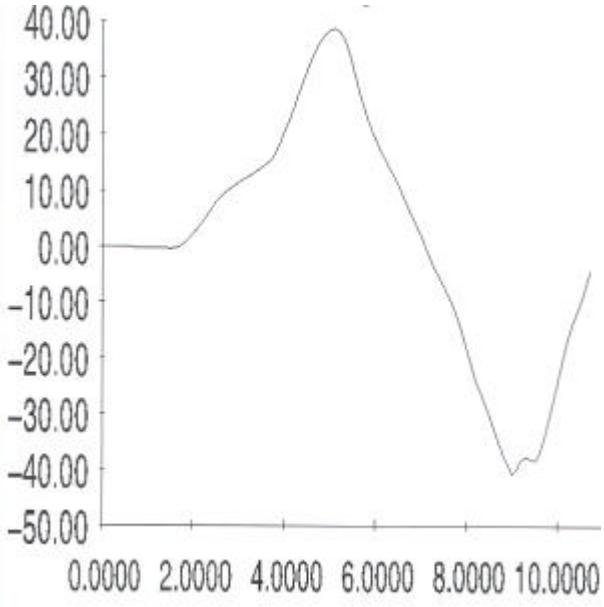


Figure Seventeen

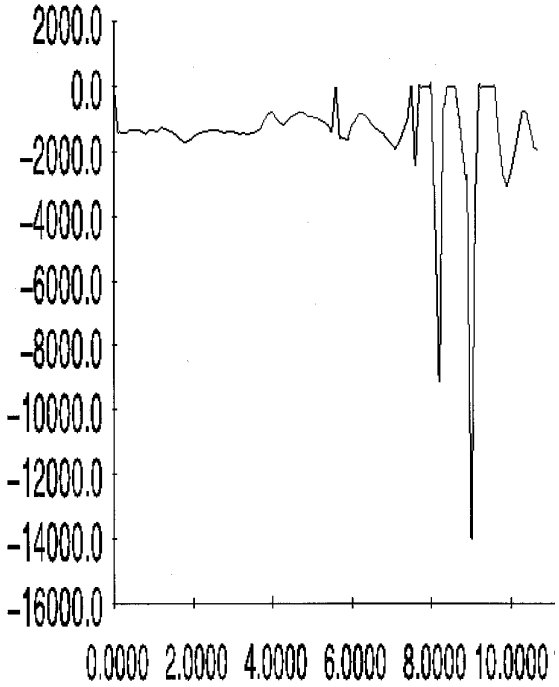


Figure Eighteen

Front tire vertical force is shown in Figure Eighteen. The vertical axis is in pounds. These loads seem consistent with the deairing of the tires, as reported by the investigating officer.

CONCLUSIONS

The contention that the general path followed by the vehicle could be achieved with a separated steering shaft was demonstrated to be valid.

Various paths could be followed by the vehicle, depending on the braking pattern employed.

The reported “zig-zag” nature of the tire paths could not be reproduced. One suggestion is that a front wheel oscillation (“shimmy”) could occur with the steering column separated. The current VSM vehicle model does not include that dynamic vibration mode.

Although the off-the-road portion of the simulation was not expected to produce accurate, detailed results, the potential for very high tire loads was indicated, suggesting a possible explanation for the deaired front tires as found by the police officer.

ACKNOWLEDGEMENTS

Special thanks to Terry Day and Engineering Dynamics Corporation for providing a pre-release version of VSM with the steering DOF capability.