SUMMER 2018 ENGINEERING DYNAMICS CORPORATION

Technical Newsletter

Available on-line in the EDC Library at www.edccorp.com

HVE 64-Bit Version Now Shipping!

At long last, after more than two years of development, *HVE* 2018 is now available.

HVE 2018 has the same look and feel as *HVE* 2017, but the internal acrhitecture is new. The 64-bit architecture provides the following new capabilities:

- Larger file sizes are now possible (the 2 gigabyte file size limit no longer exists)
- Point cloud environments may be used directly. A new feature will soon be available that allows the user to remove unnecessary points while keeping those required for true elevation changes, such as curbs (see **Point Clouds**).
- UNDO! Yes, *HVE* 2018 even includes an Undo/Redo capability.
- A new on-line Help System has also been added.

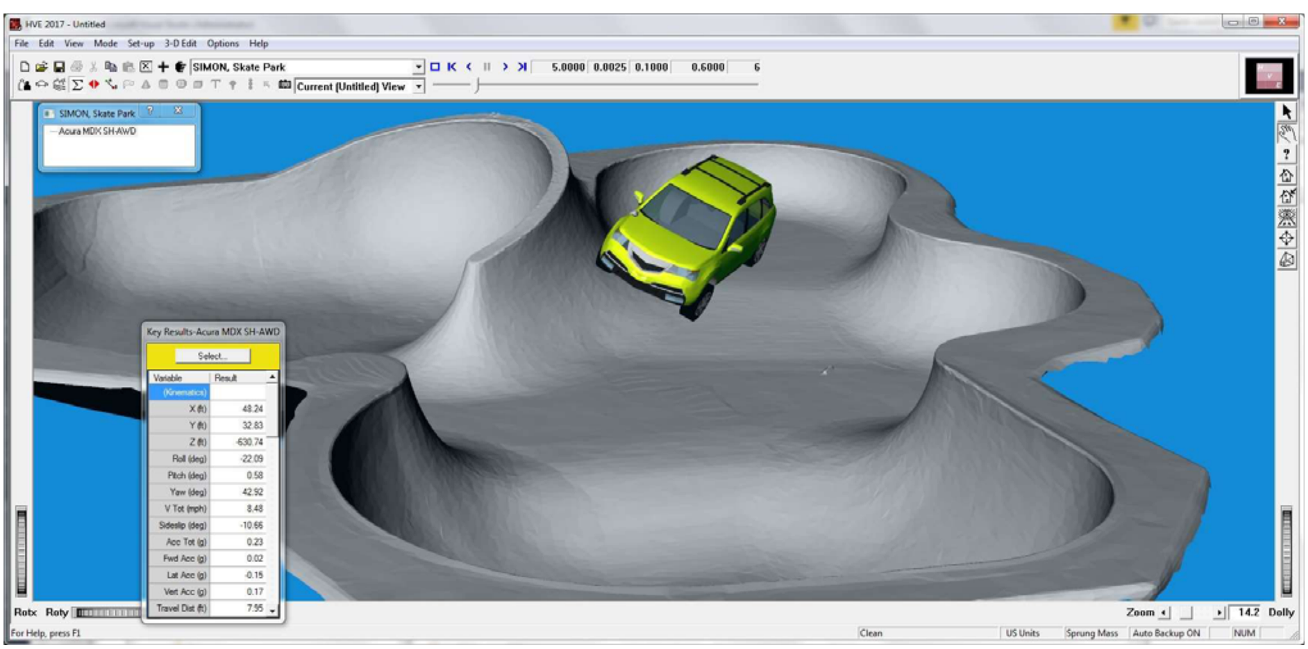
A rather extreme example, below, shows a vehicle driving in a skate park. The environment was imported directly from the Scene output of a Faro scanner.

