Hull Design Assist Tool

User Tutorial for Hull Design Assist Tool

May 2, 2014

Tel (615) 343-7472 Fax (615) 343-7440
1025 16th Avenue South Nashville, TN 37212
www.isis.vanderbilt.edu

VANDERBILT UNIVERSITY

1.0 Purpose

The purpose of the Hull Design Assist Tool (HuDAT) is to provide the designer with the capability to fully define the hull with the information needed to perform detailed analyses including, blast, ballistics, and manufacturability, in addition to the information needed to manufacture the designed hull. The functions needed to create this information include creating detailed hull plates, internal hull structure, and weld joints.

HuDAT is a plug-in to the Creo CAD tool that provides an additional set of functions and user buttons to help the designer move from a concept level design to a fully detailed design. These added functions are linked to buttons added in an additional ribbon in the Creo environment.

In HuDAT, the hull design process begins with a concept level hull that has been analyzed using CyPhy to determine a suitable length, width, height, configuration, plate thickness, and material type. This concept level hull can be downloaded from Vehicle Forge or developed by the user using a soapbar template.

The functionality provided by HuDAT reduces the engineering time needed to transition from concept to detailed design for the hull of an armored vehicle. Specifically, HuDAT automates the process of defining weld joints between ballistic plates on a hull model. HuDAT automates and/or reduces the necessary design time for the following functions:

- Analyzing ballistic material weld compatibility.
- Enlarging or reducing ballistic plate size to support the manufacturing processes needed to produce ballistic welds.
- Defining and performing edge preparation on ballistic plates (chamfers and cuts).
- Creating solid weld geometry representing the final weld bead.
- Setting plate and weld material properties and mass properties.
- Checking plate sizes against dimensional constraints which are imposed by manufacturing.
- Cutting plates into acceptable sizes and producing edge preparation for the butt joint formed.

The TACOM Ground Combat Vehicle Welding Codes for steel and aluminum define the requirements for welds for armored vehicles. These codes categorize weld requirements into four different categories; stud welding, non-critical welding, critical welding (except ballistic structures) and ballistic welding. Each weld category has a unique set of requirements for design, test and qualification with critical and ballistic welds having the most stringent requirements. Critical welds are applicable to all weld joints where failure of the joint would likely result in personnel injury, loss of life, or a mission-critical failure, whereas ballistic welds are applicable to the joints in a ballistic structure which are critical to the ballistic integrity of the structure. The HuDAT application executes the geometric rules to create valid weld joints that meet the TACOM requirements for "ballistic welds". If HuDAT is not used to produce correct edge preparation and solid weld geometry the user must manually perform the operations needed to create weld and joint configurations. More information is provided in Section 4.0 regarding the required edge prep and geometric operations needed to manually create valid weld joints.

2.0 Procedures

The user will install the plug-in, open a hull seed model, check the concept hull model, and create detailed plates and ballistic welds. The user will be able to export the hull model with detailed plates and welds in ACM compliant format.

2.1 Installation

Ensure that you have sufficient privileges to install software on your computer. The minimum system requirements are:

- Windows 7, 32- or 64 bit
- 8 GB RAM (or more is recommended)
- Creo2 Parametric previously installed

Step 1

Uninstall any previous versions of HuDAT. The resulting HuDAT installation folder may have files remaining after the uninstall process as shown in Figure 1. The user should delete any remaining files or folders that exist in the HuDAT directory from the previous installation.

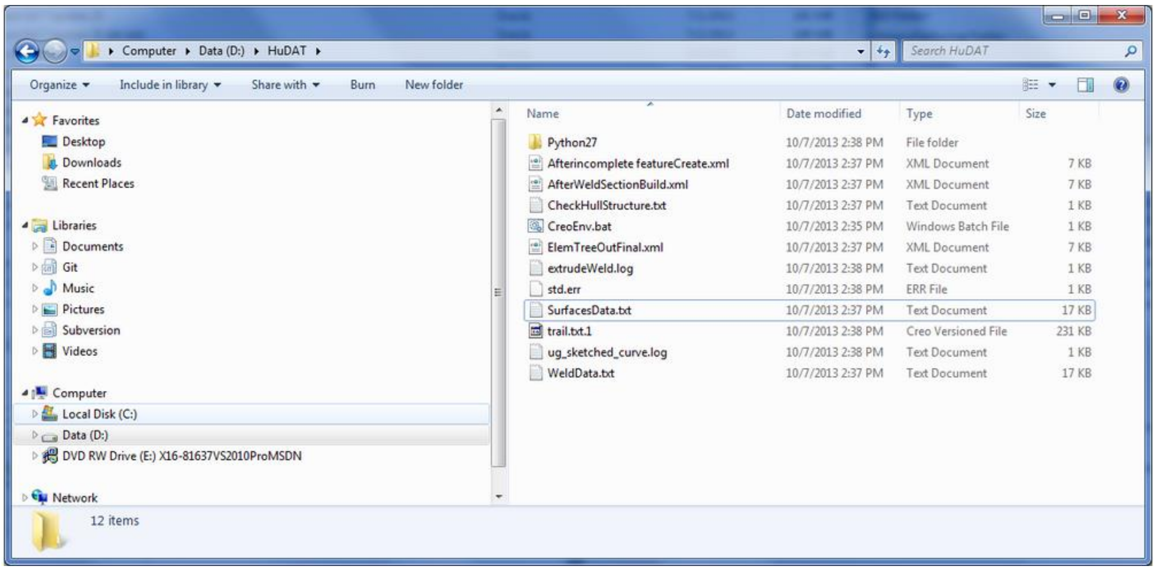
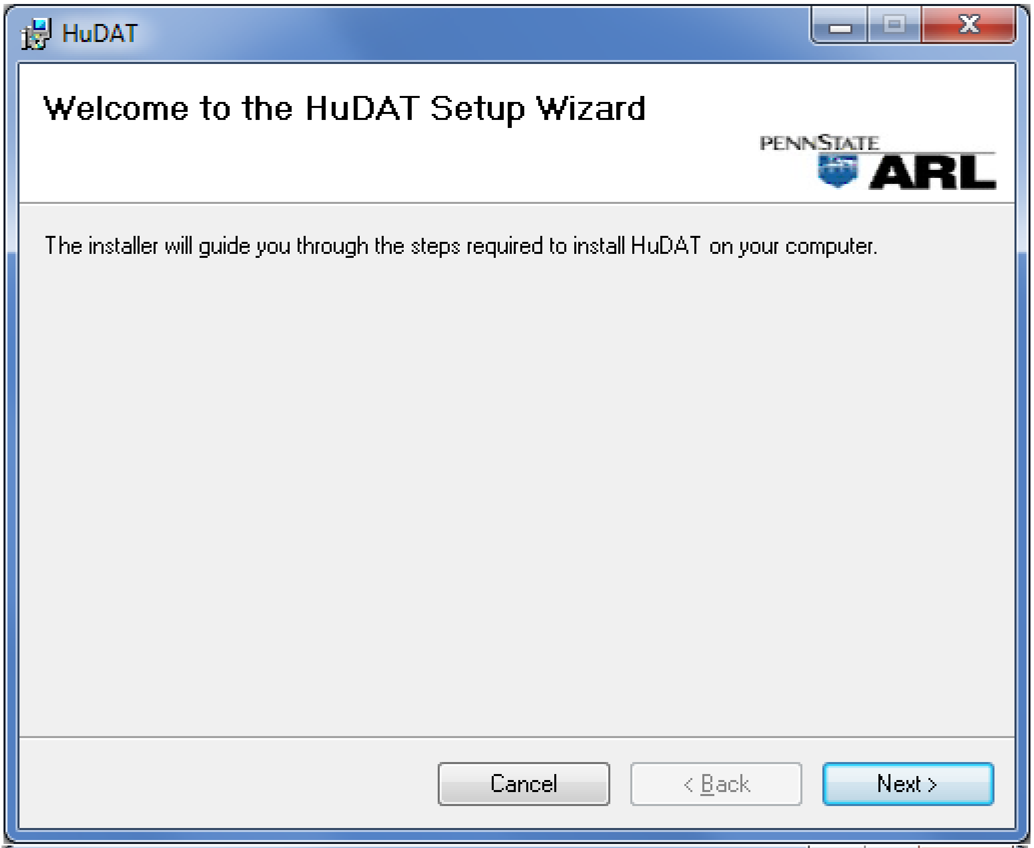
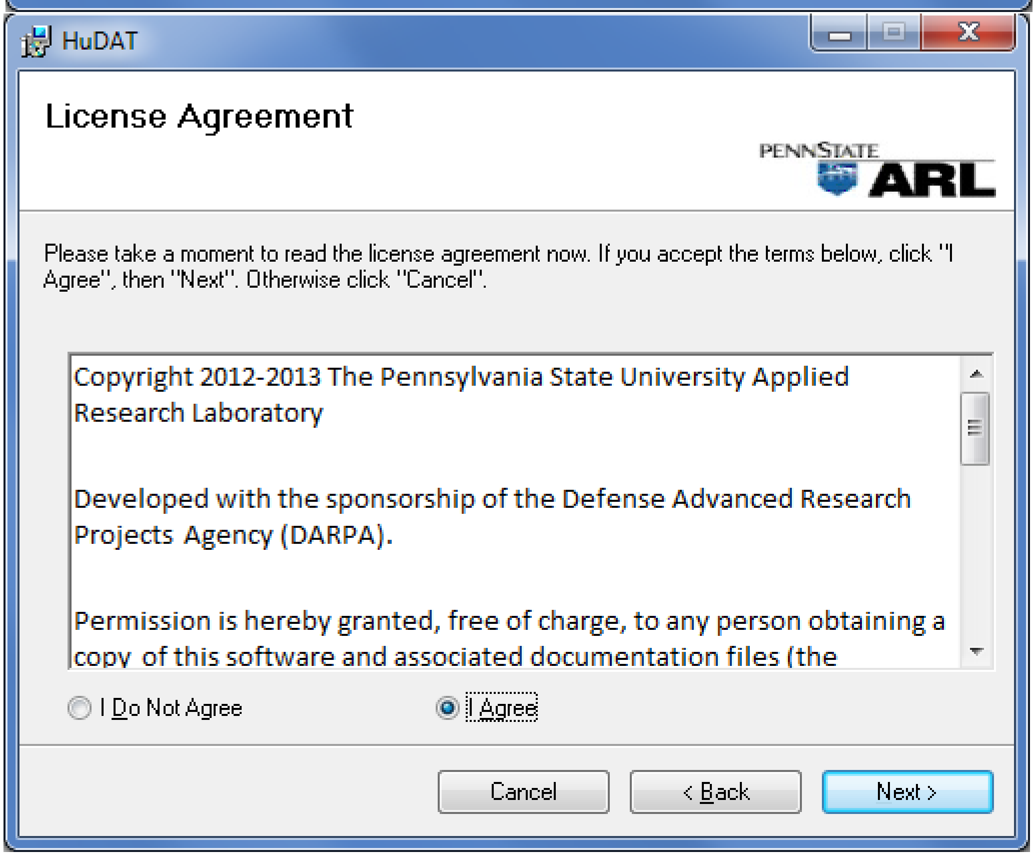


Figure 1: Files That May Be Left After Uninstalling a Previous Version of HuDAT

Step 2

Download the HuDAT tool from Vehicle Forge and start the HuDAT installation executable by double clicking on the DATInstaller.msi file. The installer includes a license agreement and installation path page as shown in Figure 2. It will notify you once the installation is successful. The environment variable $hudat_installdir is set to the chosen installation path.


HuDAT
Welcome to the HuDAT Setup Wizard
PENNSTATE
ARL
The installer will guide you through the steps required to install HuDAT on your computer.
Cancel
< Back
Next >


HuDAT
License Agreement
PENNSTATE
ARL
Please take a moment to read the license agreement now. If you accept the terms below, click "I Agree", then "Next". Otherwise click "Cancel".
Copyright 2012-2013 The Pennsylvania State University Applied Research Laboratory
Developed with the sponsorship of the Defense Advanced Research Projects Agency (DARPA).
Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the
I Do Not Agree
I Agree
Cancel
< Back
Next >

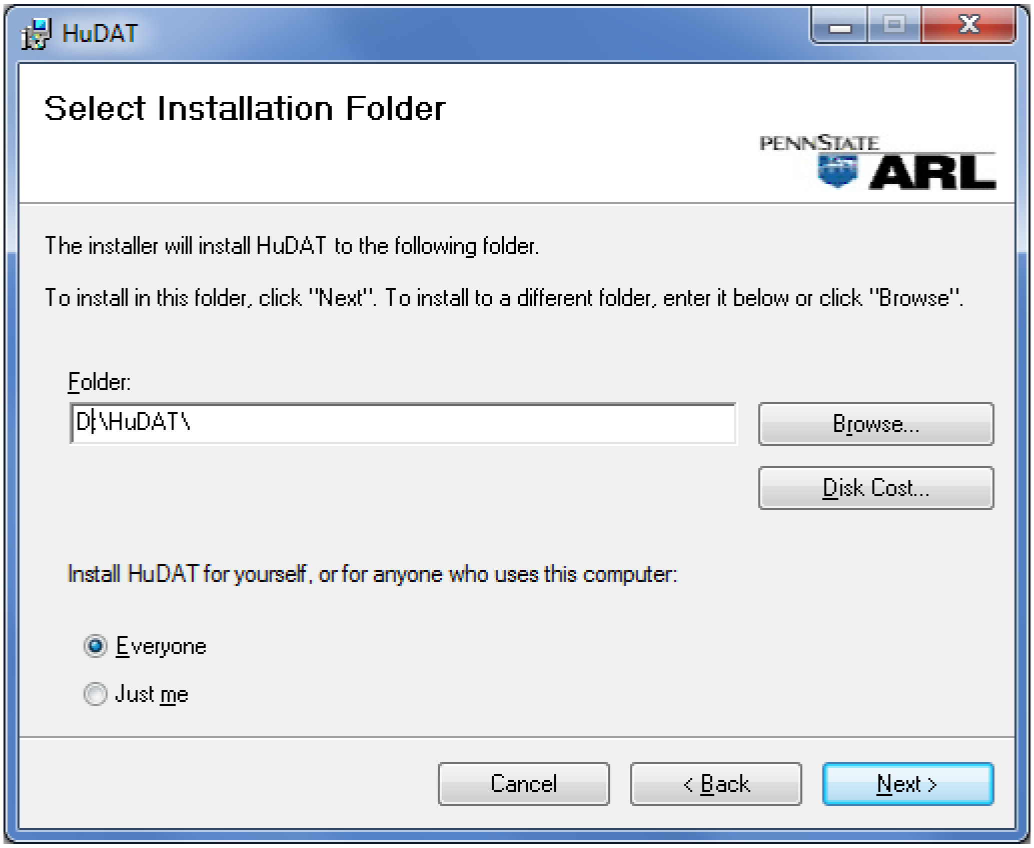


Figure 2: Windows Included in the HuDAT Installation Wizard

Section 2.2 describes how to launch Creo and run HuDAT. The HuDAT ribbon should look like the image in Figure 3. The HuDAT ribbon will only be displayed in Creo assembly mode.

