Beta 2 Resources ▾ Blast Spiral II By:

Blast

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1.0 Purpose

The Blast Analysis tool evaluates the design asembly against a variety of blast threats. The user can create custom blast threats by describing the location, charge size (in kg of TNT equivalent), and burial depth of the charge. Five tiers of analysis are supported to give the user flexibility in the trade-offs between computation time and analysis fidelity.

Tier 1 treats the entire vehicle as a rigid, non-deformable body and calculates the vertical and horizontal velocities and maximum jump height due to the blast. This calculation can be accomplished in a few minutes and is intended for experimenting with the overall shape of the undercarriage of the hull, e.g. V-hull, double-V-hull, etc.

Tier 2 takes into account the deformable nature of vehicle panels and structural members but saves significant processing time by not accounting for the case when one deforming material contacts another and continues to deform. The duration of this calculation can be as short as a few minutes and as long as many hours.

Tier 3 and up use LS-DYNA, a commercial finite element analysis code that accounts for contact between parts. The duration of these computations is measured in many hours to days, even when deployed on a compute cluster. Tier 3 employs a 30 mm resolution on the mesh generated from the STEP geometry. Tier 4 uses a 15 mm resolution mesh. Tier 5 uses a 15 mm resolution mesh and includes anthropomorphic test dummies (ATDs) to simulate the blast response on the human occupants of the vehicle.

2.0 Procedures

2.1 Tool Installation and Checkout

Run the SwRI AVM Tools installer and accept the default settings. This will install the tools into C:\SwRI-AVM-Tools. The tools need to be installed there rather than under the more typical Program Files directory, because temporary files are written to directories under the installation directory, and it is not needed, nor desirable, to run the blast and ballistics tools with administrator privileges.

In addition to the SwRI AVM Tools, LS-PrePost, a free program from Livermore Software, will be installed using its standard installer. These files are installed under the Program Files directory. LS-PrePost is a pre- and post- processor program designed to be used with LS-Dyna, the solver used for tier 3, 4, and 5 of the blast pipeline. The output from all 5 tiers of the blast pipeline can be viewed using LS-PrePost.

If you wish to test the installation of the blast portion of the SwRI AVM Tools, you can start up a cmd shell (cmd.exe) or a cygwin shell and run the following command:

```
C:\SwRI-AVM-Tools\blast.exe "C:\SwRI-AVM-Tools\Examples\Armor Plated Chassis\BlastConfigPD-C-center-center.json"
```

This will run a Tier 1 blast computation on a Meta-generated vehicle that has been included with the tool installation. A lot of text will then scroll by as the pipeline operates on the test design included with the tools. You will know that the tool is installed and operating correctly if the command finishes and you see something similar to the following:

```
==== Copying Final Results ====
Examples/Armor Plated Chassis/BlastConfigPD-A-center-front-res-mesh-Rigid.k
==== Timing Statistics ====
Startup time: XXXXXXXX Seconds
Convert to mesh time: XXXXXXX Seconds
Shader time: XXXXXXXX Seconds
Blast Calculation time: XXXXXXX Seconds
Movie creation time: XXXXXXXX Seconds
ELAPSED TIME: XXXXXX Seconds
```

You can then open LS-PrePost through the start menu. To make LS-PrePost easier to use, enable the "Text and Icon" toolbars by checking the following menu items:

```
View->Toolbar->Text and Icon (Right)
View->Toolbar->Text and Icon (Bottom)
```

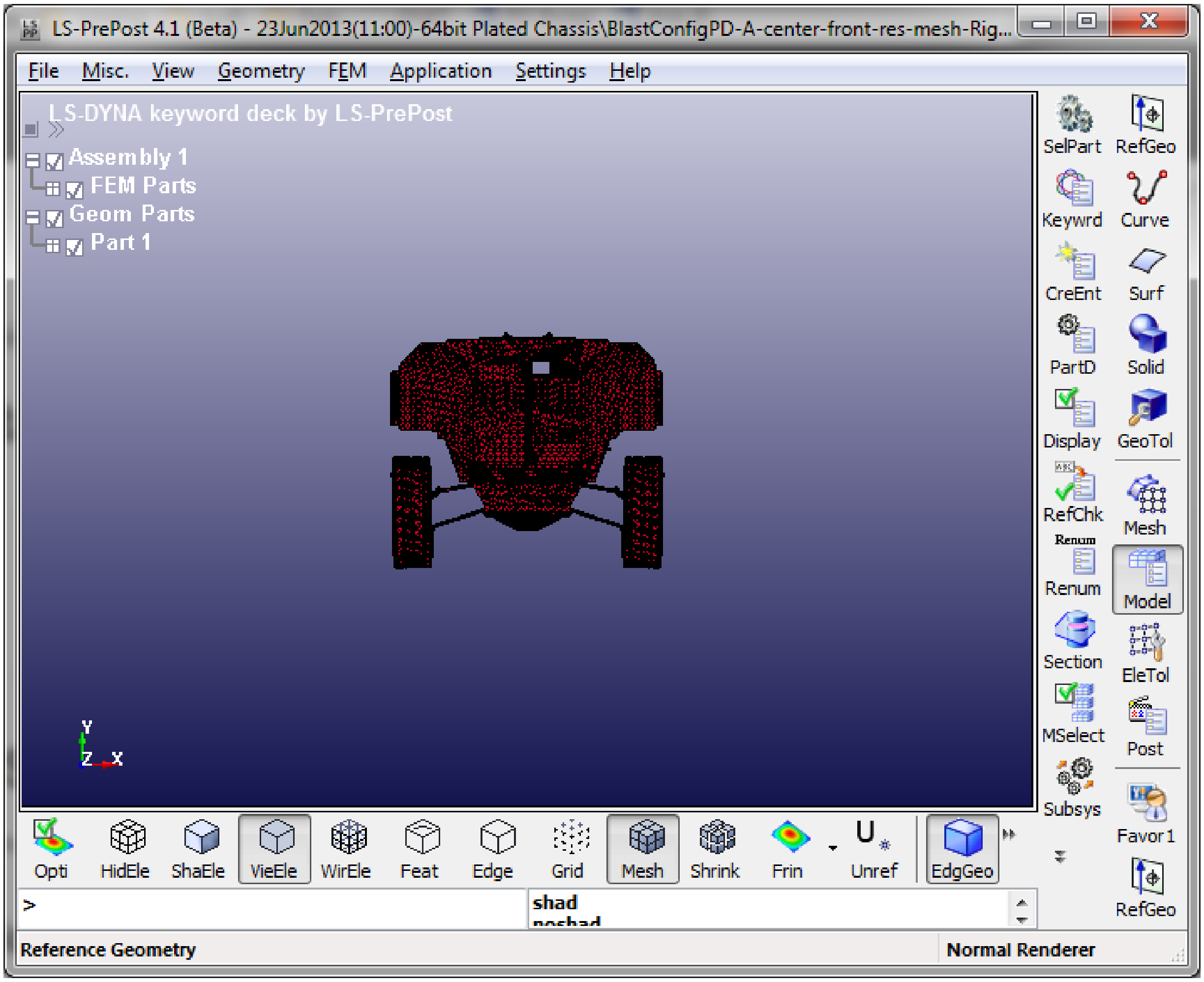
When the program opens, select:

```
File->Open->LS-DYNA Keyword File Ctrl-K
```