Point Clouds

Raw point cloud data from a scanner contains a lot of "noise." As a result, a vehicle driving on a smooth, flat highway terrain created using point cloud data behaves like it is driving on a bumpy gravel road. The next release of *HVE* 2018 includes an integrated tool that "smooths" this noise, while keeping true elevation changes, such as curbs and potholes, intact. This is a very important capability; it allows users to directly import the important characteristics of the scene, while also creating a true surface to drive on. The resulting terrain also contains far fewer polygons, greatly reducing execution time.

All future *HVE*, *HVE-2D* and *HVE-CSI* upgrades will use the new 64-bit architecture; the 32-bit version will be archived and no longer available for purchase.

All users with a current Update/Support policy will automatically receive their upgrade to *HVE* 2018. There is also an attractive promotion for users who have an expired Update/Support policy.



Technical Session

Our session this time deals with the topic of "Degrees of Freedom." Some might think this is a mundane subject. The goal of this Technical Session is to convince you otherwise, and to show how much you can learn about the design and capability of a physics model by looking at its degrees of freedom.

Let's start with a definition: Degrees of Freedom (DOF) is the number of independent directions in which an object can move. Now, that's a pretty vague definition, so let's look at some examples involving the motion of a vehicle:

A physics program that calculates the motion of a vehicle that can only move in one direction (let's say straight ahead) has one degree of freedom (that would be the vehicle's x-direction).

If the vehicle can move straight ahead and also slide sideways, it has two degrees of freedom (the x-direction and the y-direction).

If the vehicle can also rotate about its vertical axis, it has three degrees of freedom (the x-direction, the y-direction and the heading angle, ψ).

The previous example makes it clear that there can be linear (x and y), as well as angular (heading) degrees of freedom.

From the standpoint of calculating the magnitude and direction of this motion (i.e., developing a physics program), here is a very important point: When it comes to the mathematics, there must be one equation of motion for each degree of freedom. Stated another way, the number of degrees of freedom determines the number of required equations of motion.

Two very popular *HVE*-compatible physics programs are *EDSMAC4* and *SIMON*. Let's look at the degrees of freedom for each of these models.

EDSMAC4

EDSMAC4 is a physics model that has 3 degrees of freedom per vehicle: x, y and heading (ψ). To calculate motion in these directions requires calculating forces in the x and y directions and moments about the z axis. Forces are also calculated in the z direction, but these are used only to calculate the weight distribution; there is no motion calculated in the z direction. A diagram illustrating these degrees of freedom is shown in Figure 1.