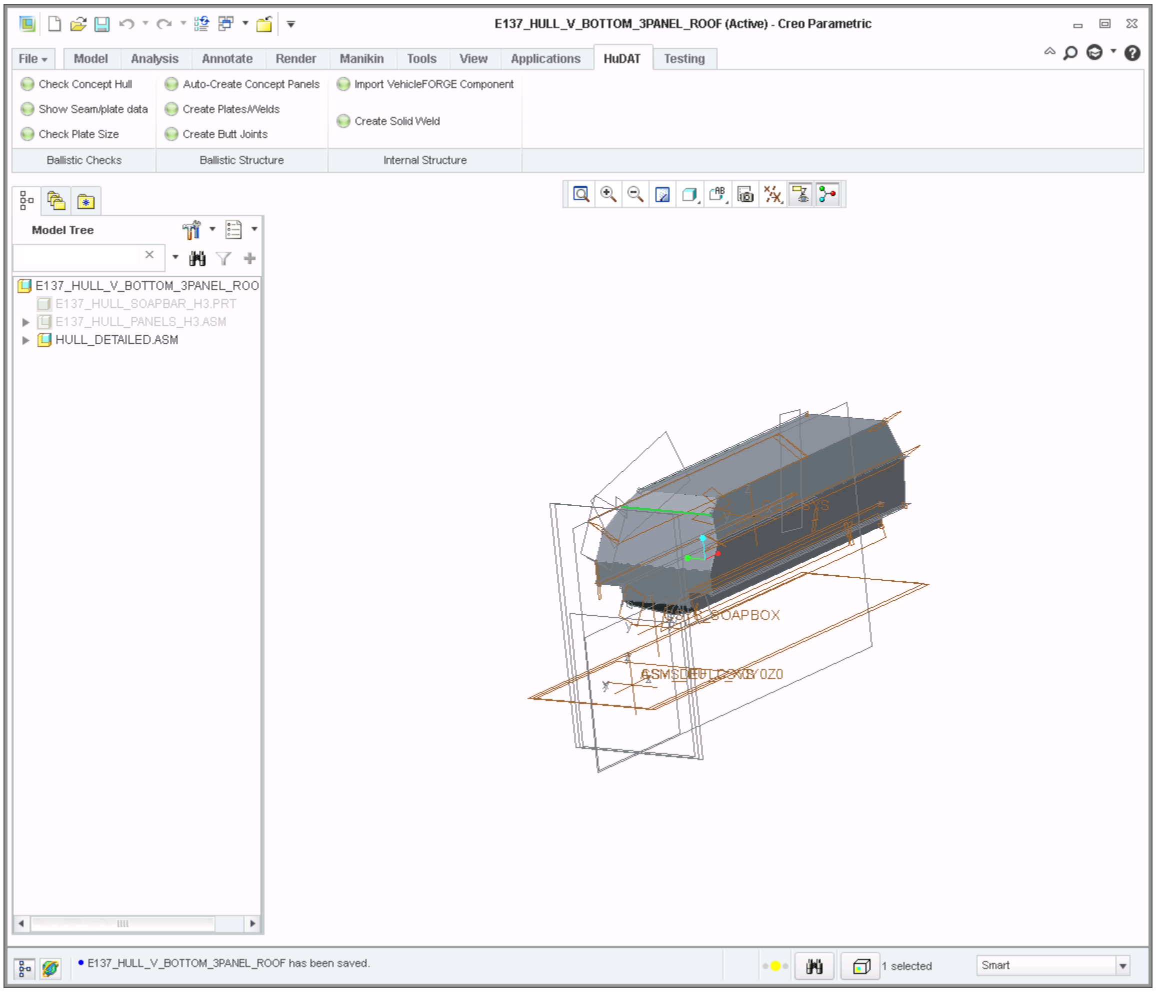


Figure 3: HuDAT Dashboard Tab Displayed in Creo

2.2 Use

The main window for Creo (standalone) is shown in Figure 4. In this figure, a conceptual hull component has been loaded into the Creo environment and is visible in the geometry window.

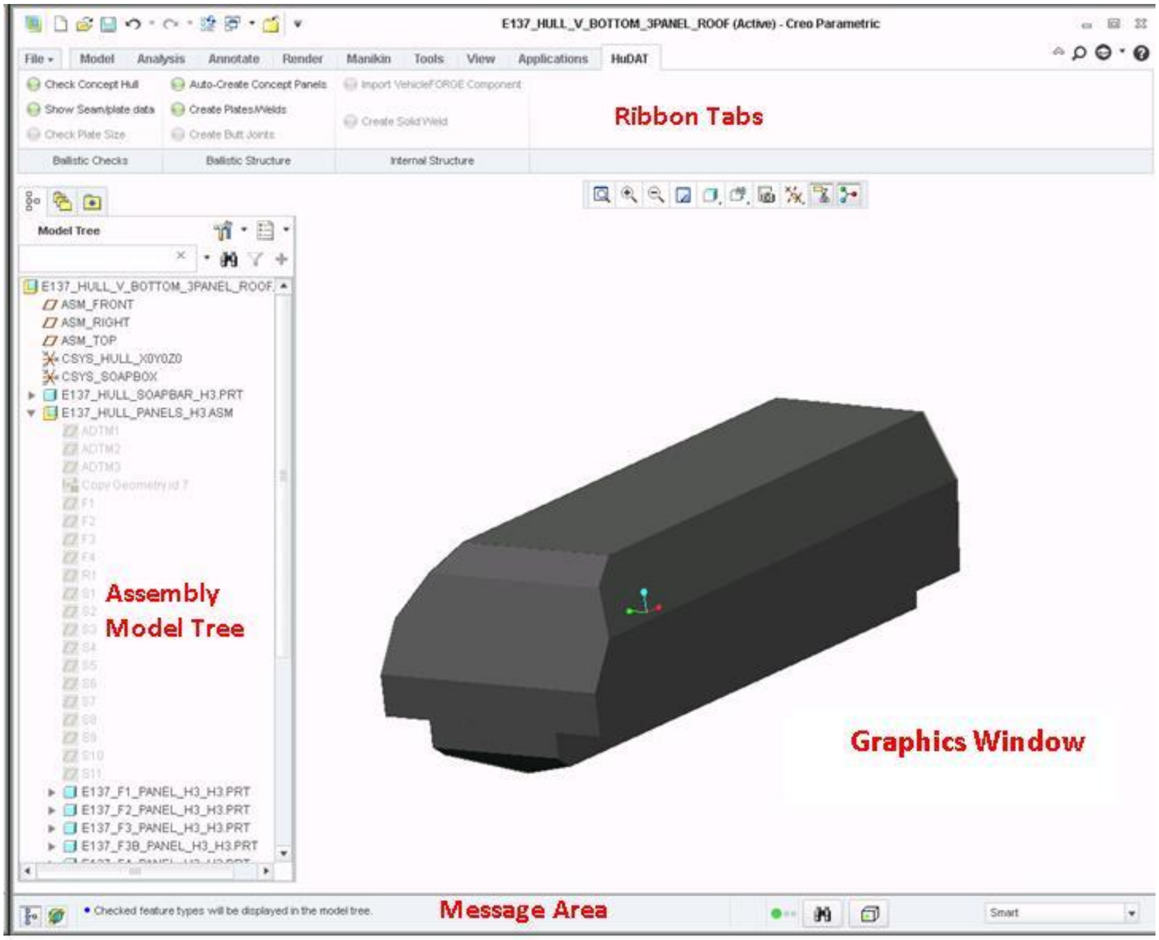


Figure 4: Creo Main Window

The Creo interface is divided into 3 main areas: 1) the Toolbars/Ribbons, 2) Tree Structure, and 3) the Geometry Window. HuDAT is comprised of a custom toolbar that contains buttons used to invoke functions that modify the Creo model tree in a structured way and show the results in the geometry window.

2.2.1 Launching Creo/Running HuDAT

After HuDAT has been installed, there are three different ways that HuDAT can be loaded into the Creo environment and applied to a concept hull design. The first way that the HuDAT ribbon will be loaded is by opening a session of Creo through METALINK. METALINK automatically checks if a version of the HuDAT software is installed and, if it is, it will load the ribbon.

For the second method, the installer will create a batch (HuDAT.bat) file in its installation directory (as shown in Figure 6) that can be used when designing in

Creo with HuDAT (double click to run the launcher). This file will start Creo, install the plug-ins, and add the HuDAT toolbars to the Creo interface.

The third method to start HuDAT is to open Creo Parametric and then enter the Utilities>Auxiliary Application functions (from the Home screen as in Figure 5). In the Auxiliary Applications you can select Register and select the Protk.dat file that was installed in the HuDAT Installation directory ($hudat_installdir\protk.dat). When prompted select both applications ("utilities" and "hudat") and the select Start to add the plug-ins into the Creo environment.

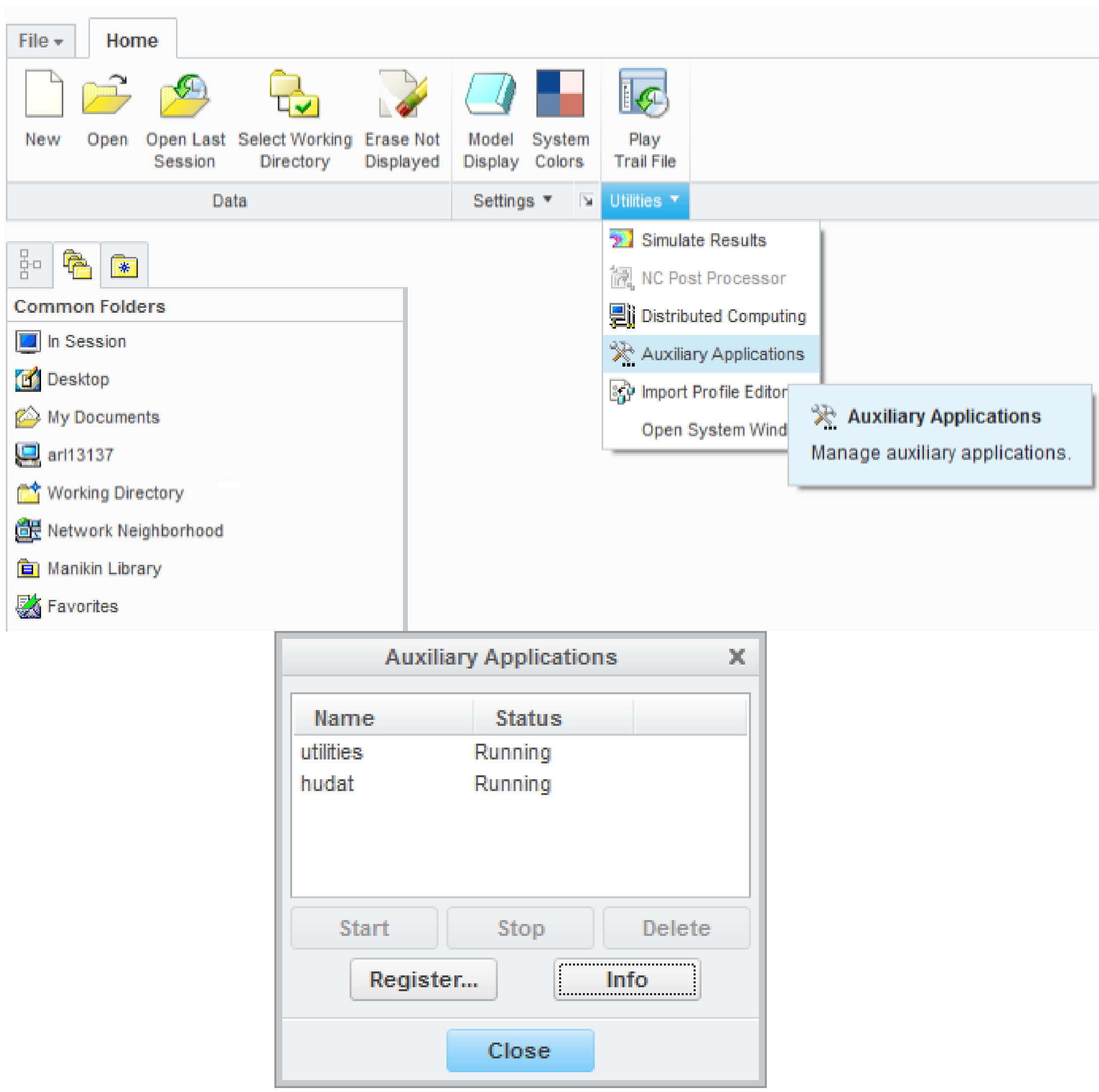


Figure 5: Auxiliary Applications Menus (left) Access from Home Screen, (right) Popup Menu

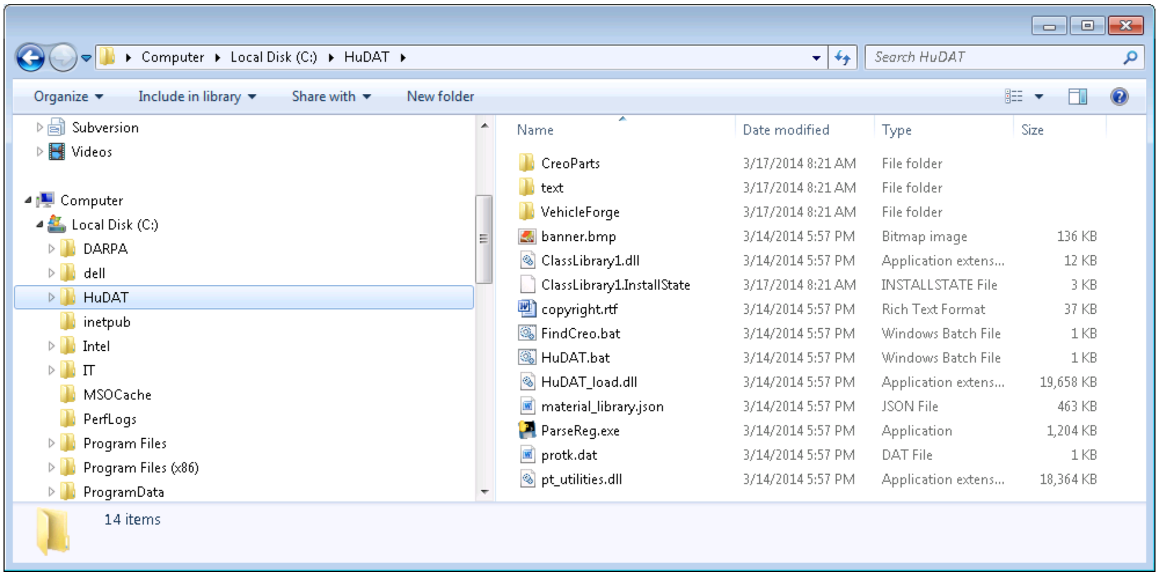


Figure 6: Launching Creo

A ribbon titled “HuDAT” is loaded whenever Creo is in assembly mode (the ribbon will not display in Part or any other mode). Selecting this ribbon will display the functions that the plug-in can perform on the concept hull. Details about the functions are discussed in sections 2.2.3 and 2.2.4.

2.2.2 Opening a Hull Component

HuDAT operates on specially defined conceptual hulls as detailed in the “HuDAT Requirements” documentation; an abridged version is given in Section 2.2.3. Pre-configured hulls can be downloaded as components from the Vehicle Forge component exchange (gamma.vehicleforge.org/exchange) under the *Hull Frame Body Cab* components.

The Vehicle Forge component download will have compressed files that must be extracted into a directory structure. The CAD folder contains the STEP and Creo specific files for the component downloaded. The *Manufacturing* folder contains the *.xml manufacturing data for the component. The doc folder contains information about the distribution statement and other important information. Figure 7 shows the file folders that exist in the directory structure from a Vehicle Forge component.

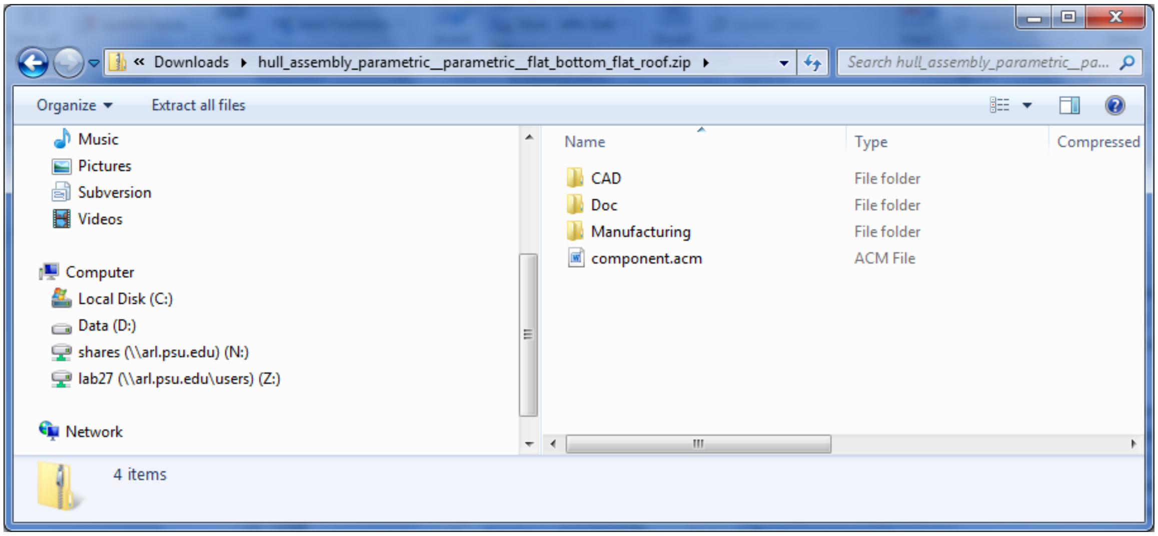


Figure 7: Select CAD Folder File Chooser

From the GME software environment, concept hull assemblies are loaded into the Creo interface using the METALINK feature. The HuDAT ribbon displays automatically when an assembly is loaded in the workspace. Concept hull assemblies can also be directly loaded into a HuDAT-enabled Creo interface by double clicking or selecting an assembly and choosing open from the Open file dialog box as shown in Figure 8.