Then navigate to:

```
C:\SwRI-AVM-Tools\Examples/Armor Plated Chassis/BlastConfigPD-C-center-front-res-mesh-Rigid.k
```

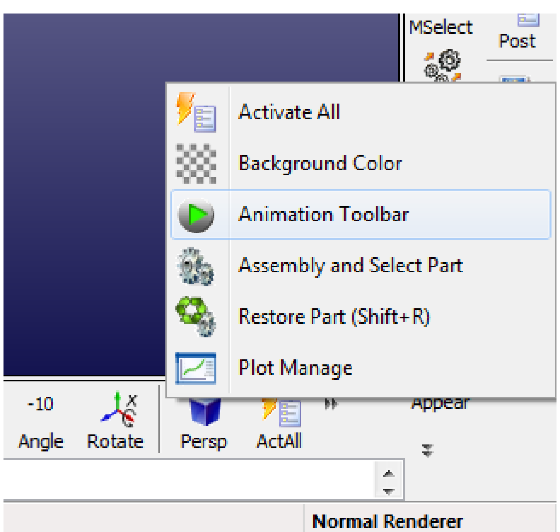
LS-PrePost should then look something like the following screenshot:



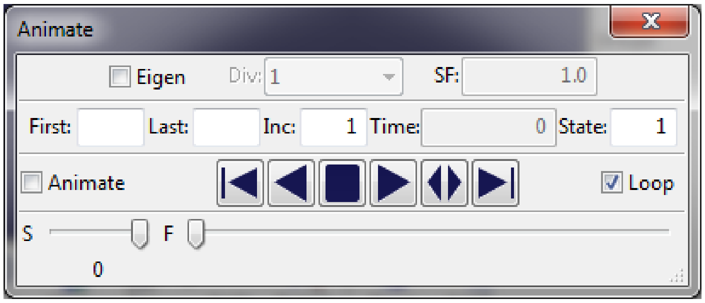
For 3D rotation of the view, hold down the Ctrl key and click-and-drag the left mouse button.

For zooming the view, hold down the Ctrl key and click-and-drag the right mouse button.

To view the animation of the blast, click the "Animation Toolbar" icon in the bottom menu. Depending on your screen resolution, you may need to click on the "double right arrow" on the right edge of the bottom toolbar as seen in the following screenshot:



The animation controls shown in the following screenshot allow the user to start, stop, and adjust the frame rate of the animation.



2.2 Use

2.2.1 Predefined Blast Suite

This tutorial will demonstrate the steps required to run a predefined blast suite on the MSD.

The tools include 24 predefined blast suites for use in test benches. It is also possible to configure a custom blast suite with variable size charge at a user-defined blast location. The predefined blast suites include 3 sizes of blast, corresponding to and equivalent blast of 1, 10, and 20 pounds of TNT. Note that the charge is described in kilograms of TNT, so 0.454, 4.536, and 9.07 kg in this case. The suites cover 8 unique locations around the vehicle. The exact x,y,z coordinates of the blast location is determined by the configured burial depth, the location of the ground plane, and the bounding box of the vehicle. For example, the -Left-Front blast suites will place the blast at a point that is 10% of the vehicle width in from the left and 10% of the vehicle length in from the front and at burialdepth below the ground plane. The -CG suites place the charge at burial depth below the ground plane and directly beneath the center of mass of the vehicle. The -Center-Center suites place the charge at burial depth below the ground plane and exactly half way between the front and rear and the right and left sides of the vehicle. The other blast suites around the perimeter of the vehicle place the charge at the 10% offset point as described for the Left-Front suites.

The following lists the predefined blast suites included with the tools and their associated charge weights.

