

# CAR-TRAILER UNDER-RIDE CRASH TEST ANALYSIS

**By: Dennis F. Andrews and Rudy Limpert**

Two car-semitrailer side under-ride crash tests were conducted at the 2010 ARC-CSI Crash Conference in Las Vegas, Nevada. This paper presents the impact speed calculations.

Analysis of Monte Carlo Crash Test.

In Test #1 a 2001 Chevrolet Monte Carlo 2-door coupe was driven under an angle of approximately 45 degrees against the left side of a stationary empty tractor-semi trailer with its right front corner leading. The measured impact speed was approximately 17 mph.

The Monte Carlo at rest is shown in Figure 1.



*Figure 1. Monte Carlo at rest partially under trailer.*

The frontal damage is illustrated in Figure 2. The left most contact point on the car is located left of center to the driver's side at the base of the windshield.



*Figure 2. Frontal view of roof damage of Monte Carlo.*

Inspection of Figure 3 shows the roof/trailer contact damage extending beyond the upper A-pillar to include approximately two-thirds of the upper edge of the passenger door. The authors measured a maximum crush penetration depth of approximately 55 in. from the baseline of the windshield to the damaged top of the right door. The initial contact between trailer rail and right A-pillar was slightly above the base of the upper A-pillar.

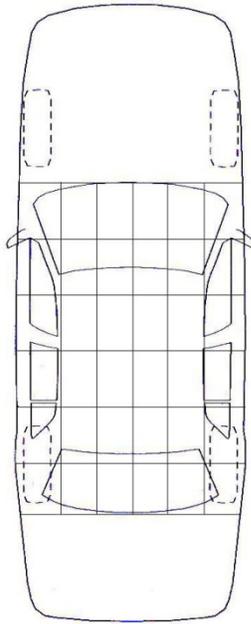


*Figure 3. Side view of Monte Carlo roof damage.*

The speed reconstruction of under-ride crashes is based upon the determination of roof crush energy. Many under-ride crash tests were conducted to develop the empirical expression relating crush energy to impact speed (Ref.1 and 2). As it is the case with any empirical relationship, the user must be careful to determine if the test parameters including vehicles tested are reasonably similar to the actual accident under investigation.

The authors have taken the roof crush methodology discussed by Bruce Enz and others (Res. 1 and 2) and formulated the software program MARC 1- Module Y for speed calculations in under-ride crashes (Ref. 3).

The top view of an automobile outline is shown in Figure 4a with the area between the bases of the windshield and rear window divided into six equal-distant sections. Each rectangle is associated with a specific amount of crush energy measured in lbft. The specific energy of each roof section was derived from the basic research data published by Enz.



*Figure 4a. Automobile top view with roof crush energy matrix*

The percentage figure involved in the roof crush used in our reconstruction is shown in Figure 4b for the Monte Carlo tested. The reader is reminded that the roof of the Monte Carlo may not entirely correlate with the test vehicles underlying the development of the empirical relationships used in MARC 1-Y. The analysis also accounts for where on the A-pillar the trailer contact occurs. An impact at the lower portion of the upper A-pillar represents larger crush energy (shorter impulse lever arm), and hence, higher impact speed, than a higher impact point. Readers are reminded, as in any speed calculation involving empirical crush energy equations, to employ a range of meaningful crush depth values. Consequently, a reasonable range of probable impact speeds should be stated.

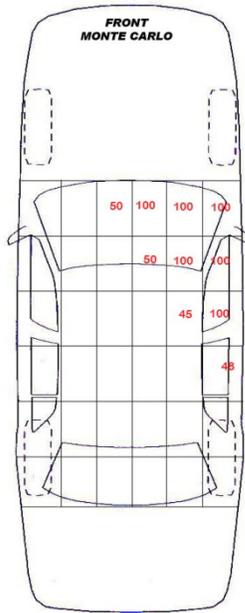


Figure 4b. Monte Carlo roof crush energy percentages.

The MARC1-Y computer results are shown in the MARC 1-Y Monte Carlo printout. The test weight of the Monte Carlo was not provided. The weight used was obtained from published Monte Carlo curb weight data. For a low A-pillar impact point an impact speed of 17.70 mph is computed. If a middle A-pillar impact point is used, the impact speed decreases to 16.3 mph.