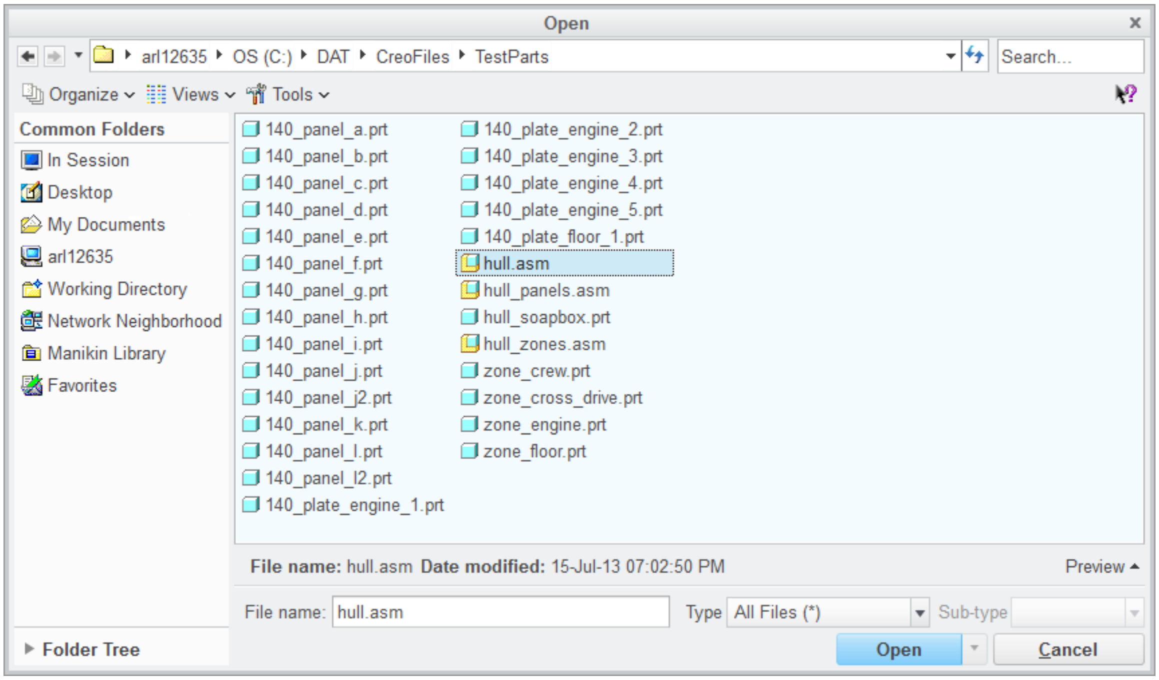


Figure 8: Select a Hull.asm File

HuDAT will perform operations and modify the tree structure of the concept hull assembly. New sub-assemblies will be added to the concept hull and new parts (plates and welds) will be added to those subassemblies. HuDAT will save all new detailed parts and assemblies in the original folder where the concept hull resides. The original concept hull assembly will also reside in its original location and will have the original tree structure and geometry.

2.2.3 Check Concept Hull

When an assembly is loaded in Creo the HuDAT ribbon bar will be displayed. Figure 9 shows the HuDAT ribbon bar buttons. The HuDAT commands are grouped into *Ballistic Checks*, **Ballistic Structure**, and *Internal Structure*.

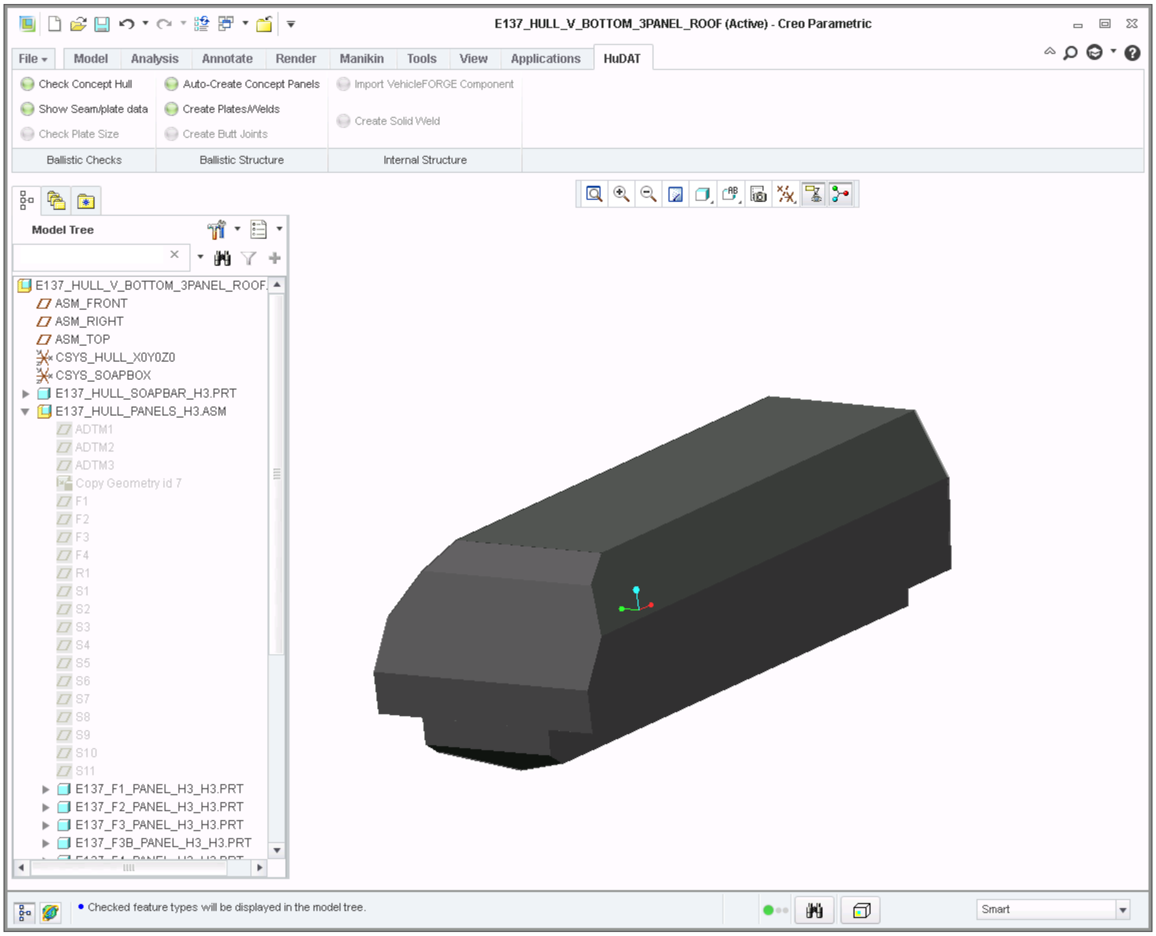


Figure 9: HUDAT Ribbon Bar

In order for HuDAT to create detailed plates and ballistic weld, a well-defined concept hull model must exist in the current Creo workspace. The *Check Concept Hull* button in the ballistic checks menu will check for a valid concept hull and provide verification status to the user. If the model contains a valid concept hull, you will be allowed to create detailed plates and welds. HuDAT checks the model for both a valid concept panel's assembly and a valid soapbar part. If a valid set of concept panels do not exist, the user will not be able to generate detailed plates and welds. However, if the user has a valid Soapbar part, they may use the "*Auto-Create Concept Panels*" button to produce a valid hull panel assembly for HuDAT to operate. This functionality is described in more detail in Section 2.2.5.

HuDAT will not execute if the concept hull contains non-planar surfaces or contains surfaces whose edges are non-linear.

To check that the active model meets the hull assembly composition requirement select the "*Check Concept Hull*" button under the HuDAT ribbon, in the "*Ballistic Check*" menu group. The command will interrogate the current model, perform several checks, and report the results.

The following information is analyzed when the "*Check Concept Hull*" button is selected:

CHECK FOR CONCEPT HULL IN ASSEMBLY

HuDAT checks that the current model is an assembly, and that the current model is or contains a hull assembly. The hull assembly must contain a parameter named "COMPONENT_CLASS" that is of type string and is set to a value of "HULL_ASSEMBLY_PARAMETRIC". This assembly will be referred to as the concept hull assembly. The concept hull assembly must also have parameters with names (in the format of S3* (i.e., S1, S2, S12), R# (i.e., R1, R2, R3) and F3 (i.e., F1, F2, F3) that represents the side rear and front panels of the soapbar, respectively. These parameters will be of the type Real Number and will contain values that are equal to the corresponding plate thickness.

NOTE:

HuDAT allows designers to use multiple concept plates to describe one surface of the soapbar by reserving an alphabetical character postfix to a parameter. For example, concept panels R1_PANEL and R1A_PANEL can both use the R1 parameter and may both be placed on the R1 datum plane. As such, it is not recommended that parameters differ by only a trailing alphabetical character. For example, a parameter F1 and F1A may have unsatisfactory output.

CHECK FOR SOAPBAR PART IN CONCEPT HULL ASSEMBLY

HuDAT checks that the Hull assembly found in the current model contains a soapbar part at the first level. It will look for a part at the first level that contains the characters "SOAPBAR" in its name.

CHECK SOAPBAR GEOMETRY

HuDAT checks that the soapbar part has acceptable geometric features. Currently the soapbar part must contain planar faces only (no curved surfaces) and all surface edges must be linear. In addition all soapbar surfaces must contain only one contour.

CHECK FOR CONCEPT PANELS IN CONCEPT HULL ASSEMBLY

HuDAT checks that a concept panel assembly exists as a sub-assembly of the concept hull assembly. The concept panel assembly will contain datum planes with names that correspond to the S#, R# and F# parameters in the concept hull assembly. Each concept panel in the Hull_Panels assembly model will be named with characters as the S#, R# and F# parameters, matching the datum planes to the parameters.

CHECK ON PLATE INCLUDED ANGLES

All internal included angles between concept plates must be within IFAB limits. In the current release of HuDAT, all angles between plates must be greater than 40 degrees and less than 320.

GENERAL CONCEPT PANEL THICKNESS CHECK

HuDAT checks that all concept panel thickness is currently stocked in at least one of the acceptable ballistic materials. The list of acceptable ballistic materials is listed in the next paragraph. This verification function looks at thickness values only and does not check thickness values against material selection. If the concept panels are made of material which is not acceptable HuDAT will allow the user to modify the material during execution. However HuDAT does not change thickness values. If a panel thickness is not available the user must modify the thickness value for HuDAT to execute. This change is made by modifying the corresponding parameter values in the top level hull assembly.

CHECK CONCEPT PANEL MATERIAL

In order to create valid ballistic weld joints, all concept panels must be made of ballistic materials. HuDAT checks that concept plates are made of an acceptable ballistic material. In the current version of HuDAT the following materials are acceptable for the concept plates. All of the materials listed below come from the AVM material database.

- Steel:
    - steel_armor_rha_mildtl_12560cl1
    - steel_armor_rha_mildtl_12560cl2
    - steel_armor_hha_mil_dtl_46100
    - steel_armor_rha_mil_dtl_46177
- Aluminum:
    - aluminum_armor_mil_dtl_46027cl1
    - aluminum_armor_5456_h131

In addition, all plates that are welded must be made from weld compatible materials. In this version of the software all aluminum armor materials can be welded to each other and all steel armor panels can be welded to each other. This check will fail if the concept plates are made of a combination of aluminum and steel armors.

CHECK IF BALLISTIC CONCEPT PANEL THICKNESS IS IN STOCK

HuDAT will check that all plates made of ballistic material have a specified thickness which is in stock. Currently the following thickness values are available for each ballistic material:

- Steel_armor_rha_mildtl_12560cl1, Steel_armor_rha_mildtl_12560cl2, and Steel_armor_hha_mil_dtlk46100 are stocked in increments of 6.35 mm starting at 4.75 mm and up to 38.1 mm.
- Steel_armor_rha_mil_dtl_46177 is only stocked in 3.556 mm.
- Aluminum_armor_mil_dtl_46027cl1 and aluminum_armor_5456_h131 are stocked in increments of 6.35 mm starting at 12.7 mm and up to 152.4 mm

CHECK MODEL UNITS

HuDAT works with millimeters, kilograms, seconds, and radians. This check checks the Concept Hull and all of its children identifying models that do not use the mmKs system of units. If any models are identified as not using this specified unit system, the report prints out a list of those models.

After performing the above checks HuDAT will display a report that shows the status of each verification function above. Figure 10 shows an example report that fails the concept plate material check.

In this release, if the concept material verification step fails the user will still be able to proceed and make detailed plates and welds. However, before weld/plate creation you will be prompted to pick a default material from the acceptable material list for each panel. After you select a default material, it is assumed that the detailed plates generated by HuDAT are made of the selected material, but HuDAT will not change the material of the concept panels. The user will also be prompted to select a valid steel or aluminum filler material for all welds generated by HuDAT. One filler material will be used for all generated welds.

```
*******************   Concept Hull Check   *******************

CHECK FOR CONCEPT HULL IN ASSEMBLY
STATUS:  VERIFIED
    Concept Hull assembly exists in current model and was initialized
    Concept hull name:   E137_HULL_V_BOTTOM_3PANEL_ROOF

CHECK FOR SOAPBAR PART IN CONCEPT HULL ASSEMBLY
  STATUS:  VERIFIED
    Hull SoapBar Exists in Hull concept assembly
    Soapbar part name:   E137_HULL_SOAPBAR_H3

CHECK SOAPBAR GEOMETRY
  STATUS:  VERIFIED
    Soapbar Geometry is acceptable for HuDAT

CHECK FOR CONCEPT PANELS IN CONCEPT HULL ASSEMBLY
STATUS:  VERIFIED
    Concept Panels Exist in Hull Concept assembly
    Concept panels name:  E137_HULL_PANELS_H3

CHECK ON PLATE INCLUDED ANGLES
STATUS:  VERIFIED
    All included angles between plates are within manufacturing limits


GENERAL CONCEPT PANEL THICKNESS CHECK
STATUS:  VERIFIED
   The thickness of all concept panels is in stock in either ballistic steel or ballistic aluminum.

CHECK CONCEPT PANEL MATERIAL
STATUS:  FAILED
    One or more concept plates are not made of ballistic materials
    Concept plate E137_R1_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S1_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S2_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S3_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S4_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S5_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S6_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S7_PANEL_H3_H3 is not made of ballistic material
    Concept plate E137_S8_PANEL_H3_H3 is not made of ballistic material


    All concept Plates must be made of same base armor material
    Number of Steel Armor Panels = 6   Number of Aluminum Armor Panels = 3


CHECK IF BALLISTIC CONCEPT PANEL THICKNESS IS IN STOCK
STATUS:  FAILED
    3 of the 9 ballistic panels have a thickness which is NOT in stock in specified Material
    Plate E137_F1_PANEL_H3_H3 (50.800 mm thick,  STEEL_ARMOR_RHA_MILDTL_12560CL2) is not in stock

CHECK MODEL UNITS
STATUS:  VERIFIED
    All assembly components have proper unit information
```