1 lb Charge	4 lb Charge	7 lb Charge	10 lb Charge	13 lb Charge	16 lb Charge	20 lb Charge
BlastA-Center-Front	BlastB-Center-Front	BlastC-Center-Front	BlastD-Center-Front	BlastE-Center-Front	BlastF-Center-Front	BlastG-Center-Front
BlastA-Center-Rear	BlastB-Center-Rear	BlastC-Center-Rear	BlastD-Center-Rear	BlastE-Center-Rear	BlastF-Center-Rear	BlastG-Center-Rear
BlastA-CG	BlastB-CG	BlastC-CG	BlastD-CG	BlastE-CG	BlastF-CG	BlastG-CG
BlastA-Left-Front	BlastB-Left-Front	BlastC-Left-Front	BlastD-Left-Front	BlastE-Left-Front	BlastF-Left-Front	BlastG-Left-Front
BlastA-Left-Rear	BlastB-Left-Rear	BlastC-Left-Rear	BlastD-Left-Rear	BlastE-Left-Rear	BlastF-Left-Rear	BlastG-Left-Rear
BlastA-Right-Front	BlastB-Right-Front	BlastC-Right-Front	BlastD-Right-Front	BlastE-Right-Front	BlastF-Right-Front	BlastG-Right-Front
BlastA-Right-Rear	BlastB-Right-Rear	BlastC-Right-Rear	BlastD-Right-Rear	BlastE-Right-Rear	BlastF-Right-Rear	BlastG-Right-Rear

The name of a predefined blast suites can be configured in META for performing the blast analysis.

2.2.2 Step 1: Set Up Test Folder

If you have **not** already created a Testing folder, in the GME Browser, insert a new Testing subfolder within the existing Testing folder and name it “Blast Test.”

Within the Testing subfolder, insert a new **BlastTestBench** model and name it “Blast TestBench, Predefined SL”

2.2.3 Step 2: Insert Design Space Reference

Copy/Paste As Reference... the MyMassSpringDamper design container into the Blast Test window.

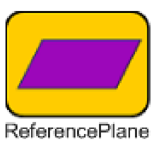
When prompted, select **TopLevelSystemUnderTest**.

2.2.4 Step 3: Predefined Blast Suite Test Bench Requirements

The Blast test bench for a predefined Blast suite has three components:

- Target you are subjecting to a blast (1)
- Predefined Blast Suite (2)

- Reference plane (3)



- CAD Workflow (3)

2.2.5 Step 3a: Select the Predefined Blast Suite

- Within the Element Browser, find the "PredefinedBlastSuite" element and Drag/Drop it into the test bench window.
- In order for the simulation to run, the Name of the predefined blast suite must be supplied.
- Highlight the PredefinedBlastSuite and fill out the information in the Object Inspector so that the Name field matches one of the options in the table below.

The tools include 24 predefined blast suites for use in test benches. It is also possible to configure a custom blast suite with variable size charge at a user-defined blast location. The predefined blast suites include 3 sizes of blast, corresponding to and equivalent blast of 1, 10, and 20 pounds of TNT. Note that the charge is described in kilograms of TNT, so 0.454, 4.536, and 9.07 kg in this case. The suites cover 8 unique locations around the vehicle. The exact x,y,z coordinates of the blast location is determined by the configured burial depth, the location of the ground plane, and the bounding box of the vehicle. For example, the -Left-Front blast suites will place the blast at a point that is 10% of the vehicle width in from the left and 10% of the vehicle length in from the front and at burialdepth below the ground plane. The -CG suites place the charge at burial depth below the ground plane and directly beneath the center of mass of the vehicle. The -Center-Center suites place the charge at burial depth below the ground plane and exactly half way between the front and rear and the right and left sides of the vehicle. The other blast suites around the perimeter of the vehicle place the charge at the 10% offset point as described for the Left-Front suites.

The following lists the predefined blast suites included with the tools. Blast A is 1 pound (0.454 kg). Blast B is 10 pounds (4.536 kg). Blast C is 20 pounds (9.07 kg).

```
BlastA-Center-Center  BlastB-Center-Center  BlastC-Center-Center
BlastA-Center-Front   BlastB-Center-Front   BlastC-Center-Front
BlastA-Center-Rear    BlastB-Center-Rear    BlastC-Center-Rear
BlastA-CG             BlastB-CG             BlastC-CG
BlastA-Left-Front     BlastB-Left-Front     BlastC-Left-Front
BlastA-Left-Rear      BlastB-Left-Rear      BlastC-Left-Rear
BlastA-Right-Front    BlastB-Right-Front    BlastC-Right-Front
BlastA-Right-Rear     BlastB-Right-Rear     BlastC-Right-Rear
```

The name of a predefined blast suites can be configured in META for performing the blast analysis.