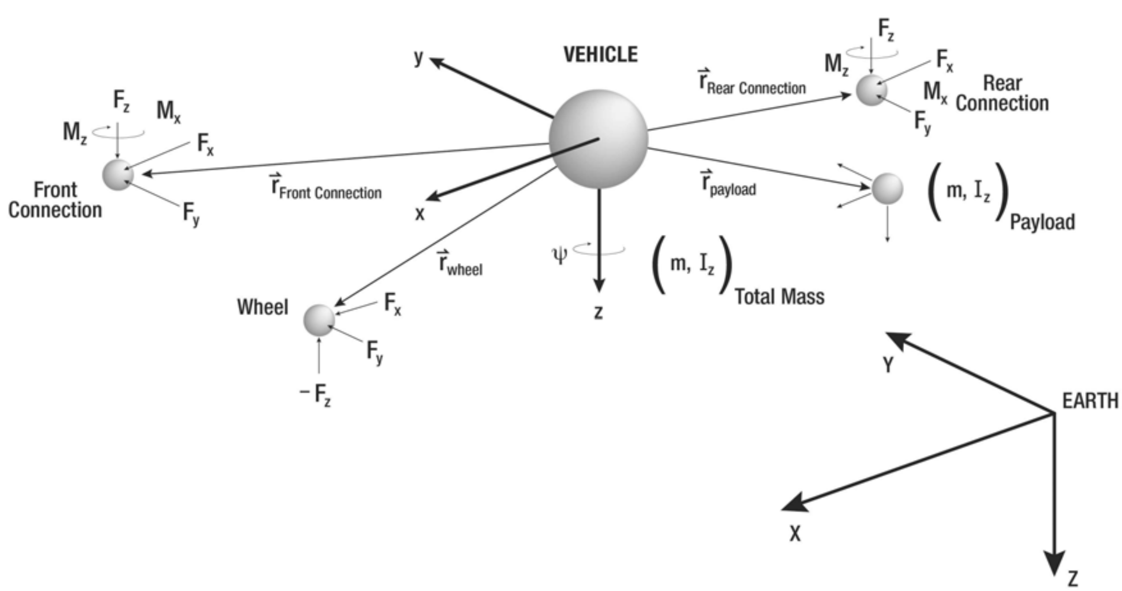


Figure 1 - 3 degree of freedom vehicle model for EDSMAC4

The large sphere in the center of the diagram represents the vehicle's total mass. It has associated with it inertias *m* and I_z (mass and yaw moment of inertia, respectively).

The other, smaller spheres are as follows:

Wheel – This sphere represents a wheel location. Only one wheel is shown, but there may be up to six. Each wheel is located a fixed distance, $\bar{r}_{Wheel}$, from the total mass CG location. The wheel location is important because it is where the tire forces are applied to the vehicle. These forces, among others, determine the motion of the vehicle in the x and y directions and rotation, ψ, about the z axis.

Front Connection – This sphere represents the location of the front inter-vehicle connection. For example, if this vehicle is a semi-trailer, it is the location of the kingpin. It is located a fixed distance, $\bar{r}_{Front\ Connection}$, from the total mass CG. This location is important because it is where the inter-vehicle connection forces, F_x, F_y and F_z, and moment, M_z, are applied. Like the forces applied at the tires, these forces and moments also determine the motion of the vehicle.

Rear Connection – This sphere represents the location of the rear inter-vehicle connection, and is otherwise identical to the front connection.

Payload – This sphere represents the location of the payload. It is located a fixed distance, $\bar{r}_{Payload}$, from the total mass CG. It has associated with it the inertias m and I_z for the payload. These inertias are added to the total mass inertias to determine the total inertias used in the equations of motion. The payload inertias also change the location of the total mass CG and, therefore, the distances $\bar{r}$, for the wheel(s), front connection and rear connection.

SIMON

Once we have absorbed the concepts regarding the degrees of freedom for the *EDSMAC4* model, let's jump to the *SIMON* model. I say *jump*, because we are going from 3 degrees of freedom to 16 degrees of freedom (or more, depending on the number of axles).

The first thing to observe is that in *EDSMAC4*, the masses of the wheels were included in the total vehicle mass. In *SIMON*, this is not the case. In *SIMON*, we consider the sprung mass (not the total mass), and the mass of each wheel (and axle for solid axle suspensions) is considered separately. That's because in *SIMON*, we are going to calculate the motion of the sprung mass (i.e., the vehicle's body) and wheels/axle separately. Note that the sum of the sprung mass and the wheel/axle masses (sometimes referred to as *unsprung masses*) equals the total mass.

The sprung mass has 6 degrees of freedom: x, y and z linear motions and roll (ϕ), pitch (θ) and heading (ψ) angular motions. (The terms *heading* and *yaw* may be

