Delta V from damage uses the CRASH3 program formulae. CRASH3, an acronym for *Calspan Reconstruction of Accident Speeds on the Highway* -- version 3, was designed as a tool for making a standardized assessment of an accident's severity.

CRASH3 employs two separate and independent methods to estimate the speed change of a vehicle in collision -- Trajectory Analysis and Damage Analysis. Trajectory Analysis involves a work-energy relationship for the spinout and conservation of linear momentum for the collision. Damage Analysis uses detailed measurements of the structural deformation of each vehicle in order to arrive at an estimate of the energy required to produce such damage, and is the subject of this paper.

CRASH3 based software programs use algorithms based on these CRASH3 formulae and are therefore subject to the same limitations as the algorithms. Most commercial software programs allow use of actual vehicle specifications, and at least two allow for a different stiffness or resistance to damage in each crush element, data that is almost impossible to obtain without destroying an exemplar vehicle.

The use of actual vehicle specifications, coupled with the use of current exemplar-vehicle stiffness data, greatly improves the accuracy of the speed estimate. Adjusting for individual crush zones is an attempt to compensate for the inadequacies of the system. The adjustment must still be explained, and possibly defended. Utilization of additional zones over the normal six (6) is another attempt at increasing the accuracy of the system, but this alone rarely produces any appreciable difference in the final calculations.

The following excerpt is from the CRASH3 Technical Manual:

"The five basic assumptions of the CRASH3 model are restated below.

1. *The driver's control of the vehicle ceases at impact.*

2. *At some time during the interaction both vehicles achieve a common velocity at the collision interface.*

3. *The program is two-dimensional: therefore, vertical effects such as rollover, steep grades, and curb mountings cannot be modeled directly.*

4. *Vehicle properties are average properties for a vehicle class. The properties used may or may not adequately represent a particular vehicle.*

5. *Crush stiffnesses are assumed to be uniform over the side, front, or back of the vehicle.*

It is also useful at this stage to consider the intent of the CRASH3 program. Because of its availability, CRASH3 is viewed by many as a tool for accident reconstructionists involved in litigation. A vehicle collision is a very complex event and one should not expect high fidelity from a computer program filled with assumptions and simplifications. CRASH3 was designed as a research tool for identifying and establishing trends in crash severity parameters such as the change in velocity, Delta V, in highway accident data. In particular, it has been useful in measuring the speed change of vehicles during an impact: a parameter that is useful in assessing crash severity. As Section 2.5 will indicate, CRASH3 can yield completely false answers for a particular case, depending on the quality of the field data, the correspondence between the real vehicle and CRASH3's assumed vehicle, as well as the degree to which the above outlined simplifying assumptions are met. On the whole, though, CRASH3 is statistically a good predictor of trends; inferences made about a large number of accidents are very likely to be representative of collisions in the real world.

One recurring theme in this chapter will be the limitations imposed by the very sparse crash test data. Many, if not most, of CRASH3's problems can be directly attributed to insufficient data from full-scale vehicle crash tests. In addition, there will always be a need for new data as the vehicle population changes.

In summary, CRASH3 is a very useful research tool which possesses certain inherent limitations. The limitations of the program should always be rigorously observed and the final responsibility for accuracy, as with all software tools, lies with the user and not with the program developer.

The user should at this juncture recall that the CRASH3 program was not designed to be a simulation program but rather a consistent, uniform method of judging accident severity in terms of the change in velocity. CRASH3 should be statistically valid for a large number of cases; it may or may not provide accurate results in a particular case.

Smith and Noga performed a linear regression analysis and developed the following regression equation.

$$DeltaV_{(TRUE)} = -0.7 + 1.1\ DeltaV_{(CRASH)} \qquad (2.126)$$

Equation (2.126) indicates that the mean value of a large number of estimates of Delta V will be approximately 10 percent lower from the true mean. Viewed for particular cases, the prediction may be in error by as much as 45 percent. This should reinforce earlier statements that CRASH3 should only be used with caution for individual accidents."