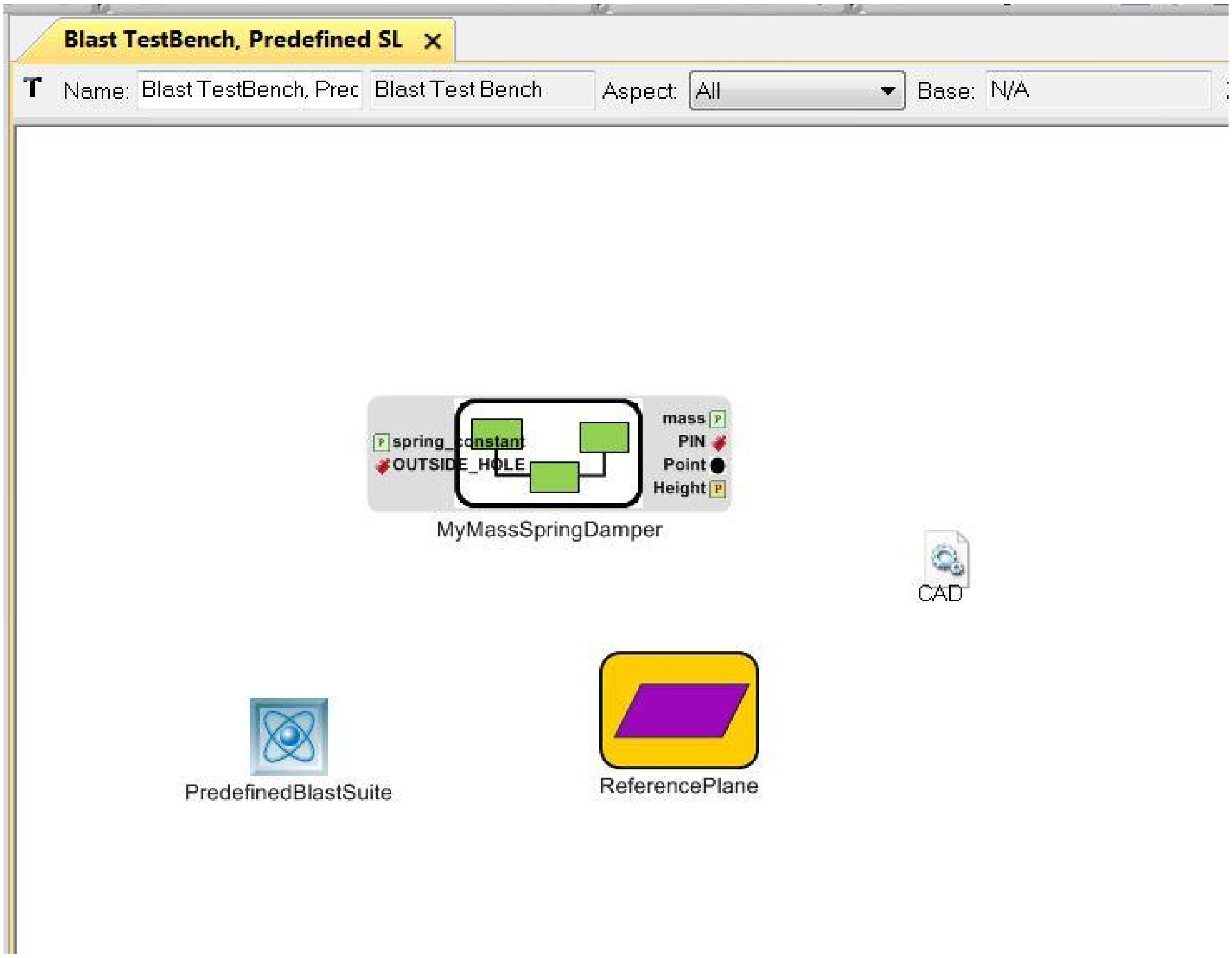
2.2.6 Step 3b: Reference Plane

- Locate the ReferencePlane element in the Element Browser and Drag/Drop it into the Blast TestBench window.
- Select the element and ensure that under the Attributes tab in the Object Inspector that its **Type** is specified as “Ground”.

2.2.7 Step 3c: CAD Workflow

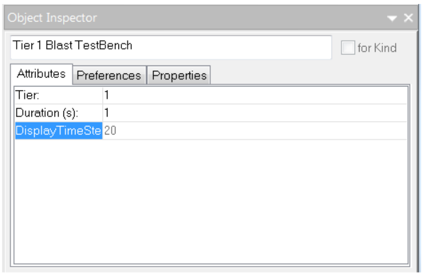
- In the GME Browser, add a workflow definition folder in your testing folder.
- Add a workflow to this folder, and call it CAD.
- Open the workflow, and drag in a task from the part browser.
- Select CyPhy2CAD_CSharp from the list.
- Copy/Paste as Reference the CAD workflow into the Blast TestBench window.

Your screen should now resemble the following figure:



2.2.8 Step 3d: Tier

- Select the "BlastTestBench, Predefined SL" under the Testing folder in the GME Browser.
- Select the Tier in the Object Inspector Window. Tiers 1-4 are supported at this time.
- For Tier 1 analysis, a duration of at least 1 second is desirable so that the vehicle has time to reach its maximum jump height and fall back down.
- For Tiers 2-4, a duration of 30 milliseconds (0.030) is more typical. After 30 milliseconds the loading from the blast has finished and the major deformations have occurred. The higher tiers are computationally expensive so it makes the most sense to only simulate as long as required to see the effects of the blast loading.



Your blast test bench is now set up.

2.2.9 Step 4: Run DESERT

- Run DESERT as usual, applying all constraints and exporting all configurations. You should end up with 3 configurations.

2.2.10 Step 5: Running the interpreter

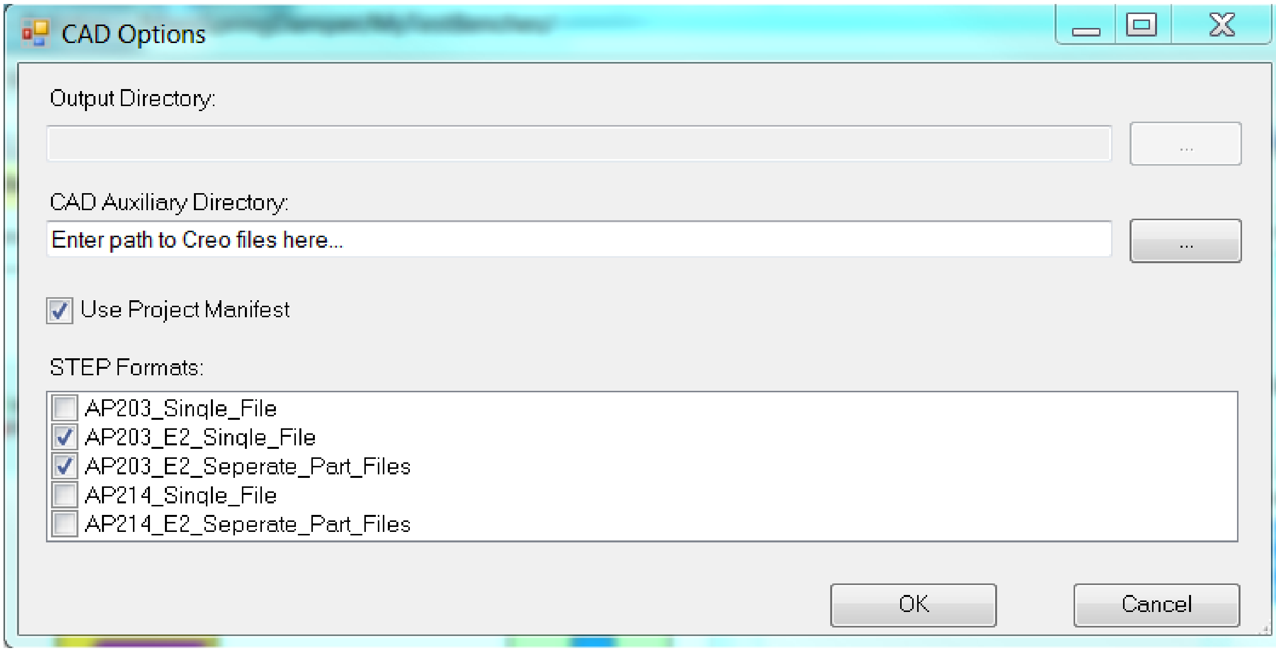
- From the META tool bar, select the Master Interpreter.