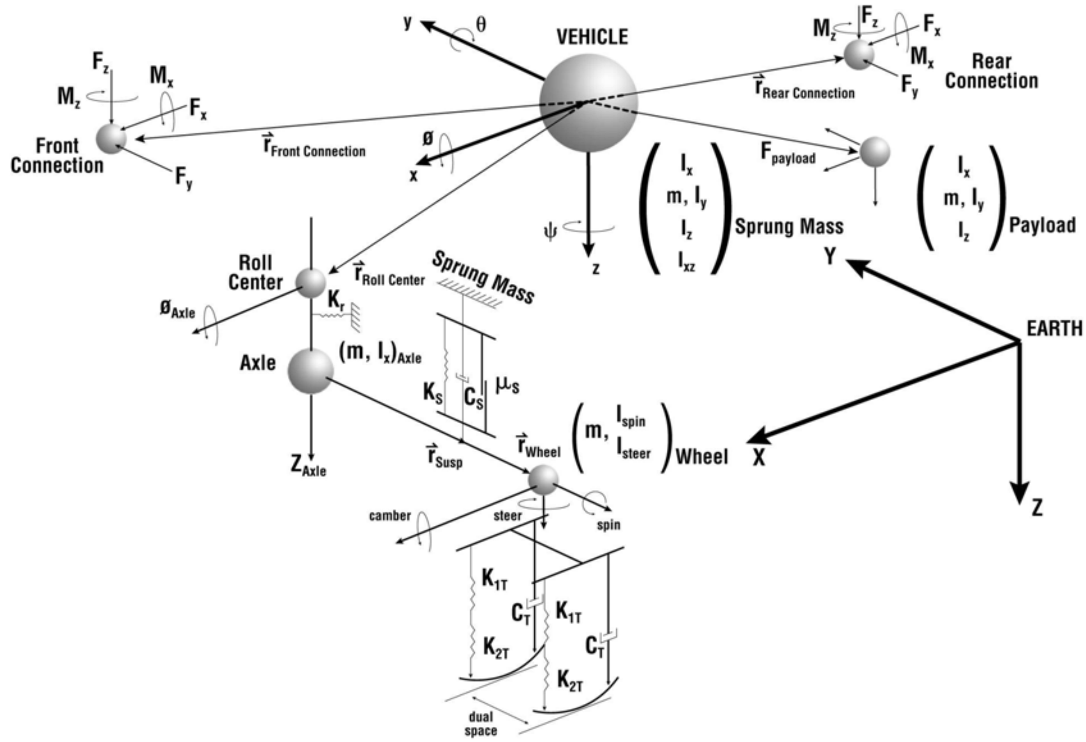


Figure 2 - 16 degree of freedom vehicle model for SIMON, solid axle suspemsion model

used interchangeably.) To calculate motion in these directions requires calculating the forces on the sprung mass in the x, y and z directions and moments on the sprung mass about the x, y and z axes. A diagram illustrating these degrees of freedom for a vehicle with a solid axle suspension is shown in Figure 2. (The diagram for a vehicle with an independent suspension is slightly different; see discussion below)

The large sphere in the center of the diagram represents the sprung mass. It has associated with it the inertias m, I_x, I_y and I_z (sprung mass and rotational inertias about the x, y and z axes, respectively).

The other, smaller spheres are as follows:

Wheel – This sphere represents the wheel location, $\bar{r}_{Wheel}$. Again, only one wheel is shown, but there may be up to six. Each wheel location is fixed in the x and y directions (sort of; more on that later when we discuss wheels that can be steered). But the motion of the wheel in the z direction is not fixed. For independent suspensions, the wheel is free to move up and down (z-direction). For solid axle suspensions, the axle's roll center moves up and down $z_{Roll\ Center}$, and the axle rotates ϕ_{Axle} about its roll center. Thus, for solid axle suspensions, each wheel can move up and down and also change its camber angle. In addition, the wheel may be steered (if it is steerable) about the local z (steer) axis and spin about the local y (spin) axis. But the steer angle is assumed to be equal for the left-side and right-side wheels. So, for either suspension type, each axle has five degrees of freedom. For an independent suspension, the degrees of freedom are z and spin for each wheel and the steer angle. For a solid axle suspension, the degrees of freedom are the axle z and roll, the spin for each wheel and the steer angle.

For these five degrees of freedom, we need to calculate for a solid angle suspension the axle vertical force and moment, the wheel spin moment and the steer moment. For independent suspension, we need to calculate the vertical force and spin moment for each wheel and the steer moment. This further requires that we need to know the mass of the wheels and axles and the rotational inertias about the roll, spin and steer axes.