Figure 10: Check Concept Hull Report

2.2.4 Displaying Plate and Seam Data

The “Show Seam/Plate data” button in the check group displays information associated with the plates and seams of the concept hull. When this button is selected, the toolkit interrogates the hull concept to gather information needed to create detailed plates and welds. Figure 11 shows an example of the report that is presented when the “Show Seam/Plate data” button is selected. If the software cannot generate this information, the user is prompted to use the “Check Concept Hull” for more information.

```
******************** Plate Data ********************

Detailed Plate name: PLATE_25
  Concept Plate Datum Name: S3
  Plate thickness: 25.400
  Number Edges: 5

Detailed Plate name: PLATE_29
  Concept Plate Datum Name: S7
  Plate thickness: 25.400
  Number Edges: 5

Detailed Plate name: PLATE_60
  Concept Plate Datum Name: S1
  Plate thickness: 25.400
  Number Edges: 5

Detailed Plate name: PLATE_62
  Concept Plate Datum Name: S2
  Plate thickness: 25.400
  Number Edges: 4

Detailed Plate name: PLATE_70
  Concept Plate Datum Name: S8
  Plate thickness: 25.400
  Number Edges: 4

Detailed Plate name: PLATE_72
  Concept Plate Datum Name: S9
  Plate thickness: 25.400
  Number Edges: 5
```

```
******************** Seam Data ********************

Seam ID: 239
  Connects detailed PLATE_25 with detailed PLATE_233
Seam ID: 307
  Connects detailed PLATE_25 with detailed PLATE_277
Seam ID: 320
  Connects detailed PLATE_25 with detailed PLATE_316
Seam ID: 135
  Connects detailed PLATE_25 with detailed PLATE_131
Seam ID: 247
  Connects detailed PLATE_25 with detailed PLATE_62
Seam ID: 240
  Connects detailed PLATE_29 with detailed PLATE_233
Seam ID: 248
  Connects detailed PLATE_29 with detailed PLATE_70
Seam ID: 138
  Connects detailed PLATE_29 with detailed PLATE_131
Seam ID: 321
  Connects detailed PLATE_29 with detailed PLATE_316
Seam ID: 308
  Connects detailed PLATE_29 with detailed PLATE_281
Seam ID: 241
  Connects detailed PLATE_60 with detailed PLATE_233
Seam ID: 250
  Connects detailed PLATE_60 with detailed PLATE_62
Seam ID: 141
  Connects detailed PLATE_60 with detailed PLATE_131
Seam ID: 140
  Connects detailed PLATE_60 with detailed PLATE_129
Seam ID: 249
  Connects detailed PLATE_60 with detailed PLATE_74
Seam ID: 242
  Connects detailed PLATE_62 with detailed PLATE_233
Seam ID: 142
  Connects detailed PLATE_62 with detailed PLATE_131
Seam ID: 243
  Connects detailed PLATE_70 with detailed PLATE_233
```

Figure 11: Show Seam/Plate Data report

2.2.5 Auto Concept Panel Functionality

The "*Auto-Create Concept Panel*" button in the ballistic structure menu creates a valid concept hull panel assembly and associated datum planes from a valid soapbar part. This functionality was added to HuDAT to reduce the time necessary to prepare a concept hull.

> **NOTE:**
> If you choose to use HuDAT to create concept panels from a soapbar, parameterized relationships may be broken and will not drive parameters in the concept hull panels.

When the user selects the "Auto-Create Concept Panels" button they will be prompted to enter a plate thickness value for the concept panels. A message dialog box will be displayed before the plate thickness selection box is displayed. All concept panels will be made with the same thickness. Figure 12 shows the "Auto-Create Concept Panels", the message dialog box and the plate thickness selection box.

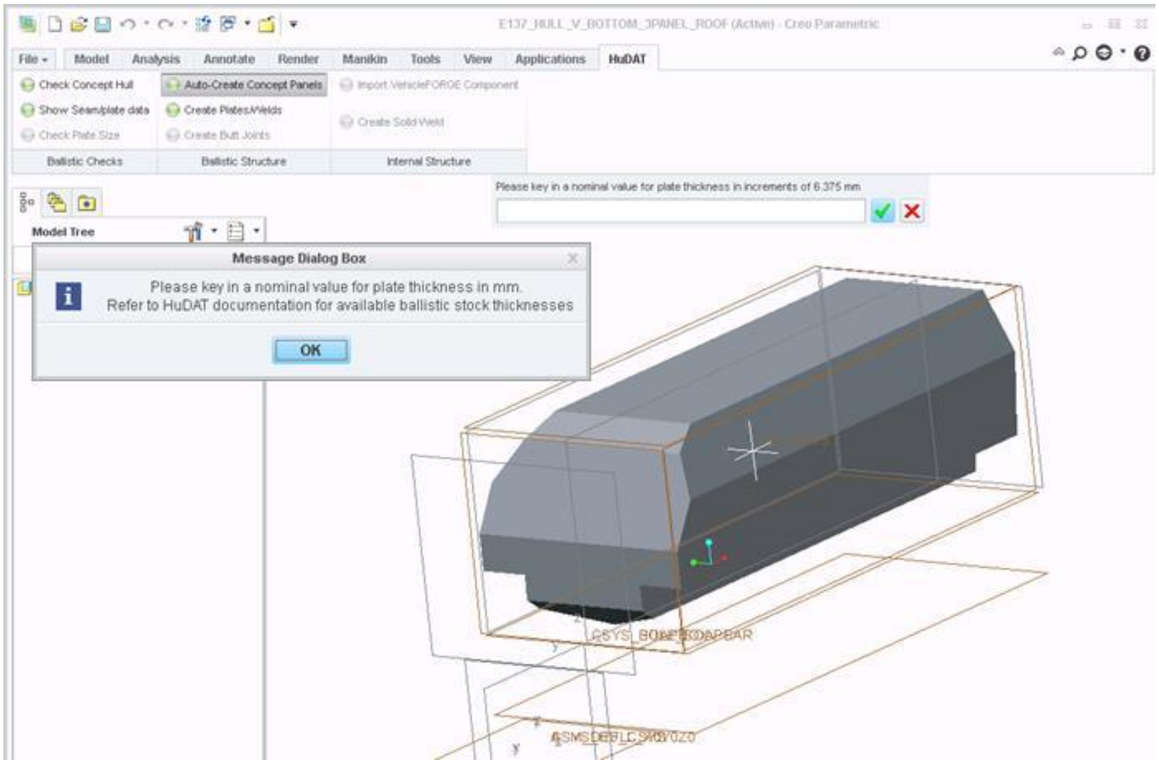


Figure 12: Auto-Create Concept Panels Button

After the user enters a thickness value HuDAT will generate a Concept Hull Panels assembly that contains the Datum surfaces and the concept panels that are needed for HuDAT to operate. In addition, HuDAT creates parameters in the Hull top level assembly, which contain the thickness values for each panel. By default HuDAT will set the material in all the concept panels to be "Steel_Low_Alloy_A36". If the user wishes to change concept panel thickness they should modify the datum parameter values as described in Section 2.2.3. After concept panels have been generated, a confirmation dialog box will be displayed to the user as shown in Figure 13.

Figure 13: Auto-Create Concept Panel Confirmation Box

A picture of a HuDAT generated Concept Hull Panels Assembly is shown in Figure 14 with the original soapbar part and several concept hull panels hidden. The hull panel assembly tree contains datum planes and concept panel parts for each soapbar surface. **Please note that if the "concept_hull_panels" assembly already exists in your model tree, you must delete it and erase it from memory before executing the "Auto-Concept Panels" button".**

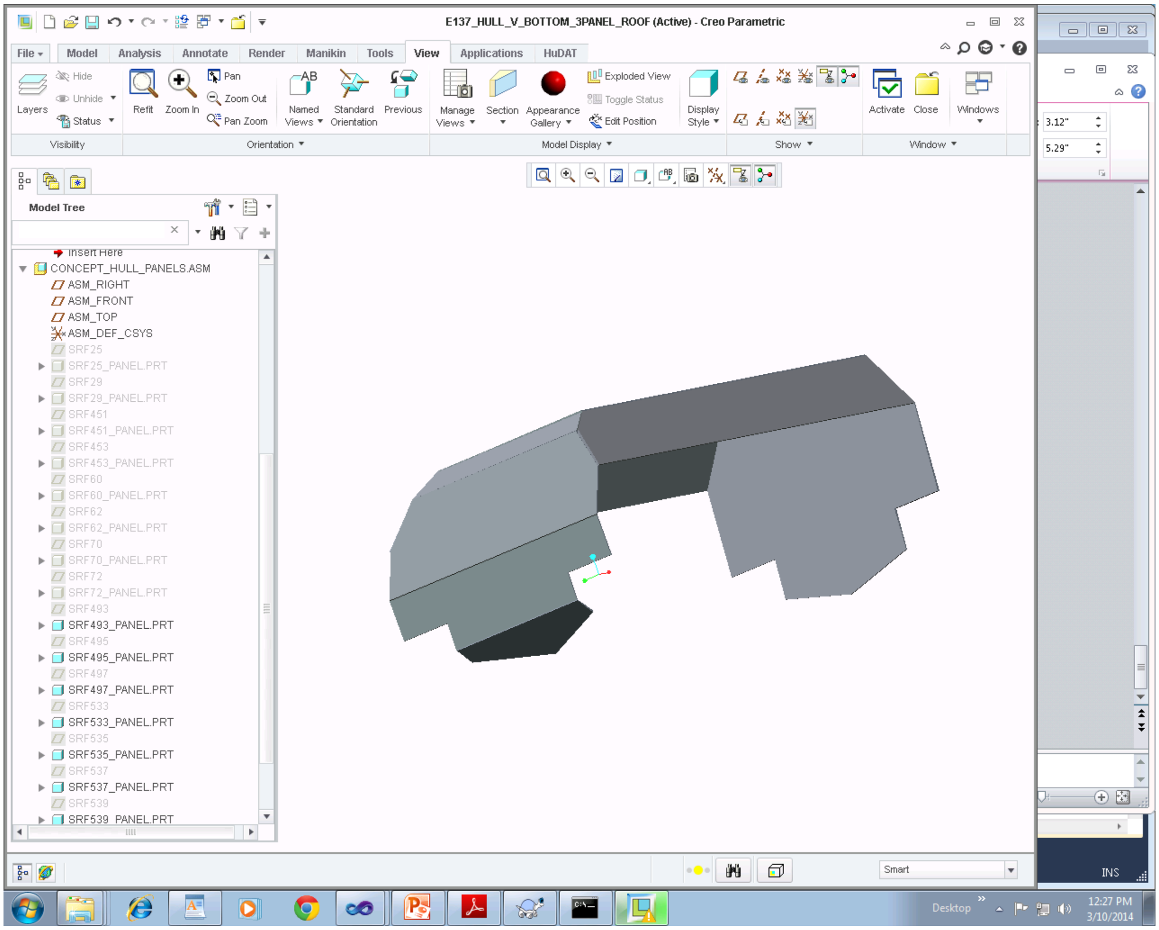


Figure 14: Results of Auto-Create Concept Panels

2.2.6 Creating Detailed Plates and Welds

The button titled "Create Plates/Welds" under the *Ballistic Structure* menu group executes the primary HuDAT functions that generate a detailed hull assembly with detailed plates and solid welds. When selected, this button opens up a HuDAT Dialog box which the user interacts with to create geometry. The primary HuDAT dialog box is shown in Figure 15.

Figure 15: HuDAT Dialog for Creating Plates/welds

The top of the HuDAT dialog box lists the names of the identified concept hull assembly, the soapbar part, and the hull panels assembly. The middle pane of the dialog box shows information on the weld properties, the weld type and plate/weld material.

The user has a choice to create all detailed plates and connecting welds or to select specific surfaces on the soapbar for geometry generation. Section 8 discusses the operations for selection of specific surfaces. If the user selects the "*Generates Plates and Welds*" button without selecting surfaces, HuDAT will use the concept hull as a template to create a detailed hull model with all corresponding plates and welds.

Before geometry creation HuDAT will call several verification functions to assure the concept hull assembly meets requirements. If the material specified for the concept hull panels is not acceptable the user will be prompted to select material for the detailed plates. These material selection options are described in section 2.2.7.

After material is verified or specified by the user a weld filler material option menu will be displayed prompting the user to specify the weld filler. After verification and filler material specification, an informational window will be displayed as shown in Figure 16. This is a reminder that if a detailed hull already exists within the assembly it will be deleted and a new detailed hull sub-assembly will be generated.

During execution a *HULL_DETAILED* assembly will be created which contains the plates and welds and weld manufacturing data will be saved in the Welds.xml file.

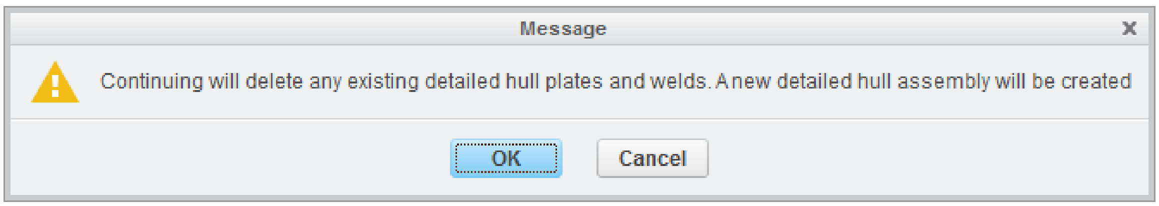


Figure 16: Informational Message regarding HuDAT Execution

Select OK to continue. Several Creo regeneration progress windows will be displayed during this operation and a HuDAT progress bar will be displayed. Figure 17 shows the message that will be displayed when the HuDAT application successfully creates the detailed plates.

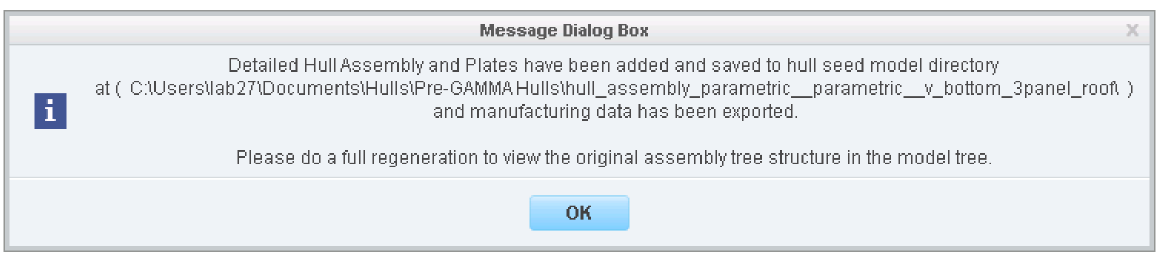


Figure 17: Create Detailed Plates

Figure 18 shows the Hull Detailed assembly structure that will be created by HuDAT after the plates and welds are created. Notice that three sub-assemblies are created under the "*HULL_DETAILED*" assembly. One sub-assembly named "*PANELS_DETAILED*" contains the panel geometric models in their final form including cuts, extensions and chamfers and it contains the solid weld geometry between the hull plates. The other subassembly, titled "*PANELS_AS_CUT*", contains a manufacturing staging model that represents the plate geometry as cut from stock and before edge preparations are applied. Notice in Figure 18 that the *PANELS_AS_CUT* assembly inside the*HULL_DETAILED* assembly is hidden in this model tree.