EXPANDING THE POSSIBILITIES

Recall from the section above that CRASH3 should be statistically valid for a large number of cases but it may or may not provide accurate results in a particular case.

Some new techniques since the release of CRASH3 may have reduced the severity of that warning as it applies to the reconstruction and analysis of a particular accident. As we have already seen in another recent article (IPTM 2005) by the author titled *Understanding DeltaV from Damage*, many software programs now offer more than the highly restrictive 2, 4 or 6 “C” measurements of the original CRASH3 program. In addition the huge database of vehicles that have been crashed and documented greatly improves the accuracy of the model.

Some software now allows the user to change the weight given to the individual damage profile elements defined by the “C” measurements. While this flies in the face of the original concept of a homogeneous vehicle surface, it is obvious that treating the entire surface of the vehicle as uniform was one of the contributing factors to the inaccuracy of the earlier approach. The problem now is that a user wishing to change the uniformity of the surface must be able to defend the action in deposition or in court.

A WORD ABOUT DAUBERT

Even seasoned experts have their blood run cold at the thought of defending a Daubert challenge. Does their work truly conform to the standards of the general scientific community?

In an editorial for the Wall Street Journal on 8 August 2005, James Schlesinger expressed a thought so profound that it should be memorized by every expert and given to every judge holding a Daubert hearing:

"Science is not a matter of consensus, as the histories of Galileo, Copernicus, Pasteur, Einstein and others will attest. Science depends not on speculation but on conclusions verified through experiment. Verification is more than computer simulations -- whose conclusions mirror the assumptions built into the model. Irrespective of the repeated assertions regarding a "scientific consensus," there is neither a consensus nor is consensus science."

A NEW ERA

In the past, several attempts have been brought forth to enhance the effectiveness of the basic CRASH3 technology. One of these has been to advocate the use of a three-dimensional crush profile. This has met with a great deal of resistance, as the opponents claim that the resulting difficulty of implementation far outweighs the increase in accuracy.

But there has been another development that is having a devastating effect on the CRASH3 model. This development is not particularly new; it is just becoming more widespread and therefore more potent. More and more manufacturers, in an attempt to differentiate their product from the others in the marketplace are taking their inspiration from the female anatomy. To make the product more seductive to potential purchasers, they simply add curves.

How is this detrimental to the CRASH3 model? For the answer we must go back to the basics of what the model does. The damage profile is critical to computing the forces acting on the vehicle. CRASH3 uses "C" measurements to define the damage profile. The "C" measurements define the damage profile by quantifying the depth of the permanent damage along the damage width. In the programs allowing for non-equidistant "C" measurements, "L" measurements are used to denote the positions of the individual "C" measurements along the width of the damage.

GET BACK TO THE CURVES!

The problem is that CRASH3 is incapable of doing that. One of the inherent assumptions in CRASH3 is that all vehicles are "square," meaning the opposite of "cool" or "sexy." Actually the vehicles are treated as rectangles.

Rectangular vehicles solve a myriad of problems. This assumption makes measuring the damage profile easy. The problem is that easy is not synonymous with accurate. Rectangular vehicles cannot be used to accurately model the damage profile on a curved surface such as the slick bullet-shaped front ends on modern vehicles. As manufacturers add more curves to their vehicles, they may increase their sales but also add to the inaccuracy of the system used by CRASH3 as the primary determinant of vector positioning that results in the forces acting on the center of gravity of the vehicle.

The other weakness in the model is that CRASH3 treats the resistance to deformation as a linear function through the utilization of Hooke's Law, modeling the vehicle as a spring. Without being able to treat the vehicle as linear, the entire model would fail. What a paradox. The very feature that makes the system work is one of the primary weaknesses of the system. This paradox results from the fact that the resistance to damage is not linear in the real world of deforming vehicles. Real vehicles have bumpers, radiators, cooling fans with plastic shrouds that offer little resistance before a penetrating vehicle or other object literally runs into the frame, an engine, a transmission or some combination thereof. These transitions from one resistance level to another that occur with increasing penetration are not always linear in nature. Sometimes a transition can be radical in nature.