Thus, for a typical two-axle vehicle, like a passenger car or a pickup, the total number of degrees of freedom is 16 (six for the sprung mass and five for each axle location). Remember that there is an equation for each degree of freedom, so there are 16 motion equations for a 2-axled vehicle modeled by *SIMON*; there are 21 motion equations for a 3-axled vehicle, such as a Freightliner. Compared to *EDSMAC4*'s 3 equations, that's a lot of calculations!

Front Connection – This sphere represents the location of the front inter-vehicle connection, just like in *EDSMAC4* (see earlier discussion). However, this connection also calculates the roll moment, in addition to the x, y and z forces and yaw moment, at the inter-vehicle connection. And, like *EDSMAC4*, these forces and moments are included, along with the other forces and moments, in the six equations of motion for the sprung mass.

Rear Connection – This sphere represents the location of the rear inter-vehicle connection, and is otherwise identical to the front connection.

Payload – This sphere represents the location of the payload. It is located a fixed distance, $\bar{r}_{Payload}$, from the sprung mass CG. It has associated with it the mass, m, and rotational inertias I_x, I_y and I_z for the payload. These inertias are added to the sprung mass inertias to determine the total inertias used by the equations of motion. The payload inertias also change the location of the sprung mass CG and, therefore, the distances, $\bar{r}$, for the wheel(s), front connection and rear connection.

Steered Wheels

We mentioned earlier that a wheel's location is fixed in the x and y directions. While this is true for a non-steerable wheel, it is not exactly true for a steered wheel. *SIMON* has a sophisticated model for steerable wheels that includes the effects of suspension geometry. A steerable wheel does not steer about a vertical axis through the center of the tire plane. Rather, it steers about an axis defined by the caster angle and kingpin inclination angle. This axis is located a distance, called the stub axle length, from the center of the tire plane (this is beyond the scope of our discussion on degrees of freedom; refer to the *HVE* User's Manual, Chapter 11, for a complete discussion of steering geometry). But steering geometry has an effect on wheel location: When a wheel steers about its steer axis, the wheel center also moves in the x- and y-directions.

The Punch Line

So why do we care about these degrees of freedom? It's simple: You cannot calculate the motion of a vehicle unless you have an equation for that direction of motion. If you want to study the motion of a rollover, your model needs a roll degree of freedom. If you want to study the vertical motion of a vehicle (like a vehicle going down an embankment), you need a z degree of freedom for the sprung mass (probably roll and pitch, too!). If you want to study the suspension or tire forces of a vehicle traveling over a bumpy road, you need a z degree of freedom for the wheels. This is why you use *SIMON* and not *EDSMAC4*. If you want to study the spin motion of a vehicle's wheel, you need a spin degree of freedom. A wheel that is braked by an ABS brake system absolutely requires the calculation of the wheel's spin velocity, thus requiring the spin degree of freedom. This same wheel spin DOF is required by the vehicle's traction control and yaw stability control systems as well.

In Summary

We hope we have convinced you that the topic of degrees of freedom is not mundane. Rather, understanding the degrees of freedom provides a rich knowledge of the capabilities of any given physics model. If this subject is new to you, please spend a little more time with this article. It is an excellent learning tool!

2019 *HVE* Forum February 25 - March 1 Tropicana Hotel Las Vegas, Nevada

Pack your bags, grab your laptop, and head to Las Vegas during the week of February 25, 2019, to attend the 2019 *HVE* Forum! Yes, there's something else to do in Las Vegas besides gambling!

The *HVE* Forum is a great way (actually, the *fastest* way) to get up to speed on all of *HVE*'s powerful features and capabilities. From Monday morning until noon on Friday, there are 3 or 4 concurrent workshops from which to choose exactly what you want and need to learn.

Hands-on Learning

Many of the workshops, including the Advanced *HVE*, Advanced *HVE-2D* and Simulation Fundamentals, include hands-on exercises, so be sure to bring your laptop! EDC will issue a temproary license with all program options to each attendee.