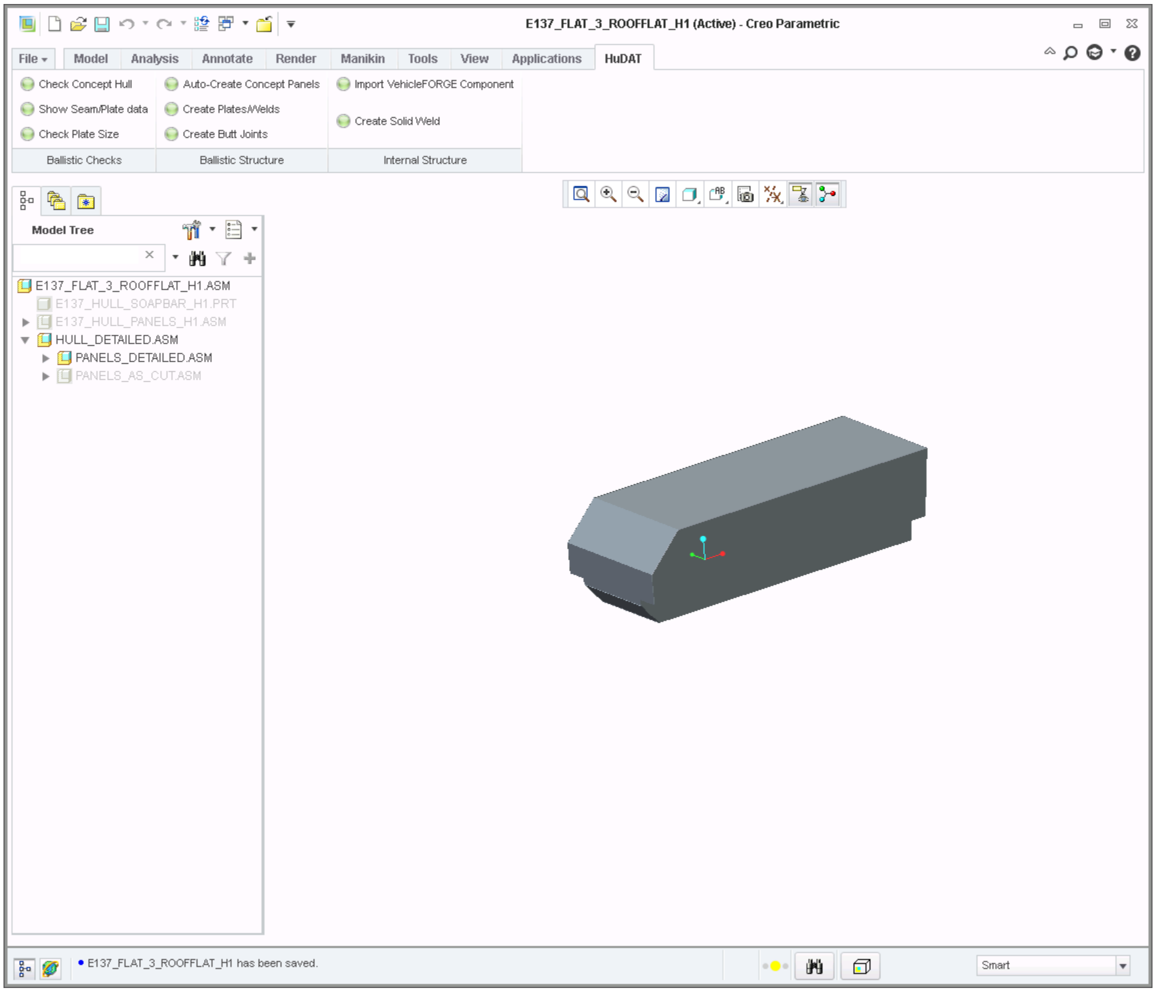


Figure 18: Hull Detailed Model Tree Structure

Figure 19 shows the Hull Detailed assembly structure with the "*PANELS_DETAILED*" assembly exploded to see the weld and plate parts.

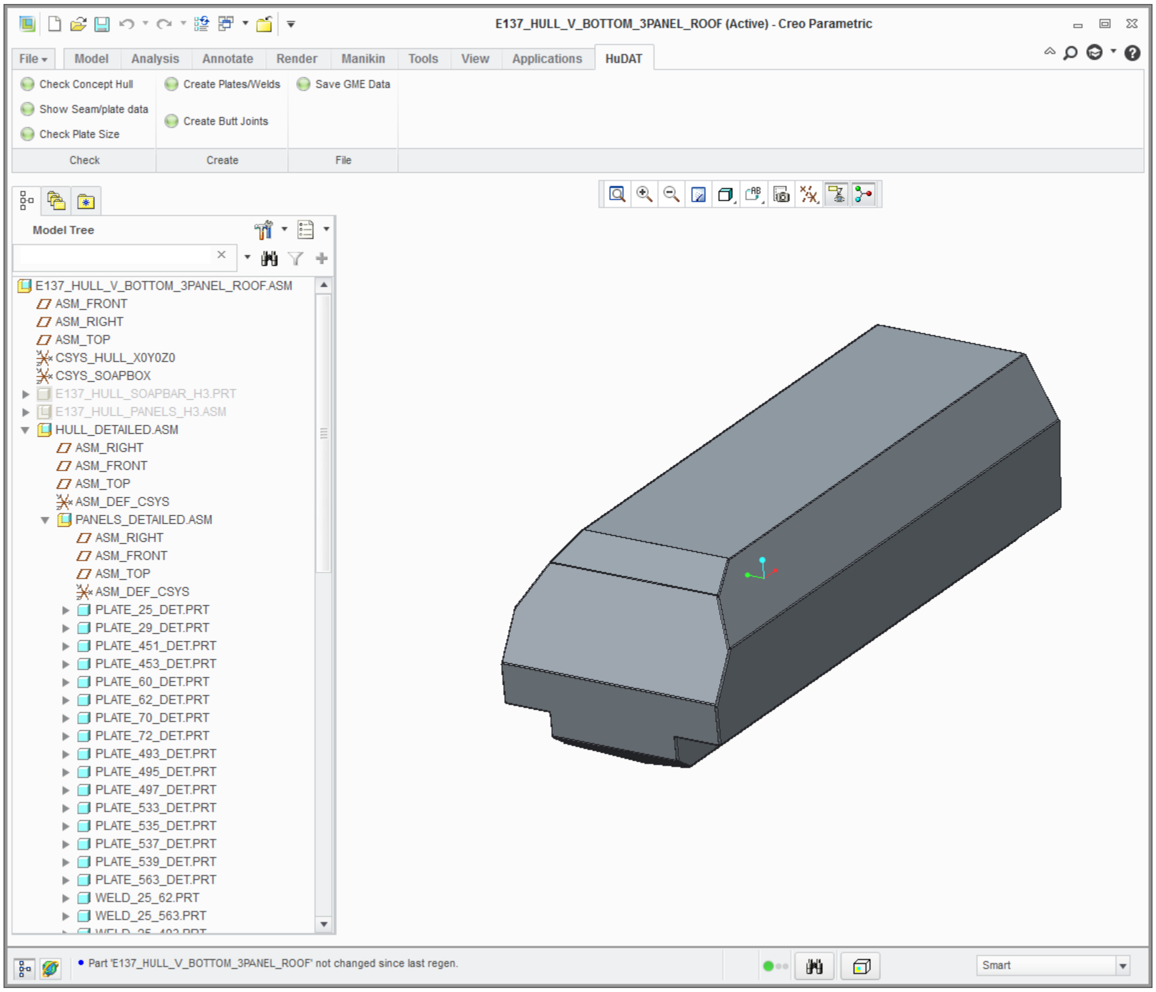


Figure 19: Hull Detailed Assembly With Panels Expanded

The detailed plates are configured to create a valid ballistic weld, which is always a full penetration weld. Figure 20 shows the arrangement between two plates to assure a full penetration weld can be accomplished.

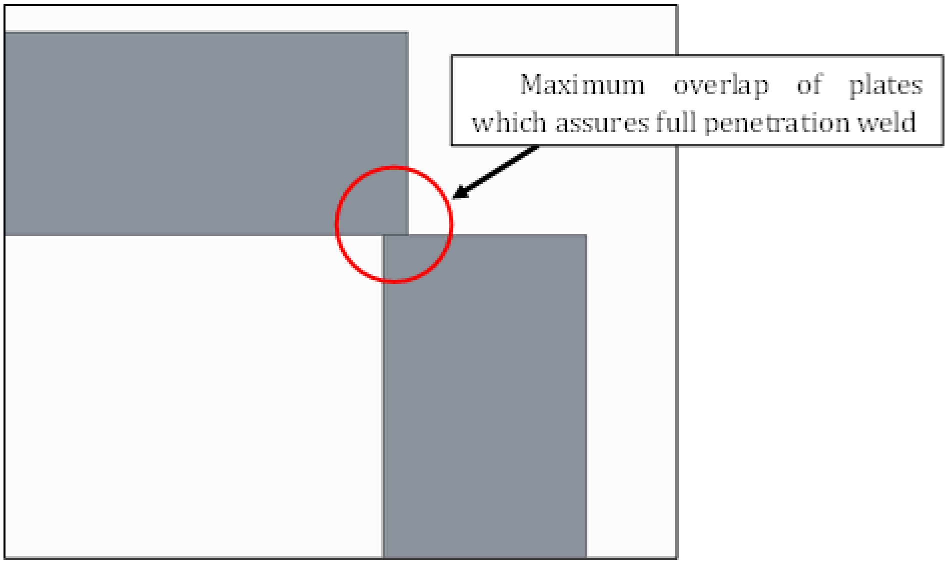


Figure 20: Ballistic Plate Configuration

The weld parts are created by extruding a solid along the weld seam line with the correct weld section geometry. Each ballistic weld part will contain two solid welds, one interior and one exterior to the hull. In order to clearly see the welds it helps to hide the concept hull soapbar and concept hull panels and to change the color on the welds. Figure 21 shows a close view of two of the welds between two plates.

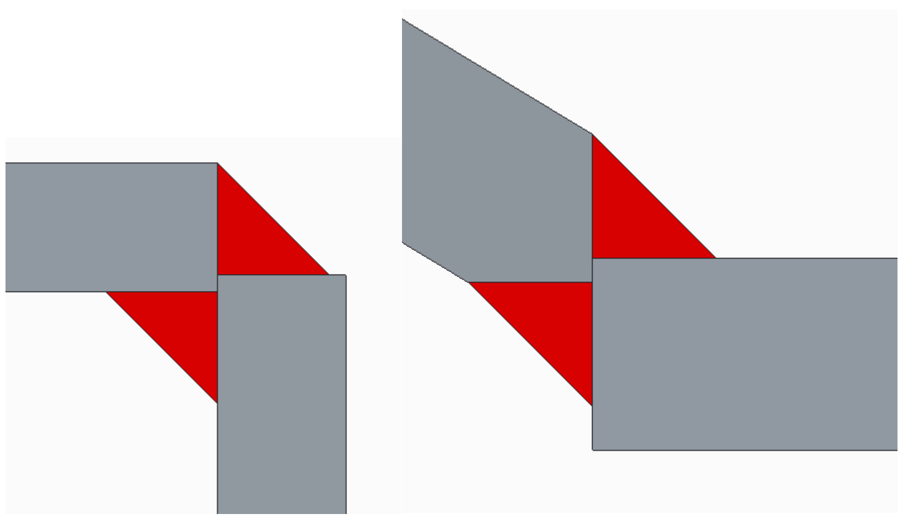


Figure 21: Example of 2 Ballistic Welds

The plate edge prep and weld configuration are determined based on the plate material, plate thickness, and plate included angle. A weld produced between two steel plates may not have the same configuration as a weld produced between two aluminum plates. An example of the difference between steel and aluminum ballistic weld joints is shown in Figure 22.

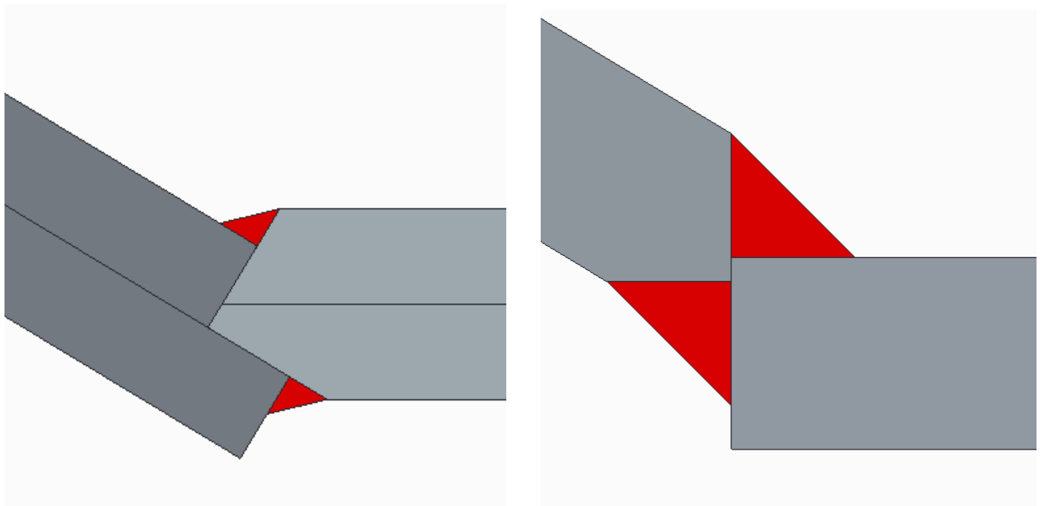


Figure 22: Differences between Aluminum (left) and Steel (right) Ballistic Joints

2.2.7 Material Selection

Before HuDAT generates detailed plates and welds for manufacturing, it performs verification functions against the hull concept model. One of these verification functions is to check that the concept hull panel material is ballistic and is weld compatible. In this release of HuDAT, if the concept material verification step fails, HuDAT will prompt the user to enter information for the plate and filler material. Figure 23 shows the series of dialog boxes that will be displayed to select ballistic weld material for each plate. The first dialog box prompts the user to choose either all Steel or all Aluminum armor. After a material type is selected the next menu will list each plate whose material is unacceptable with a drop down selection list of valid material choices. The user may modify each panel material or they may choose to enter a default material at the bottom of the dialog box to be used for all plates listed. HuDAT will only show a default material selection list at the bottom of this pane if at least one material is in stock that is compatible with all concept plate thickness values. At the bottom of this panel all concept plates will be listed that have valid materials and thicknesses. After valid plate materials are selected the user will be prompted to select a valid steel or aluminum weld filler material.

When selecting the ballistic weld material, one can hover over the name of the material to view the density, elongation, and strength values.

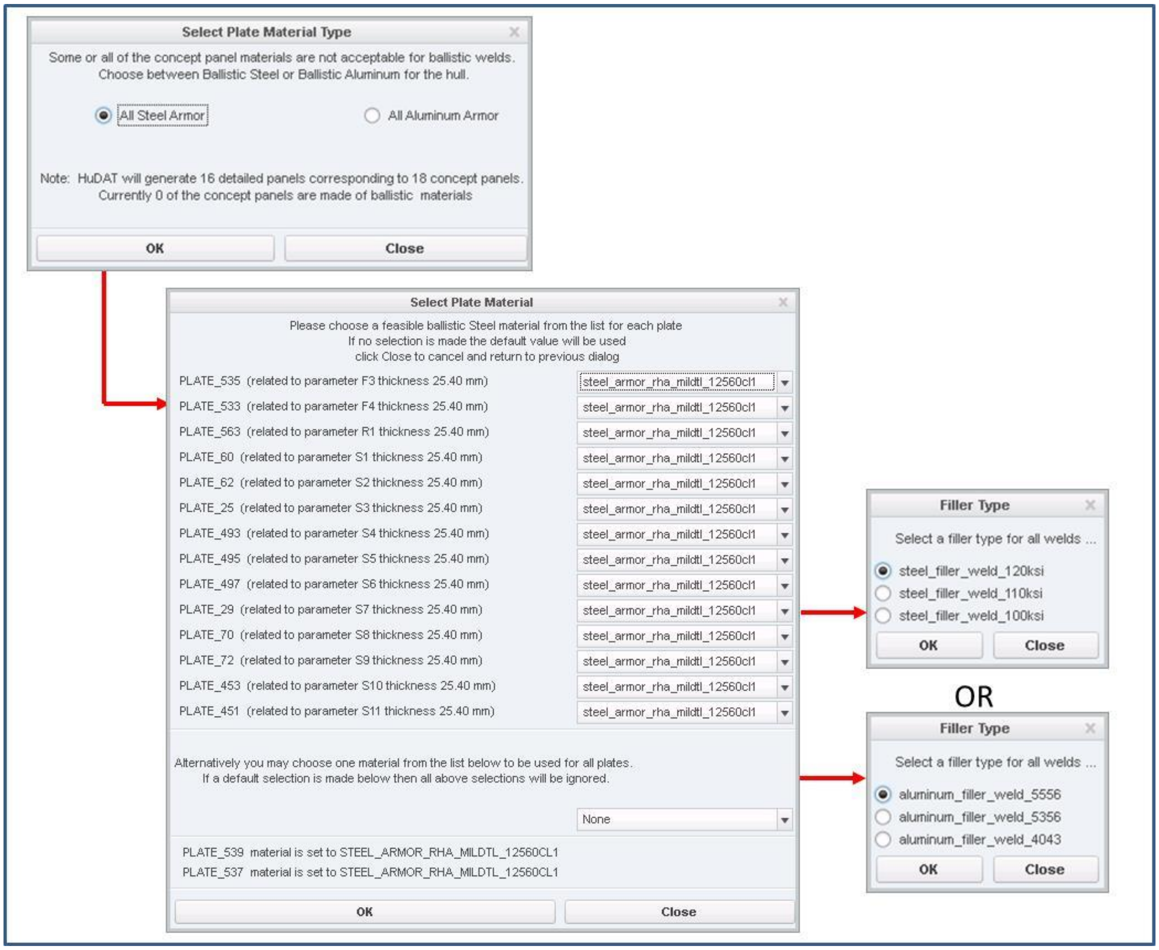


Figure 23: Material and Weld Selection Dialogs.