Select the design configurations you would like to run the test on, and click OK.

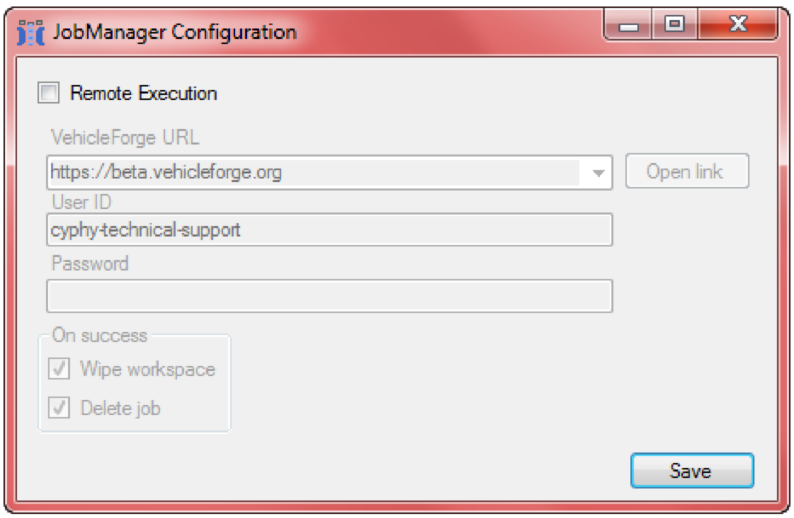
When you run this interpreter, you must:

- Choose the location of the Creo part files that make up the assembly.

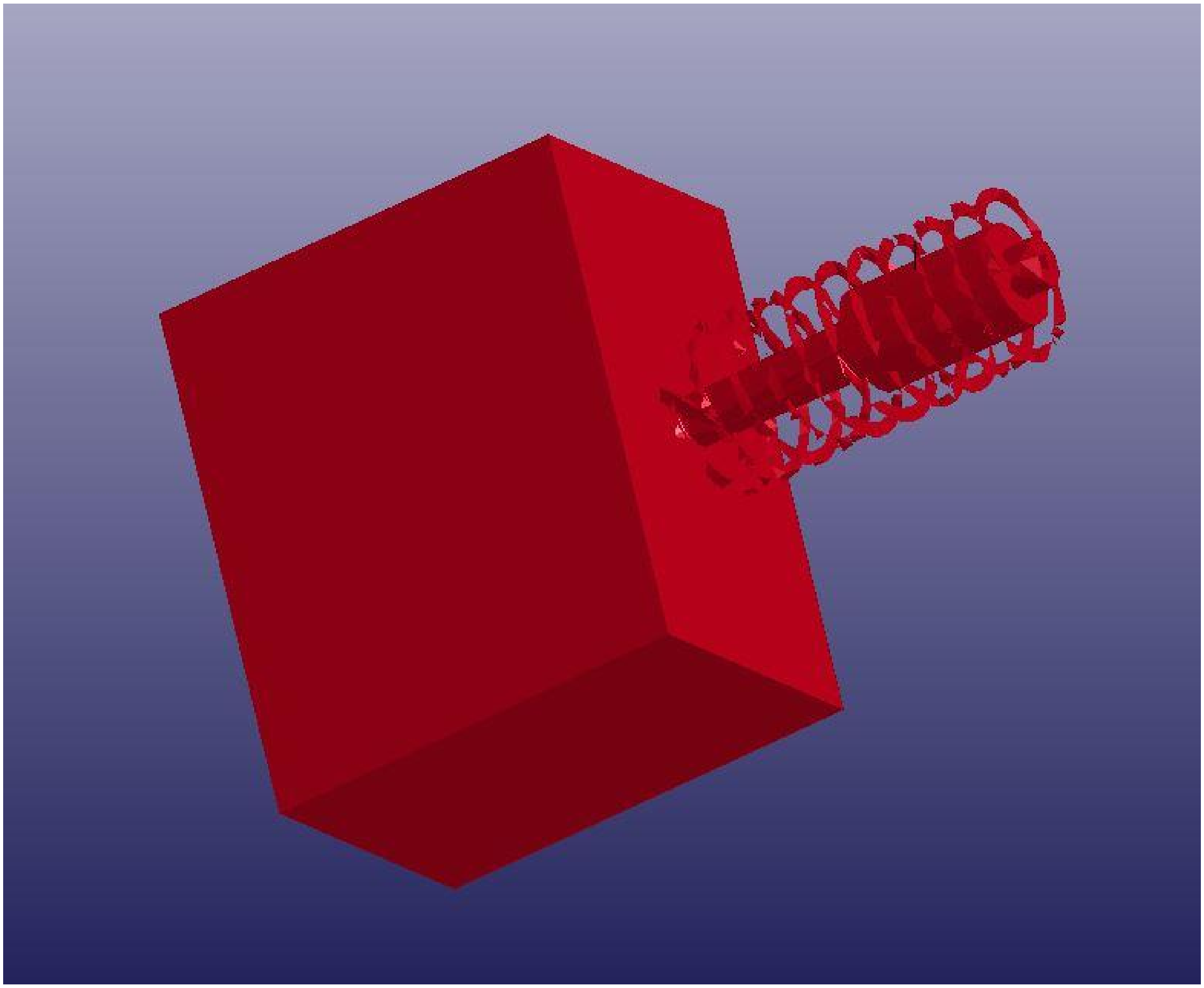
- Make sure that both “AP203_E2_Single_File” and “AP203_E#_Separate_Part_Files” are checked.