Workshop Registration

Workshop schedules, descriptions and registration forms are available to view and download at www.edccorp.com/2018HVEForum. You can also call EDC Customer Service at 888-768-6216 and let us help you choose the perfect set of workshops to suite your personal needs.

EDC Reconstruction November 5 - 9, 2018 Miami, FL

EDC Reconstruction is an extensive one-week training seminar that offers an excellent way to learn the inner workings of *EDCRASH*. The course focuses on the physics model, the calculations and the underlying assumptions for each of the program's five major calculation procedures.

EDC Reconstruction is designed to be like a college physics course - a combination of morning lectures and afternoon hands-on lab exercises. The fact that this course has been presented annually for over 25 years ensures that students benefit from a well designed and well executed week of instruction.

EDC Reconstruction has been pre-approved for 30 ACTAR CEUs. All course materials, including a handbook, training manual, software and temporary licenses, are provided to each student.

Bring your scientific calculator and laptop computer. Four lab exercises include damage-only analysis, collinear head-on and rear-end collisions and oblique collision.

Links to download your course registration form and to make your hotel reservations at the Hampton Inn Dadeland, Miami, FL, are available on the EDC Reconstructions page in the Training section of edccorp.com. Contact EDC at 888.768.6216 to sign up today!

DyMESH Version 4

DyMESH Version 4 was introduced as part of HVE 2017 on January 23, 2018. *DyMESH* Version 4 introduced a simple, but important, change to the contact algorithm. In previous versions, *DyMESH* determined the vertex displacement based only on the slave vehicle. The resulting crush depth was a function of the slave vehicle geometry. Changing the vehicle stiffness had little effect. A simple change to the contact algorithm proportions the vertex displacement according to the relative stiffness of the vehicles, as follows:

Given -

Master Vehicle Stiffnesses = A_{Master}, B_{Master}

Slave Vehicle Stiffnesses = A_{Slave}, B_{Slave}

Slave Vehicle Vertex Displacement = δ_{Total}

Note that the total vertex displacement, δ_{Total}, is always calculated using the slave vehicle mesh.

Based on the above, the force on the master vehicle would be

$$F_{Master} = A_{Master} + B_{Master} \times \delta_{Total}$$

and the force on the slave vehicle would be

$$F_{Slave} = A_{Slave} + B_{Slave} \times \delta_{Total}$$

The forces on the master vehicle and slave vehicle will be different whenever the stiffnesses are different. To equalize these forces, the total vertex deformation is adjusted by the following fraction, Θ:

$$\Theta = \frac{F_{Master}}{F_{Master} + F_{Slave}}$$

Finally, the deformation for the slave vertex is adjusted:

$$\delta_{Slave} = \delta_{Total} \times \Theta$$

The deformation to the master vehicle is not required because only the slave vehicle's vertices are displaced during the current timestep.

An interesting side effect of the new design: If one of the vehicles is a rigid barrier (i.e., infinite stiffness), the proportioning of the vertex displacement results in 100% of the displacement occurring on the other vehicle and none to the barrier. In other words, the results for a barrier impact are identical in *DyMESH* Version 4 and earlier versions.

EDC Presents 2 Technical Papers at 2018 SAE International Congress

The following technical papers were presented at the 2018 SAE International Congress in Detroit:

Paper No. 2018-01-0534: Day, Terry D., "Development of a 12-Node Thermodynamic Simulation Model of a Disc Brake Assembly." This paper provides a technical backgrounder for *HVE*'s new disc brake temperature model (see also the Summer 2017 Technical Session).

Paper No. 2018-01-0528: Day, Terry D., "Truck Brake Failure: Differences between Failure Modes for Drum and Disc Brakes." This paper provides brake temperature results for a long, downhill braking simulation. An identical event is performed for two vehicles, one fitted with drum brakes and the other fitted with disc brakes.