HuDAT will generate all welds using the filler material specified and will make detailed plates with the material selected for each panel. ***Please note that the concept panel material will not be modified!***

2.2.8 Custom Selection of Surfaces

The user will have a choice through the HuDAT dialog box to create all detailed plates and connecting welds or to select specific surfaces on the soapbar for geometry generation. This section describes how specific surfaces are selected for plate and weld creation. Figure 24 shows the HuDAT dialog box for creating welds and plates. To select custom surfaces the user should check the box to the left of the "Select Surfaces to weld" text. This will initiate a Creo object selection mode and a selection dialog box will open. The user can select surfaces from the soapbar that represent the plates to be welded. The user must pick at least two surfaces and the surfaces selected must have at least one shared edge. If surfaces are selected that do not meet this requirement, an error message will be displayed. Figure 24 shows the HuDAT dialog box with the select surfaces box checked and the Creo selection box open to the right of the Creo window. A label in the Creo selection box will specify how many items can be selected. This number represents the maximum number of surfaces that can be selected. If you cannot see the Selection dialog box, it may be hidden by the main Creo window or the HuDAT dialog box. You may need to move the primary window to display the selection dialog box. The user must select OK or CANCEL in the selection dialog box to close it and return control to the HuDAT Dialog box.

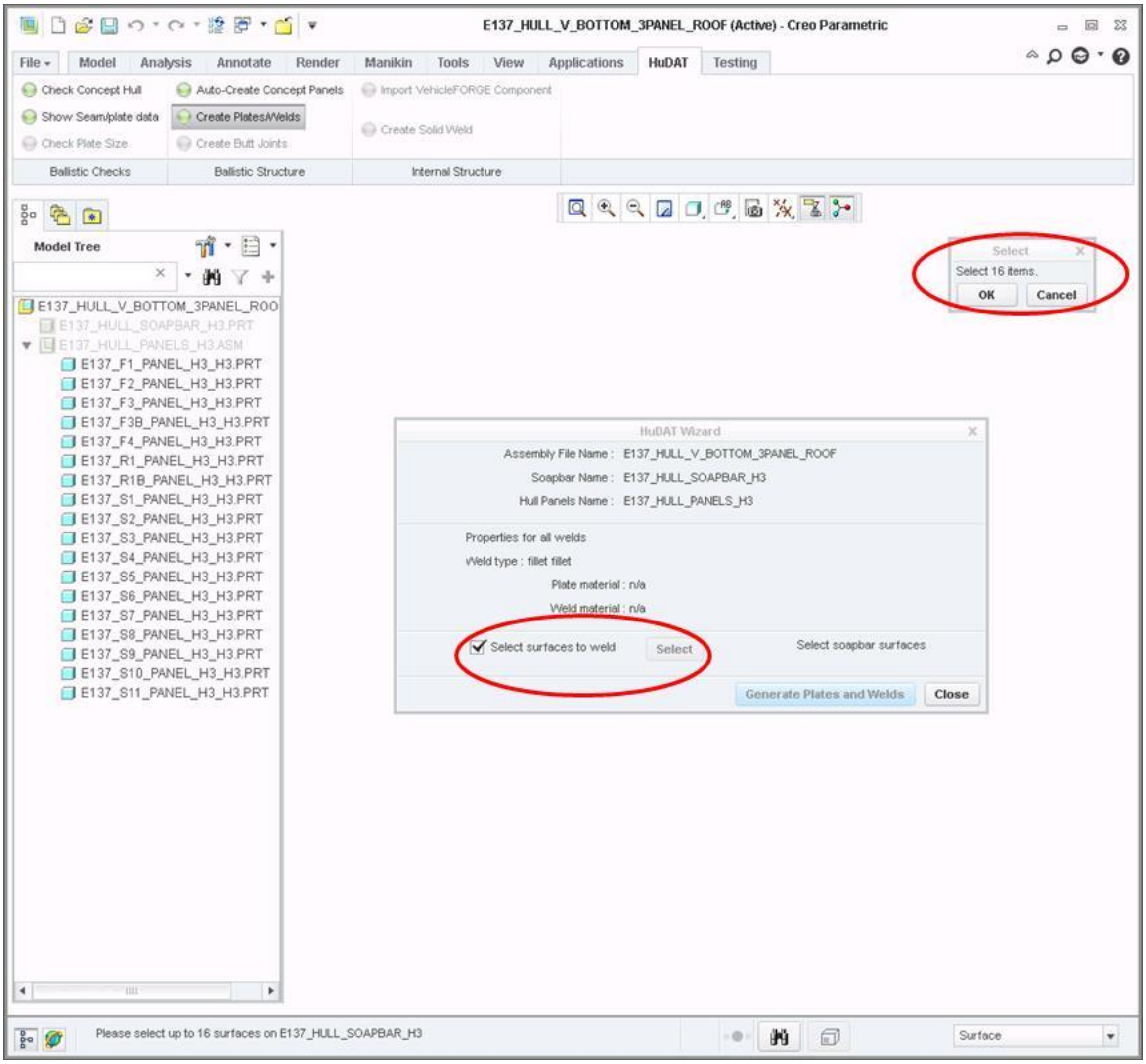


Figure 24: HuDAT Dialog with Surface Selection Chosen

To select multiple surfaces, hold the CTRL key down while selecting surfaces with left mouse click; the surfaces will be highlighted as they are chosen. Figure 25 shows 4 surfaces being selected and highlighted within Creo. After surfaces are chosen select the OK button on the Creo dialog box. Control returns back to the HuDAT dialog box and the number of surfaces selected will be displayed. Selecting "Generate Plates and Welds" will execute the function to create plates and welds associated with the selected surfaces. If surfaces are selected that do not share an edge, an error will be thrown. If the concept panels are not made of ballistic materials or if the concept plate material is not weld compatible you will be prompted to select a valid material for each plate.

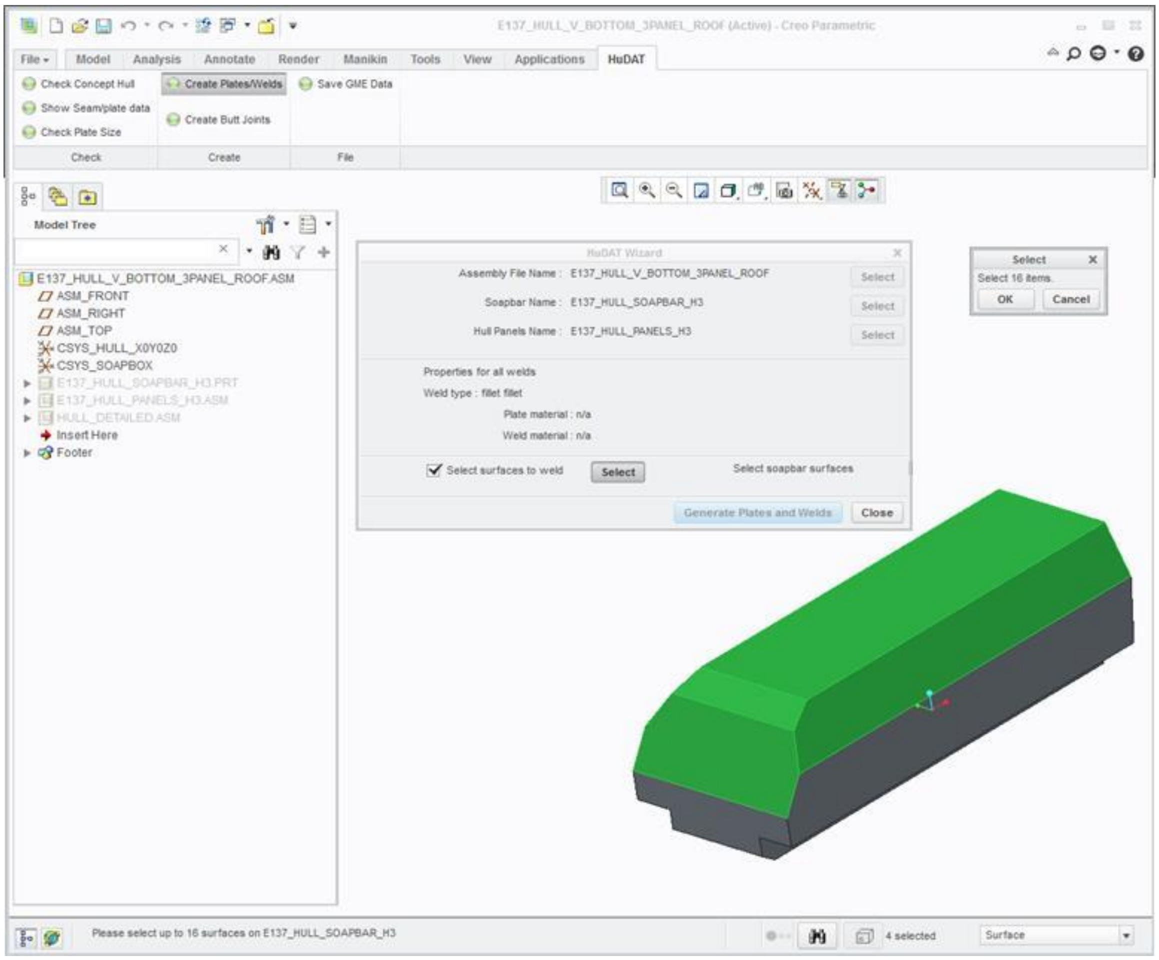


Figure 25: Select Surfaces Dialogs

Figure 26 shows the results in CREO of creating plates and connecting welds for the four surfaces chosen in Figure 25.

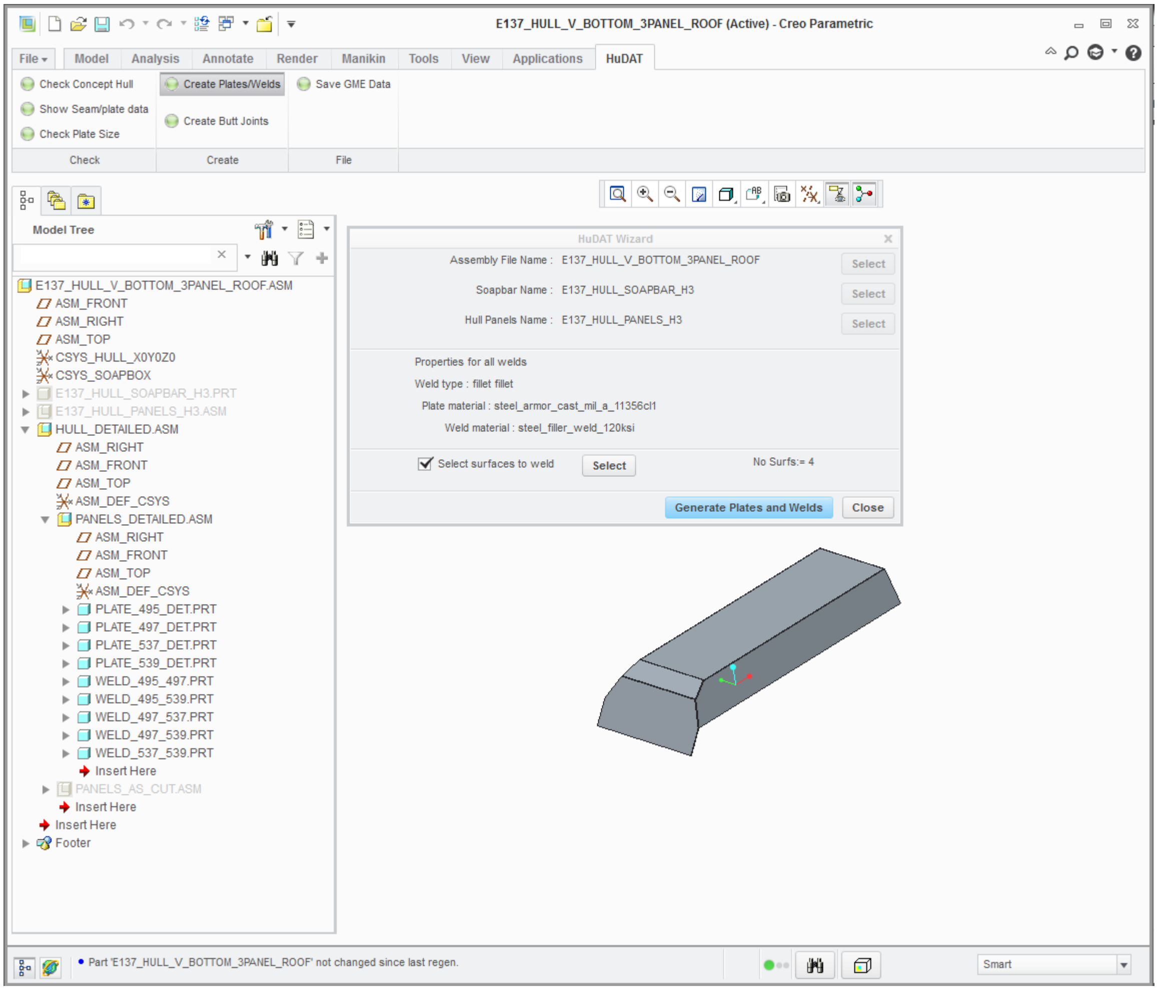


Figure 26: Example Detailed Plates and Welds on Selected Surfaces

If the user does not close the HuDAT dialog box and again selects surfaces for plate creation (i.e., pressing the “Select” button in the HuDAT dialog), the Creo selection buffer is retained and the surfaces already selected will be highlighted. To add surfaces to this list press and hold the CTRL key **before** selecting new surfaces. To remove the current surface selections, select a new surface without holding down the CTRL key. Similarly, if you want to deselect an already selected surface, hold down the CTRL key and select the surface. After selecting OK in the Creo selection box, the “number of surfaces selected” will be updated in the HuDAT dialog box. At this point you can generate plates and welds, or you can re-enter the surface selection model by selecting the “Select” button again.

If surfaces are selected that do not share an edge the user will see an error box that displays one of the following messages:

- **“Please select surfaces that share an edge”** – user must choose two surfaces that are connected
- **“Surfaces do not form a connected graph”** – every surface must ‘touch’ one another

Additionally, if only one surface is selected the user will not be able to generate detailed hull geometry until another surface is selected.

When the HuDAT dialog box is closed, the selection buffer will be lost. Therefore, if the user chooses to Create Plates/Welds again after closing the HuDAT dialog box, the detailed hull will be deleted and the user must select all surfaces for plate and weld creation again.

2.2.9 Exporting Data

Each time that HuDAt is used to generate plates and welds, a file called **Welds.xml** is created which contains the xml data for each weld that was created in the detailed hull assembly. The weld name element is derived from the part name without the .PRT suffix and the UUID element is generated programmatically. The rest of the elements in each weld come from named parameters of the weld part in Creo. The **Welds.xml** file will be created in a **Manufacturing folder** residing in the same directory as the hull model. If the user has modified the *Hull_Detailed* assembly to contain any empty sub-assemblies the XML file will produce errors in GME. For example, if the user uses the HuDAT Vehicle Forge interface button to import structure HuDAT will create a new assembly called “Internal Structure”. If the user then deletes the stock parts but leaves the Internal Structure assembly in the model tree, the import back into GME will fail.

2.2.10 Creating Simplified Representations

Simplified representations (simp rep) are one way to include or exclude certain components from analysis tools, such as mass calculations. HuDAT uses two simp-reps to place the concept level hull and the HuDAT generated plates. The two simp reps used by HuDAT are named “DEFEATURED_REP” and “FEATURED_REP” respectively. These can be created or viewed using the “Manage Views” button from the “View” tab in a Creo session as shown in Figure 27.