Tuesday, June 15, 2010

MOTOR VEHICLE ACCIDENT RECONSTRUCTION AND CAUSE ANALYSIS  
 \*\*\*\*\* PROGRAM 'Y' RUN FOR Monte Carlo Under-ride \*\*\*\*\*  
 TRACTOR-TRAILER SIDE UNDERRIDE ANALYSIS

```

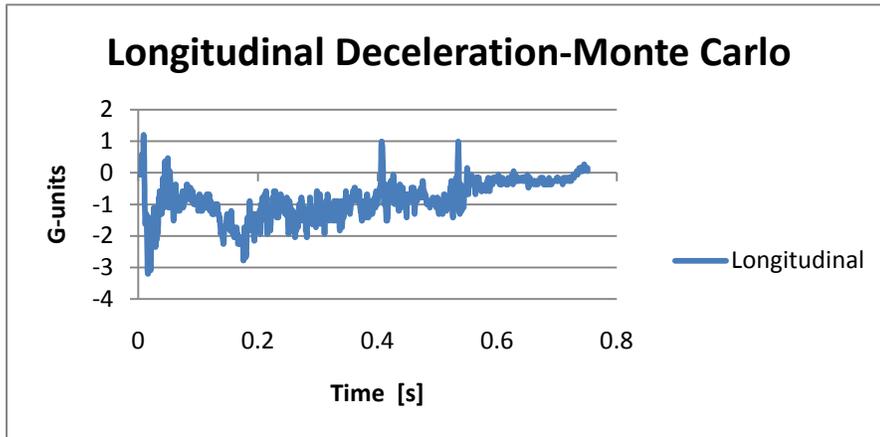
Information For Vehicle          2001 CHEVROLET Monte Carlo
=====
Vehicle Weight, LBS:           ==> 3366.00
Angle of Impact, DEG:          ==> 45.00
After Exit Distance Traveled, FT: ==> 0.00
After Exit Drag Factor, g-units: ==> 0.00
Before Impact Braking Distance, FT: ==> 0.00
Before Impact Drag Factor, g-units: ==> 0.00
Driver Reaction Time, SEC:      ==> 0.00
=====

Crush Energy, LB*FT:           ==> 17568.68
Vehicle Energy Equivalent Speed, MPH: ==> 17.70
Vehicle Exit Speed, MPH:        ==> 0.00
Vehicle Speed at Impact, MPH:   ==> 17.70
No Pre-Impact Braking . . . . .

Distance from Driver Reaction to Impact, FT: ==> 0.00
Time from Driver Reaction to Impact, SEC:    ==> 0.00
=====
  
```

MARC 1-Y Monte Carlo printout.

The deceleration determined from the EDR down load is shown in Figure 5. It is interesting to note that the average deceleration computed from the average test impact speed of 17 mph and a stopping distance of 55 in. (4.58 ft) is 2.1g indicating general agreement with the download.



*Figure 5. Monte Carlo longitudinal acceleration.*

#### Analysis of Saturn Crash Test

In Test #2 a 1996 Saturn was driven at 90 degrees into the same side of the trailer. The impact speed was determined by the authors from the video tape provided at approximately 20 mph.

The rest position of the Saturn is shown in Figure 6 indicating a roof crush penetration to the B-pillar area.



*Figure 6. Rest position of Saturn.*

The right upper A-pillar is shown in Figure 7 indicating initial trailer contact near the top.



Figure 7. Trailer/A-pillar contact point.

The percentage roof crush penetration is shown in Figure 8.

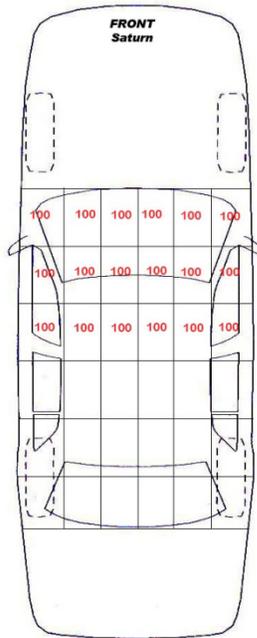


Figure 8. Saturn roof crush energy percentages.