Call for *HVE* White Papers

All users interested in presenting an *HVE* White Paper at the 2018 *HVE* Forum are invited to submit an abstract (approximately 150 to 250 words in length) for consideration. *HVE* White Paper topics include *HVE* case studies, novel applications that showcase *HVE*'s capabilities, and any tips and techniques that show other *HVE* users how to take full advantage of *HVE*'s power features. It is also a great opportunity to contribute your knowledge and experience to the *HVE* user community. Submit your abstract via email to forum@edccorp.com. Abstracts are due by November 1, 2018.

HVE Admissibility List

EDC maintains a list of court cases in which *HVE* was used. As an expert preseenting the results produced by an *HVE* analysis, it is very helpful to provide a lengthy list of State and Federal court cases in which *HVE* results were successfully admitted.This list is available in the EDC Technical Reference Library (EDC Library Reference No. 3029).

Please email info@edccorp.com or call EDC Customer Service at 888.768.6216 with the following information: Case number, Citation (i.e., Smith v State of Ohio), Court/Jurisdiction (State or Federal), State, Date, Programs Used, Admitted? (Yes or No), and User number (optional).

HVE and *HVE-2D* F.A.Q.

This section contains answers to frequently asked questions submitted to EDC Technical Support staff by *HVE* and *HVE-2D* users.

Q: The Key Results are visible within the event but not within the Video Creator Window, why?

A: Select *View->Set Camera*, from the top pull-down menu. In the Camera Setup dialog, make sure the camera's *Depth of Field – Near* value is less than 4 feet. If this does not resolve your issue please contact EDC Technical Support at 503-644-4500.

Q: Some or all of the Key Results windows within the Event Editor are missing. Why?

A: Assuming you typically or occasionally run *HVE* on dual monitors, the Key Results windows were probably on your secondary monitor when yu closed your last *HVE* session. *HVE* stores these locations in your computer's registry so they'll be in the same place next time you use *HVE*. If you change your computer set-up to use a single monitor, those Key Results windows will be missing from your display. Follow these steps to get your missing Key Results windows back: Before launching *HVE*, setup both monitors and (this is key) switch your primary monitor so what is typically the second monitor is now your primary monitor. Now launch a fresh session of *HVE* and make sure it displays on the desired primary monitor. Search your secondary monitor for the missing Key Results windows, once located please drag them over to the primary monitor and then close *HVE*. You can now switch your primary monitor back to the original and you should be all set.

Q: How does the "Include Free Space" option within EDSMAC4's Calculation Options dialog affect my results?

A: In a word: It doesn't. *Free Space* is the gap between the actual vehicle geometry and the rectangular bounding box defined by the Vehicle Editor's red spheres located on the exterior surfaces of the vehicle. When working with generic vehicle geometries the *Include Free Space* option has no effect because no free space exists on generic vehicle geometries (the exterior dimensions of the rectangular-shaped generic vehicle are directly controlled by those red spheres). Custom vehicle geometries, on the other hand, will have free space at the corners of the geometry since real world vehicles are not shaped like simple rectangles. So when working with custom vehicle geometries the "Include Free Space" option allows the Damage Data report to report the total calculated crush depths instead of just the damage that extended beyond the free space and into the custom vehicle geometry. With that said, this option only affects the Vehicle Crush Depth Tables and Max Crush value. There is no effect on the "Vehicle Collision Kinetics" and the rest of the "Vehicle Damage Profiles".

Q: Why is there a difference between the vehicle's reported Velocity and its Speedometer value?

A: The difference occurs because the *Speedometer* value uses the speed from the wheels, just like a real vehicle. On the other hand, the *Total Velocity* value and its components are calculated by integrating the equations of motion (accelerations). The Total Velocity is the true velocity of the vehicle relative to the earth. The *Speedometer* and *Total Velocity* values are normally very similar, but a small difference often exists because the *Speedometer* value needs an estimate of the tire radius, which is calculated from the tire's nominal radius, the tire's radial stiffness and the nominal vertical tire load. In reality, the tire radius changes as a result of changes in the vertical tire load, thus causing a smalll difference between the two reported values. Another reason for a difference (and a potentially large one!) is that the wheels may be locked by braking, or spinning at a high rate because a teenager is driving. In these cases, the Speedometer reading will be zero or very high. Just like on a real vehicle, the Speedometer reading will differ greatly from the inertial velocity of the vehicle.