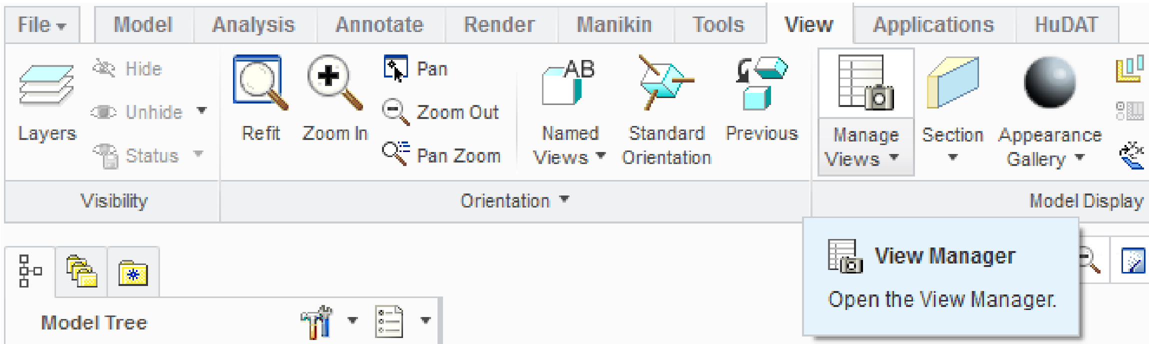


Figure 27: Accessing the 'View Manager' from the 'View' tab

Clicking this button will open the 'View Manager' as shown in Figure 28. A new simp rep is created by clicking the 'New' button and entering a name, e.g., FEATURED_REP.

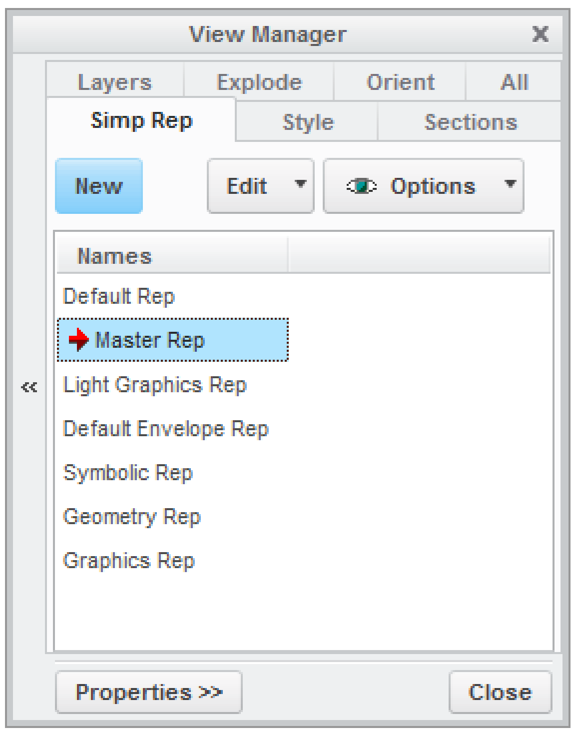


Figure 28: Creating a New Simplified Representation

After choosing a name for the simp rep, a dialog will appear (Figure 29) that allows the user to choose options for the representation of each component in an assembly. If a representation is chosen for an assembly, its children will inherit the representation unless explicitly chosen otherwise. For HuDAT, the FEATURED_REP will have the*SOAPBAR*, *HULL_PANELS*, and the *PANELS_AS_CUT* excluded, while the PANELS_DETAILED are included (i.e., Master Rep). These are changed by selecting the drop-down menu to the right of each component and selecting the appropriate option.

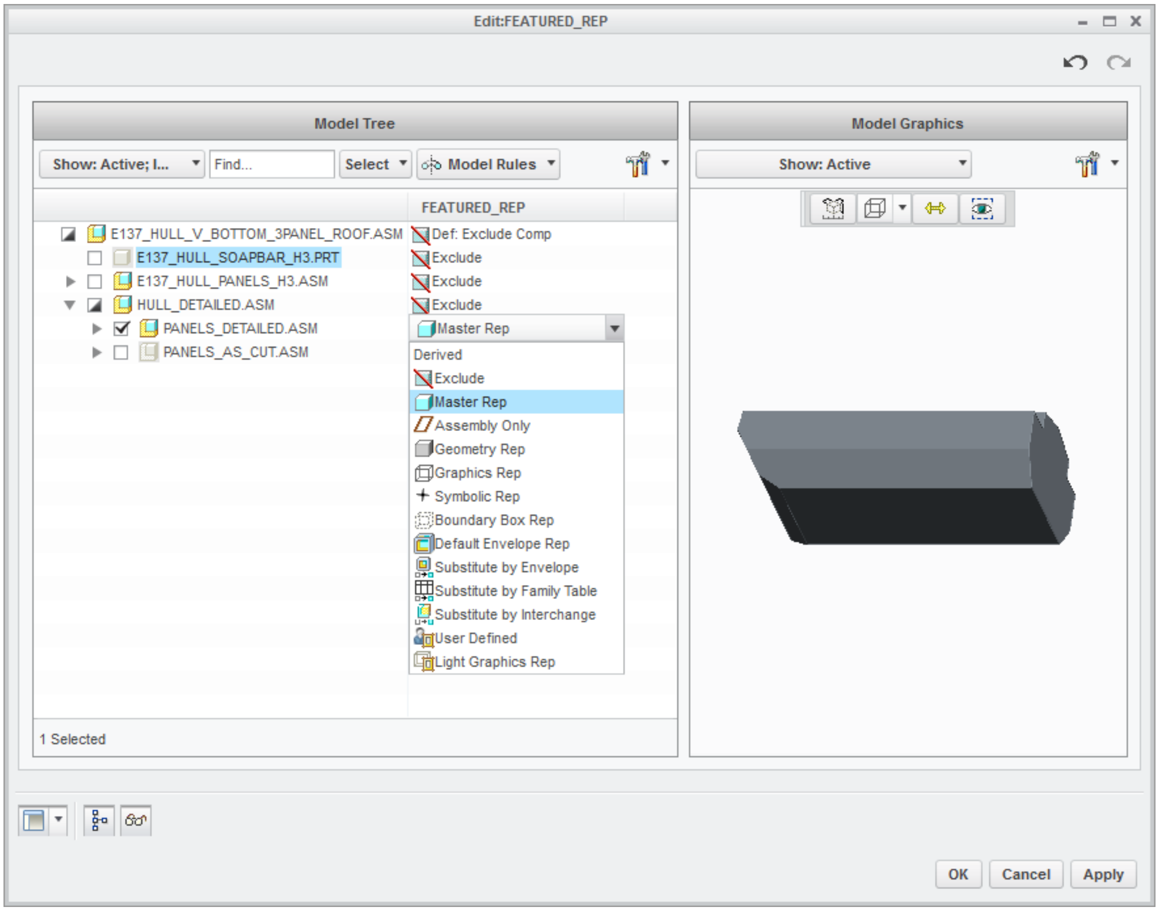


Figure 29: Modifying the representation of models

NOTE:
If HuDAT detects that the simp reps FEATURED_REP and DEFEATURED_REP exist, the algorithm will automatically place the entities into their appropriate representations. The preceding information is to provide explanation as to what simp reps are and how to create them

2.2.11 Concept Panel Feature Transferal

The HuDAT algorithm will duplicate some features that are in a concept panel by creating a similar feature in the HuDAT plates (some geometry may be modified for manufacturing purposes). Currently, features that are EXTRUDE with the option REMOVE_MATERIAL that have fully defined external sketches can be transferred. A fully defined external sketch is a Creo sketch that can placed using the “Sketch” tool from the Model ribbon tab. Figure 30 shows an example of an external sketch (CIRCLE_SKETCH) and an internal sketch (RECTANGLE) in part mode.

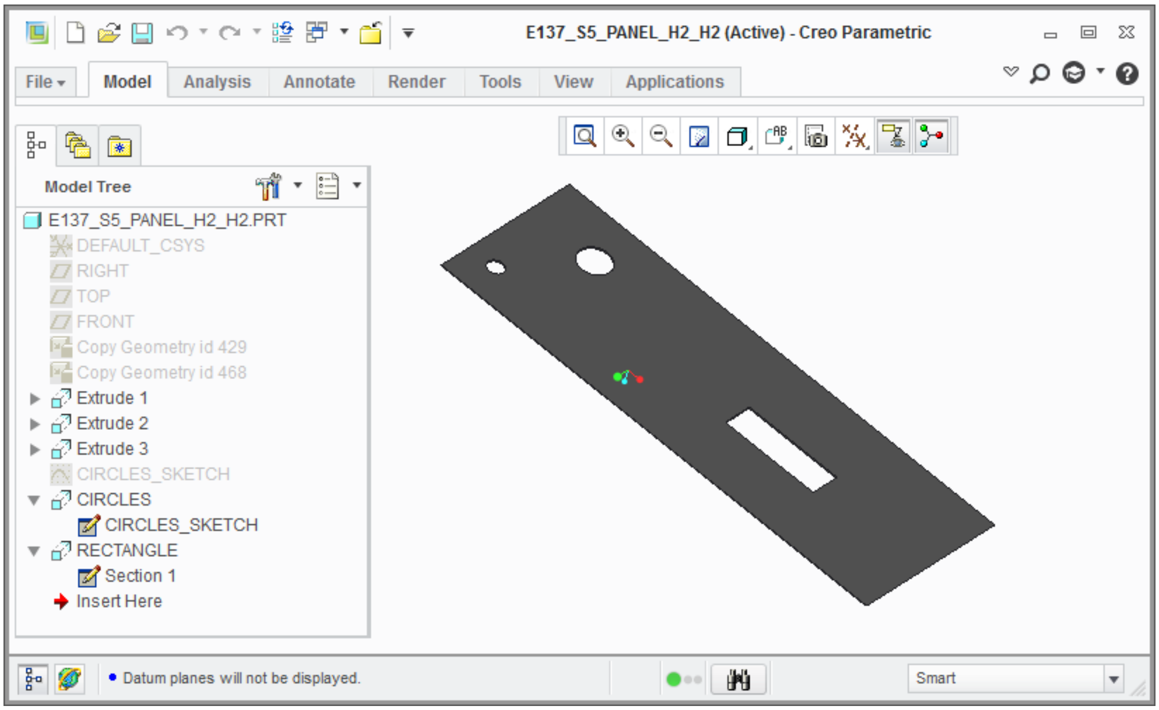


Figure 30: External Sketch (CIRCLE_SKETCH) and Internal Sketch (RECTANGLE)

The external sketch must have both its “Sketch Plane” and its “Reference” defined from geometry that is inside the owning part, i.e., these sketch placement values can only have references to its containing part as in Figure 31.

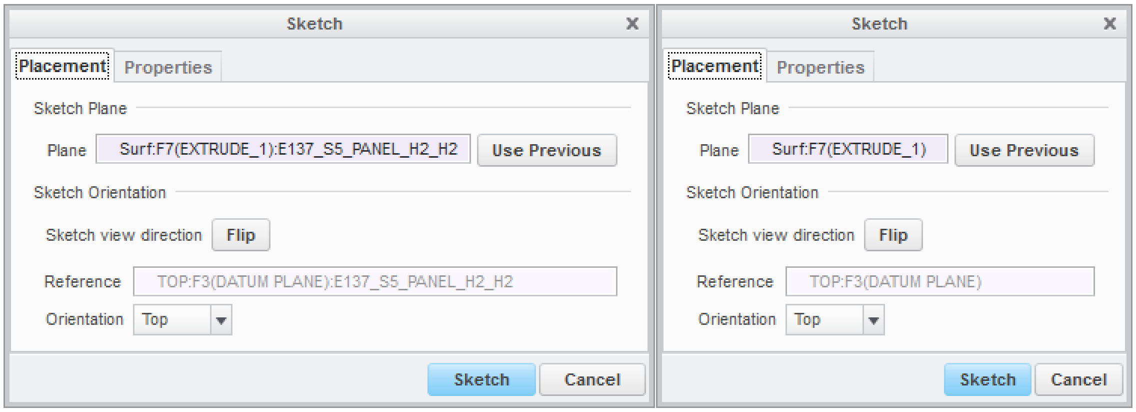


Figure 31: Fully defined sketch with appropriate references: (left) assembly view, (right) part view

The preceding information can be found by selecting the "Sketch Setup" button in the upper left hand corner of the sketch ribbon tab while editing a sketch as shown in Figure 32.

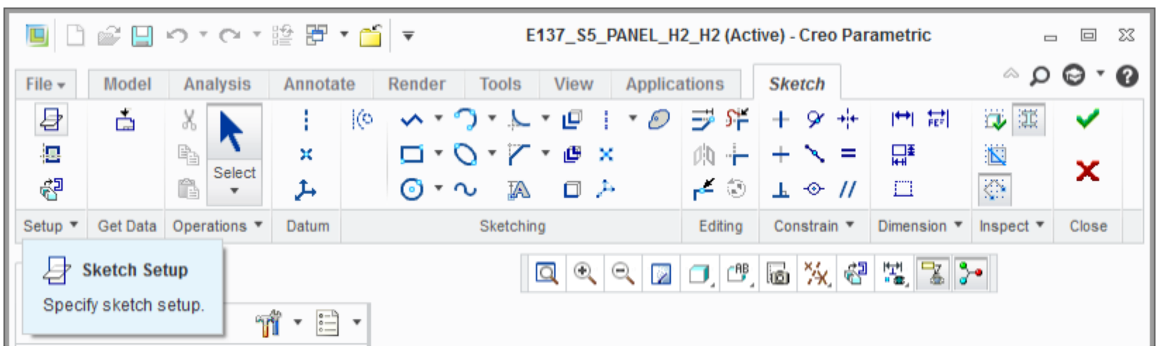


Figure 32: Sketch Setup Button Location

The HuDAT algorithm will also attempt to place HOLE features. These features are created using the Hole command found in the "Cut & Surface" group of the Model tab in assembly mode or the "Engineering" group of the Model tab in part mode
(

).

Finally, if an EXTRUDE cut or a HOLE is part of a feature pattern, HuDAT will create the leader of the pattern, but not any of the pattern's members.

2.2.12 Butt Joints

The HuDAT algorithm allows designers to cut plates into 2 sub-plates and auto-generate the edge preparation and weld seam for a butt joint. Currently, the tool can handle double-v ballistic joint configuration for ballistic plates with material type of “steel_armor” or “aluminum_armor” and have no additional features (such as extrude cuts or holes). A designer may wish to use this tool to ensure that each plate’s dimensions are in stock or are within the allowable manufacturing table limits for end mills.

The first step in using this tool is to select the “Check Plate Size” button from the HuDAT ribbon as shown in Figure 33.

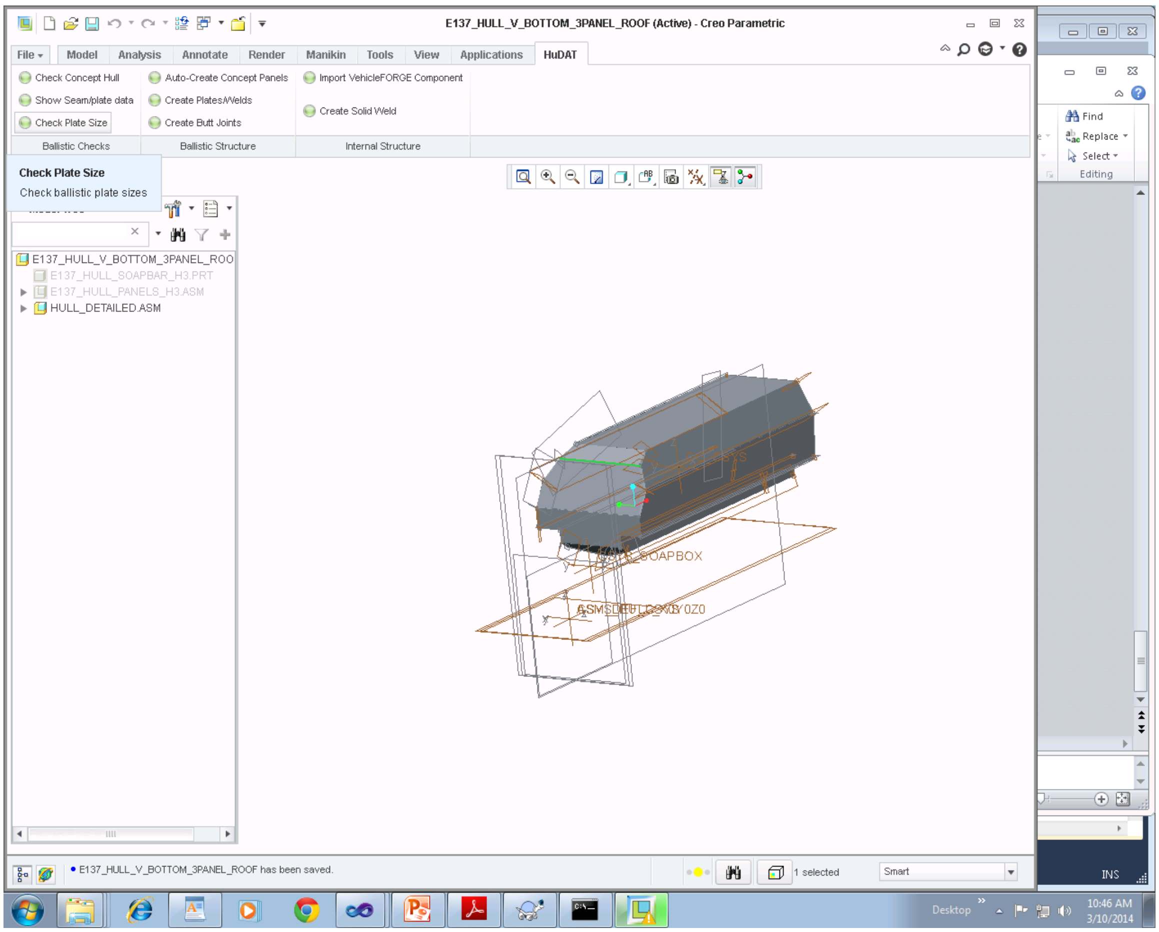


Figure 33: Check Plate Size Button on the HuDAT Ribbon

By selecting this button, HuDAT will check the size of the ballistic plates generated by HuDAT and display a popup menu detailing the number of plates that are too large for manufacturing as shown in Figure 34.