- Select OK.
- Make sure to run the job locally by deselecting the remote execution box in the job manager configuration box.

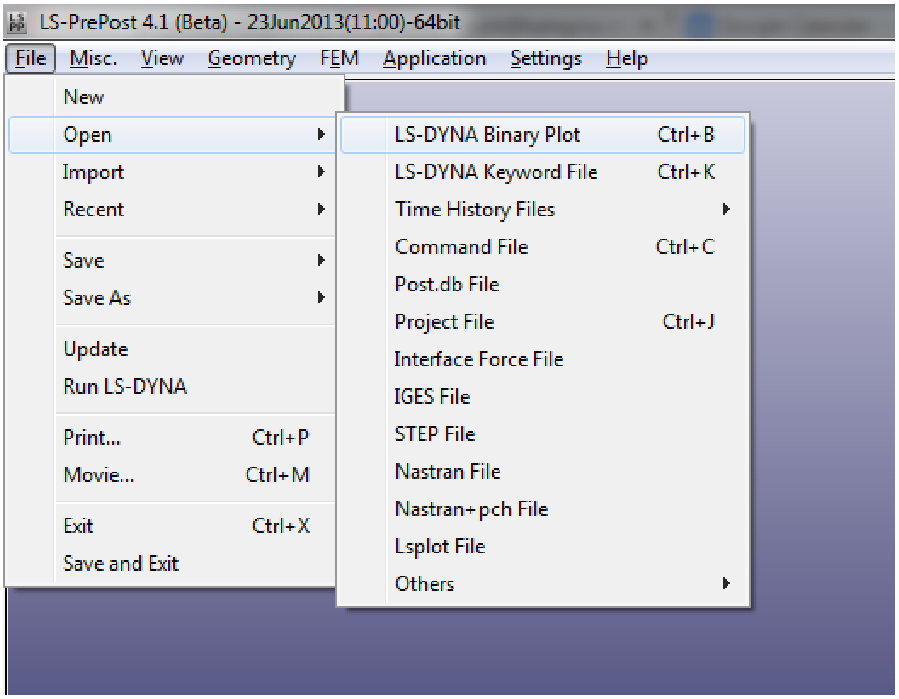


- If the test bench was correctly set up after the analysis is completed, a file ending in ".k" should be in the same directory where the files were exported. Start up LS-PrePost and load in the "k-file".