Q: Can I modify the location of the Video Creator's Key Results window?

A: Yes! Within the Video Creator window, you can drag the Key Results window to any desired location by using your mouse pointer. First confirm that the Video Creator viewer window is in *Pick* mode (i.e., the mouse cursor looks like an arrow). Then, simply click anywhere on the Key Results dialog and drag it to the desired location.

Visit the Support section of www.edccorp.com to download software updates and to view more FAQs from the Knowledge Base.

EDC Training Courses

EDC Reconstruction & Simulations

EDC offers excellent one-week courses on the use of the *EDCRASH* reconstruction program and the *EDSMAC*, *EDSMAC4*, *EDSVS* and *EDVTS* simulation programs. The **EDC Reconstruction** and **EDC Simulations** courses are designed to fully investigate the inner workings of these *HVE*-compatible physics programs. Lectures are full of helpful hints gained from years of experience. During the course, students will use the physics programs to complete several lab exercises highlighting the capabilities of each program discussed in the course.

All users of *HVE* and *HVE-2D* agree that these courses are extremely beneficial and challenging. It's the fastest way to learn what you really need to know – how to effectively use the physics programs and get the right results. *Note: These courses focus on the physics programs, not on the HVE user interface.* For courses that focus on the *HVE, HVE-2D* or *HVE-CSI* user interface, check out the workshops at the *HVE* Forum.

HVE Forum

The ***HVE* Forum** offers over 30 workshops designed to help *HVE, HVE-2D* and *HVE-CSI* users improve their modeling and application skills. By participating in workshops, attendees learn new techniques and also how to use the latest advancements in the software. The *HVE* Forum is also a great opportunity to meet other users and expand your network of resources.

Engineering Dynamics Corporation
Training Course Schedule

EDC Reconstruction

Los Angeles, CA . . . . January, 2020
Miami, FL . . . . November 5 - 9, 2018

EDC Simulations

Miami, FL . . . . November, 2019
Los Angeles, CA . . . . January 14 - 18, 2019

Theoretical & Applied Vehicle Dynamics

Upon Request

2019 *HVE* FORUM

Las Vegas, NV . . . . . . Feb 25 - Mar 1, 2019

Vehicle Dynamics

The **Theoretical & Applied Vehicle Dynamics** course extends the scope of a general vehicle dynamics discussion by including several direct applications using the *SIMON* vehicle dynamics simulation program within *HVE* and providing a solid theoretical background for such simulations. The course is focused towards engineers and safety researchers with an interest in an understanding of vehicle dynamics and automotive chassis systems development.

Course Registration

To register for a course, download a registration form from the Training page at edccorp.com or contact EDC Customer Service at 888-768-6216 or by email at training@edccorp.com. All courses are eligible for Continuing Education Units and ACTAR credits.

HVE Training Partners

HVE, *HVE-2D* and *HVE-CSI* users looking to improve their skills, but unable to attend one of EDC's regularly scheduled courses, can contact an *HVE* Training Partner for assistance. *HVE* Training Partners are experienced *HVE* and *HVE-2D* users who offer introductory and custom training courses on the use of *HVE*, *HVE-2D*, *HVE-CSI* and *HVE*-compatible physics programs. The list of *HVE* Training Partners may be found at www.edccorp.com.

HVE Discussion Groups

Websites hosted by experienced *HVE* Users offer information about using *HVE* as well as moderated online discussions with other users. Be sure to visit:

AccidentReconOnline.com - Online training courses and also the DiscoverHVE video tutorials and discussion group hosted by Wes Grimes of Collision Engineering Associates.

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