The MARC1-Y results are shown in MARC 1-Y printout for the Saturn indicating an impact speed of 19.59 mph. A high trailer/A-pillar contact point was used in the analysis. The crush

penetration measurements are much cleaner than those of the Monte Carlo, resulting in a smaller range of probable impact speeds.

*MARC 1-Y Saturn data printout.*

```

Tuesday, June 15, 2010

MOTOR VEHICLE ACCIDENT RECONSTRUCTION AND CAUSE ANALYSIS
***** PROGRAM 'Y' RUN FOR Saturn Under-ride *****
TRACTOR-TRAILER SIDE UNDERRIDE ANALYSIS

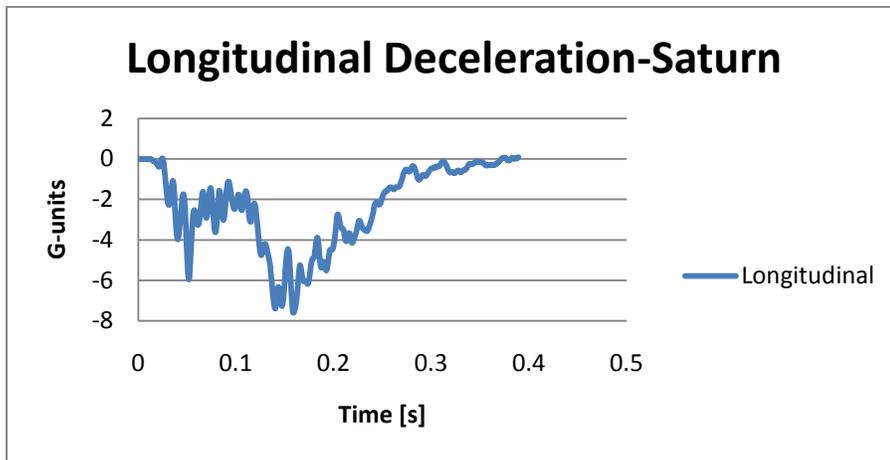
Information For Vehicle                               1996 SATURN SL
=====
Vehicle Weight, LBS:                               ==> 2330.00
Angle of Impact, DEG:                              ==> 90.00
After Exit Distance Traveled, FT:                  ==> 0.00
After Exit Drag Factor, g-units:                    ==> 0.00
Before Impact Braking Distance, FT:                ==> 0.00
Before Impact Drag Factor, g-units:                ==> 0.00
Driver Reaction Time, SEC:                          ==> 0.00
=====

Crush Energy, LB*FT:                               ==> 29784.00
Vehicle Energy Equivalent Speed, MPH:               ==> 19.59
Vehicle Exit Speed, MPH:                           ==> 0.00
Vehicle Speed at Impact, MPH:                       ==> 19.59
No Pre-Impact Braking . . . . .

Distance from Driver Reaction to Impact, FT:        ==> 0.00
Time from Driver Reaction to Impact, SEC:           ==> 0.00
=====

```

The longitudinal acceleration of the Saturn downloaded from the EDR is shown in Figure 9.



*Figure 9. Saturn longitudinal acceleration download.*

**Conclusions**

The reconstruction of under-ride crashes using MARC 1-Y yields acceptable results provided the subject vehicle is similar to the test vehicles used for the roof crush energy analysis.

Reference:

1. Trego, Angela, et al., A Scientific Approach to Tractor-Trailer Side Underride Analysis, SAE paper 2003-01—178.
2. Enz, Bruce, et al., Mathematical Approach to Side Underride Vehicular Accident, Mathematical Modeling and Scientific Computing, Vol. 13, No. 1-2, pp. 136-156, 2001.
3. MARC 1 Software available as free download from [www.pcbrakelinc.com](http://www.pcbrakelinc.com).

Contact Information:

Dennis F. Andrews

[fox@trilobyte.net](mailto:fox@trilobyte.net)

Rudy Limpert

[prosourc@xmission.com](mailto:prosourc@xmission.com)