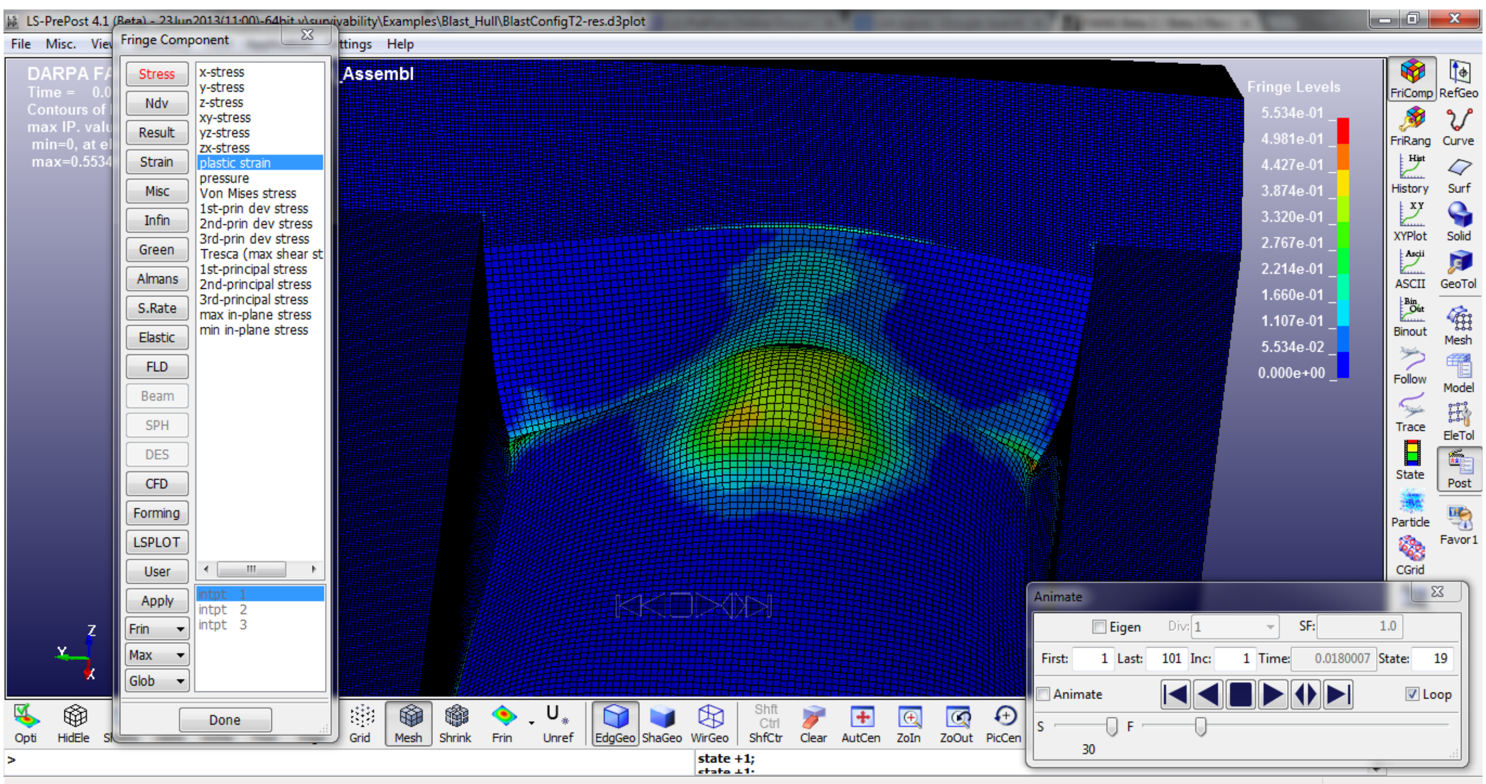


2.3 Viewing Results from Tiers 2-5

Blast tiers 2 through 5 perform a deformable blast analysis of the assembly. Depending on the amount of simulation time selected and the complexity of the assembly, the calculation can take anywhere between a few hours to many days to complete. However, when the user has access to the machine on which the solver is running, he/she can view the results of calculations completed to that point. Simply open LS PrePost and select "File->Open->LS-Dyna Binary Plot" and select C:\SwRI-AVM-Tools\blast-tools\d3plot. To view results from a simulation that has already completed, select the BlastConfig.d3plot file in the results directory.



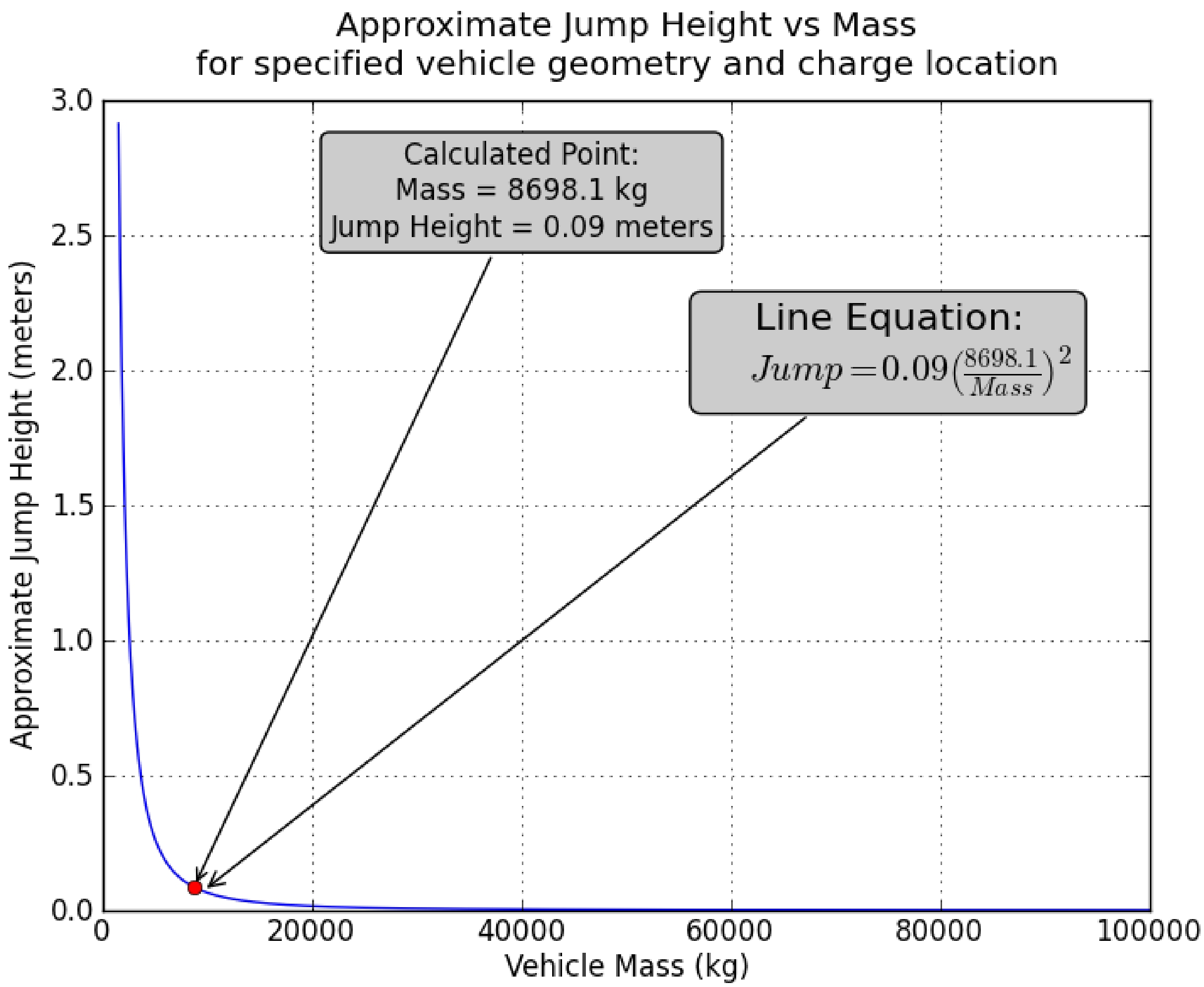
With the d3plot file loaded into LS PrePost, the user can view the animation of the blast event as with the tier 1 analysis. Additionally for tiers 2-5, the user may select to view stresses or strain data overlaid on top of the mesh. In LS PrePost these are referred to as "Fringe". To view fringe data, open the Fringe Component window by clicking on the "FriComp" button in the upper-right corner of the display. This will bring up the Fringe Component window and allow the user to select the fringe data to be viewed on the mesh. The following image shows the plastic strain data from a tier 2 analysis on a flat-bottomed hull. The user is able to view the animation and step forward and backward to view the fringe data or to generate an AVI movie file of the data by selecting File->Movie.



2.4 Jump Height Versus Mass Surrogate -- Notes on Multi-Fidelity Modeling

One of the goals of the AVM tools is to enable the exploration of design spaces in a more automated fashion than previously possible. An example of this type of activity might be examining the intersection of the competing constraints of jump height caused by an underbelly blast and the time for the drive train to accelerate the vehicle to top driving speed in the horizontal direction.
If, for example, you increase the mass of the vehicle, it experience less vertical jump under blast scenarios, which is desirable; however, the increased mass results in a longer time required to accelerated to top driving speed, all other things being equal.

The SwRI Blast tools assist in evaluating these competing constraints by producing a PNG image containing a plot of expected vehicle jump height versus mass each and every time a Tier 1 blast scenario is computed. Generally the file is called "BlastConfig-jump-vs-mass.png" and is located in the results directory where the blast scenario was computed. The following is an example of this auto-generated plot.

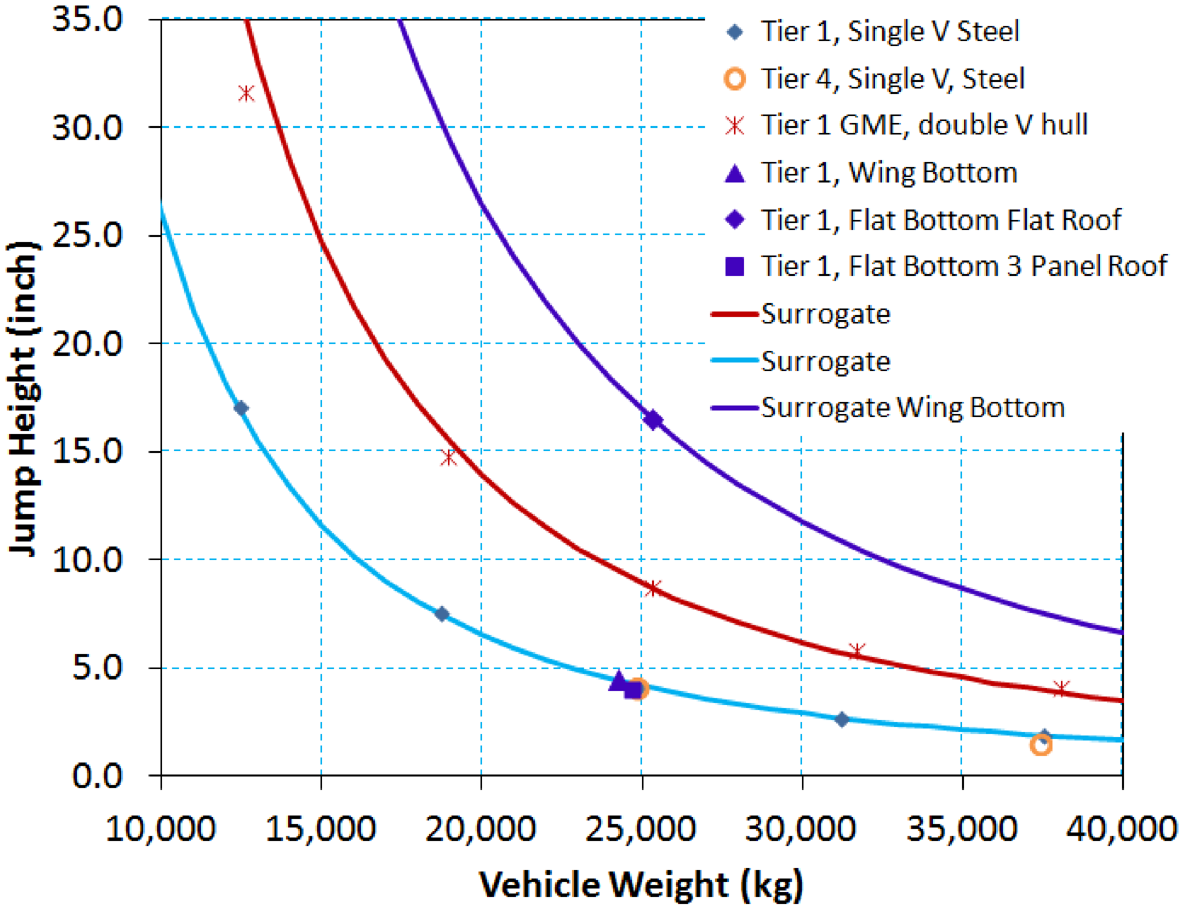


In addition to the plot, on this plot the equation is printed for the mass vs. jump height for the specific hull shape and charge size and location. This equation can be used in conjunction with other mass-based performance equations for quickly exploring the design space.

The mass vs. jump height is sensitive to:

1. Blast charge size
2. Blast charge location relative to the vehicle (which depends, in part, on the placement of the ground plane)
3. The outer hull geometry of the vehicle.

For these reasons, care must be taken if the goal is to compare the results for different hull geometries. For example, the Double V parametric hull and the Single V parametric hull, produce very similar standoff distances to the ground plane and therefore the results are directly comparable. Likewise the Flat Bottom and Wing Bottom hulls have similar flat bottom shapes and the same height above the ground plane, thus the blast loading on these hulls is nearly identical. However the results from these latter calculations cannot be directly compared with the Single V hull because the standoff distances are different (the ground plane location is not the same). The following plot is a comparison of results for individual blast analyses (the points) with their respective blast surrogate (jump-height-versus-vehicle-mass) curves. The ground plane location used was that provided by the system during



the Beta testing.

2.5 Release Notes and Future Capabilities

Tier 1, tier 3 and tier 4 are currently supported. The tier 2 solver produces erroneous results and is not yet ready for use. Support for tier 5 will be added in a future release once support for handling of pre-meshed seats that contain the correct placement of Anthropomorphic Test Devices (ATDs) a.k.a. test dummies, is added to the META toolchain.