Figure 34: Check Plate Size Button Popup Fialog

In this example, there are 16 panels that are too large for manufacturing and should be cut into manufacturable sized plates. The popup menu prompts the user to select the "Create Butt Joints" button form the HuDAT ribbon, which is shown in Figure 35.

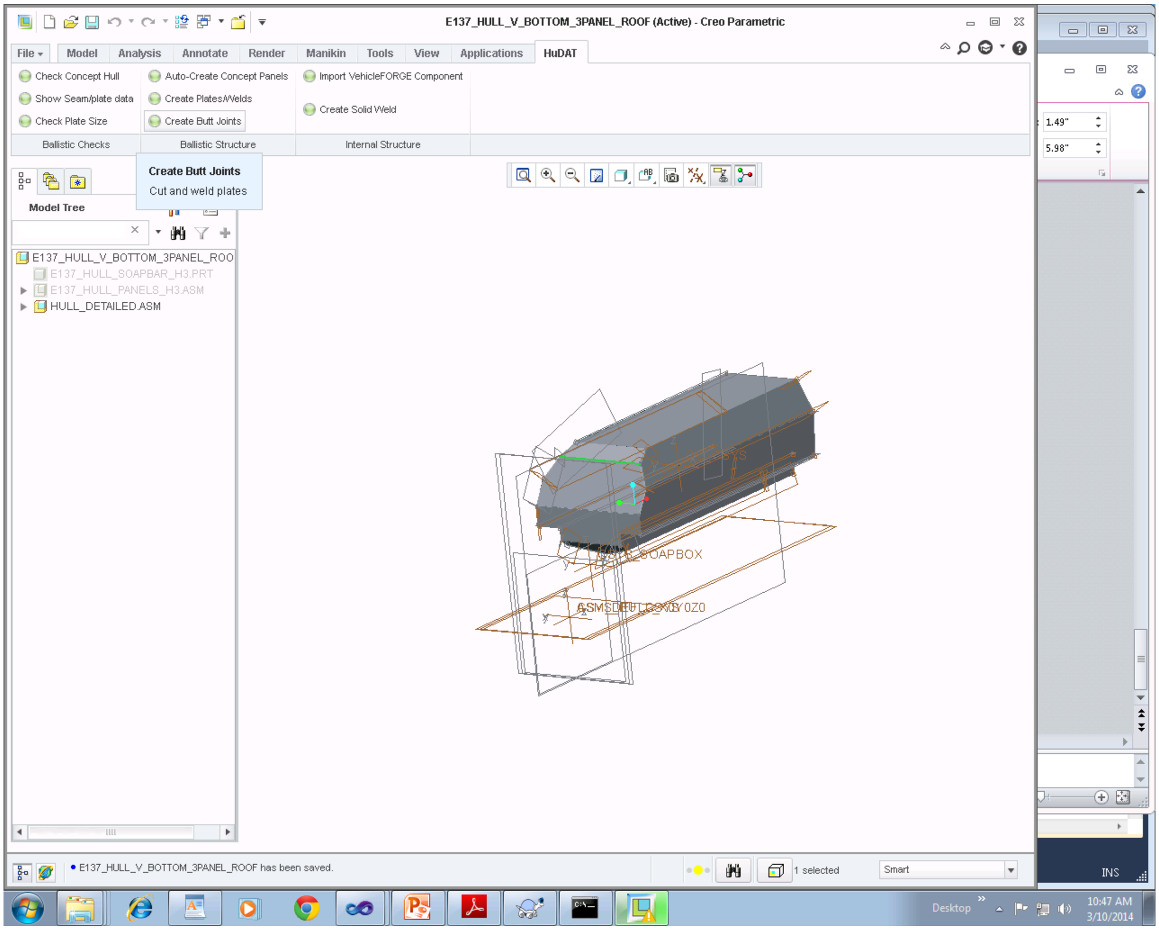


Figure 35: Create Butt Joints Button on the HuDAT Ribbon

After selecting this button, a dialog box will appear that will guide the designer in creating butt joints for plates. This menu is shown in Figure 36. A red x next to a plate indicates that it that plate is too large to manufacture and should be cut into smaller plates. A green check indicates that those plates are within manufacturing limits.

Figure 36: Butt Weld Wizard Dialog Menu

Selecting the red x push button will present the user with an information box (shown in Figure 37). This box describes how HuDAT will aid the user in creating a butt joint.

Figure 37: HuDAT Wizard Assist Information Dialog

HuDAT requests that either the user select two points on different edges of a plate to determine the cutting location or that the user select one point and HuDAT will assume an orthogonal cut is desired. After selecting OK, the user will be prompted to select two points on two different edges of the presented plate, or if the user selects one point, HuDAT will attempt to create an orthogonal cut to the corresponding alternative edge. The plate will be oriented so that the largest surface is normal to the graphics window and text will be displayed to show vehicle orientation in relationship to the plate. Users are expected to use the CTRL key and the left-mouse button to select points.

NOTE:
The location where a user picks on an edge will be the location of one end of the butt joint cut so care should be taken when selecting these points.

After the user selects either one point for an orthogonal cut or two points and selects OK in the menu selection, HuDAT provides a point selection assist tool to allow the user to more accurately selection point locations. Figure 38 shows the Edge Point Adjustment Interface tool for an orthogonal line selection. In this case, the user may use the slide bar to move the location of the first point and the orthogonal line.

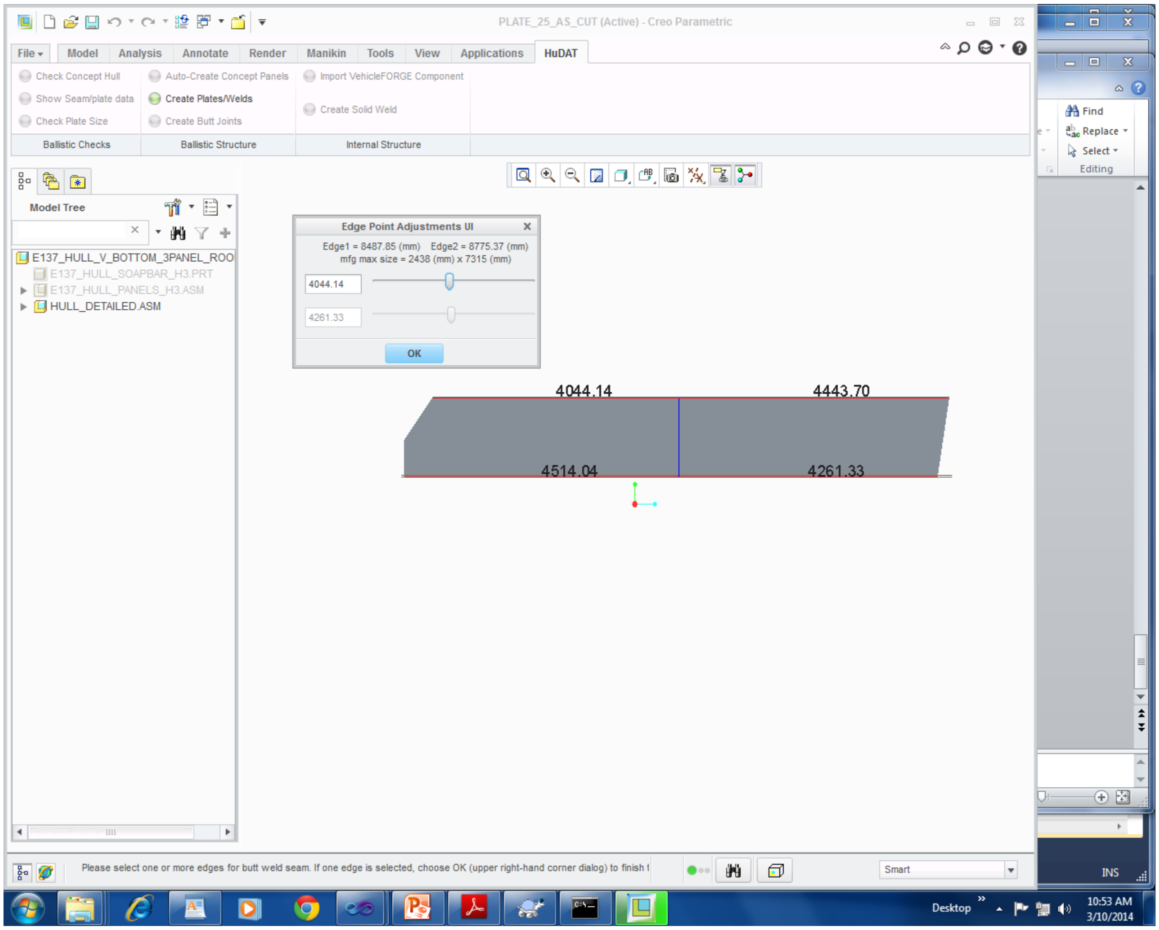


Figure 38: HuDAT Butt Joint Selection and Edge Point Adjustment UI.

Figure 39 shows the **Edge Point Adjustment Interface** for a non-orthogonal line selection; in this case, the user has selected two points beforehand and will be able to modify both points using the slider bars.

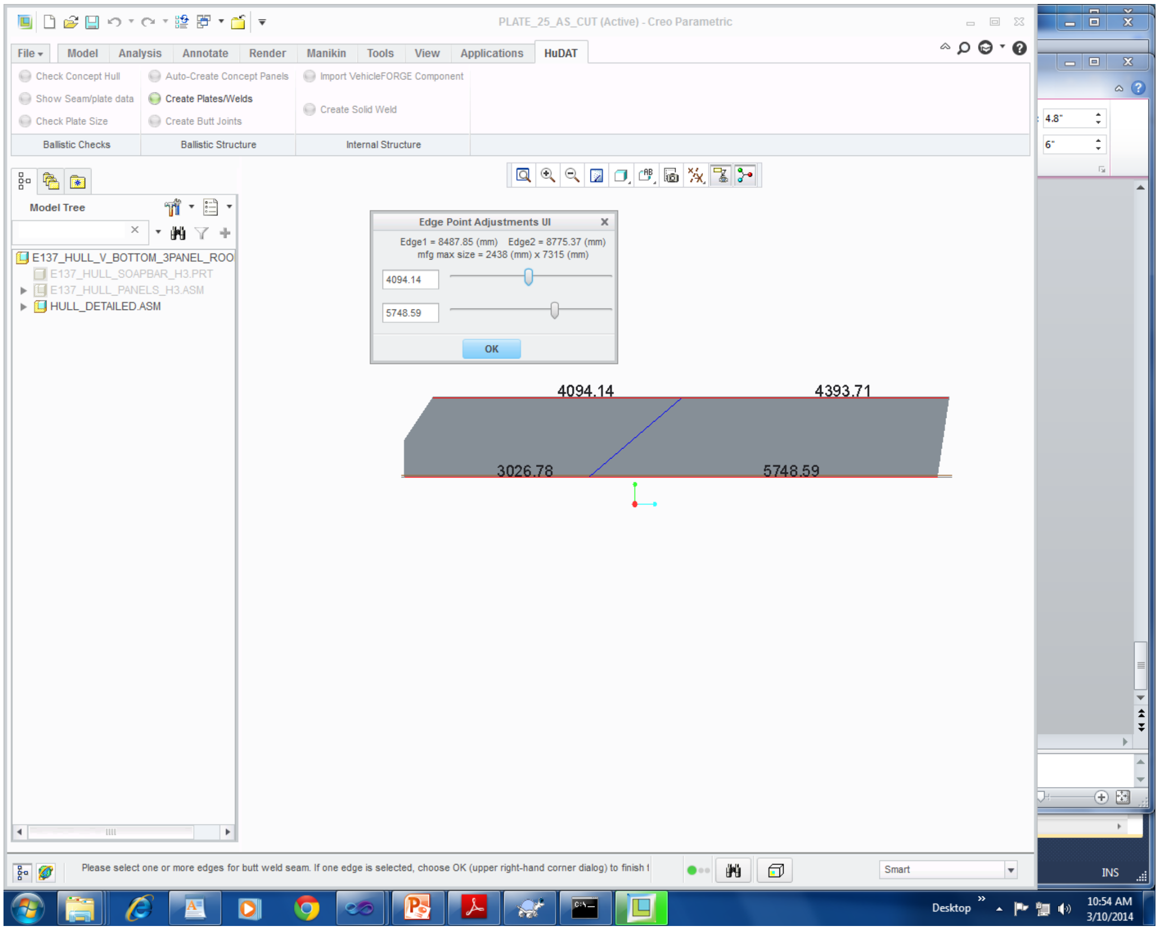


Figure 39: HuDAT Butt Joint Selection Process for Non-orthogonal Lines.

HuDAT displays a line between the cut points and also shows key dimensions of the cut line from the edge end. After selection OK from the **Edge Point Adjustment UI** the user will be prompted to confirm the cut points and will have an option to retry or cancel the operation as well. An example of the cut point display and the dialogue box is shown in Figure 41.

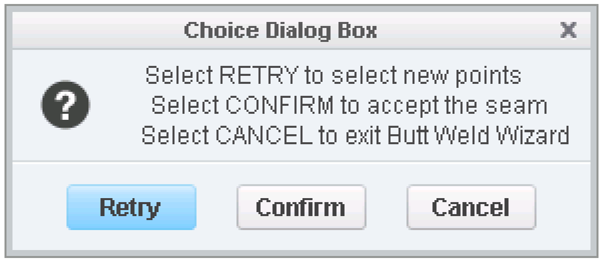


Figure 40: Butt Joint Confirmation

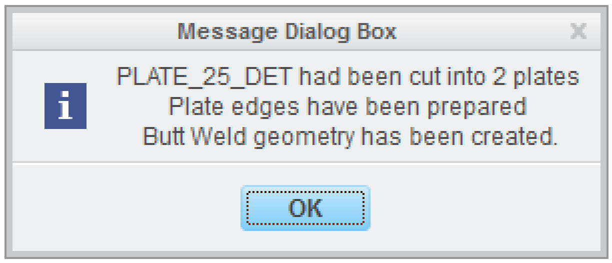


Figure 41: Resultant Dialog from Butt Joint

In the process of taking one plate, cutting it into two, and creating the weld seam, HuDAT will create a new sub-assembly with the resultant geometry. The sub-assembly is named the same as the plate that was cut (e.g., PLATE_25_DET.prt is now a PLATE_25_DET.asm) and the component of the sub-assembly are a PLATE_*A, DET a PLATE*B_DET, and a WELD_*A*_B (where *, in this case, would be 25). An example of this model tree structure is shown in Figure 42.

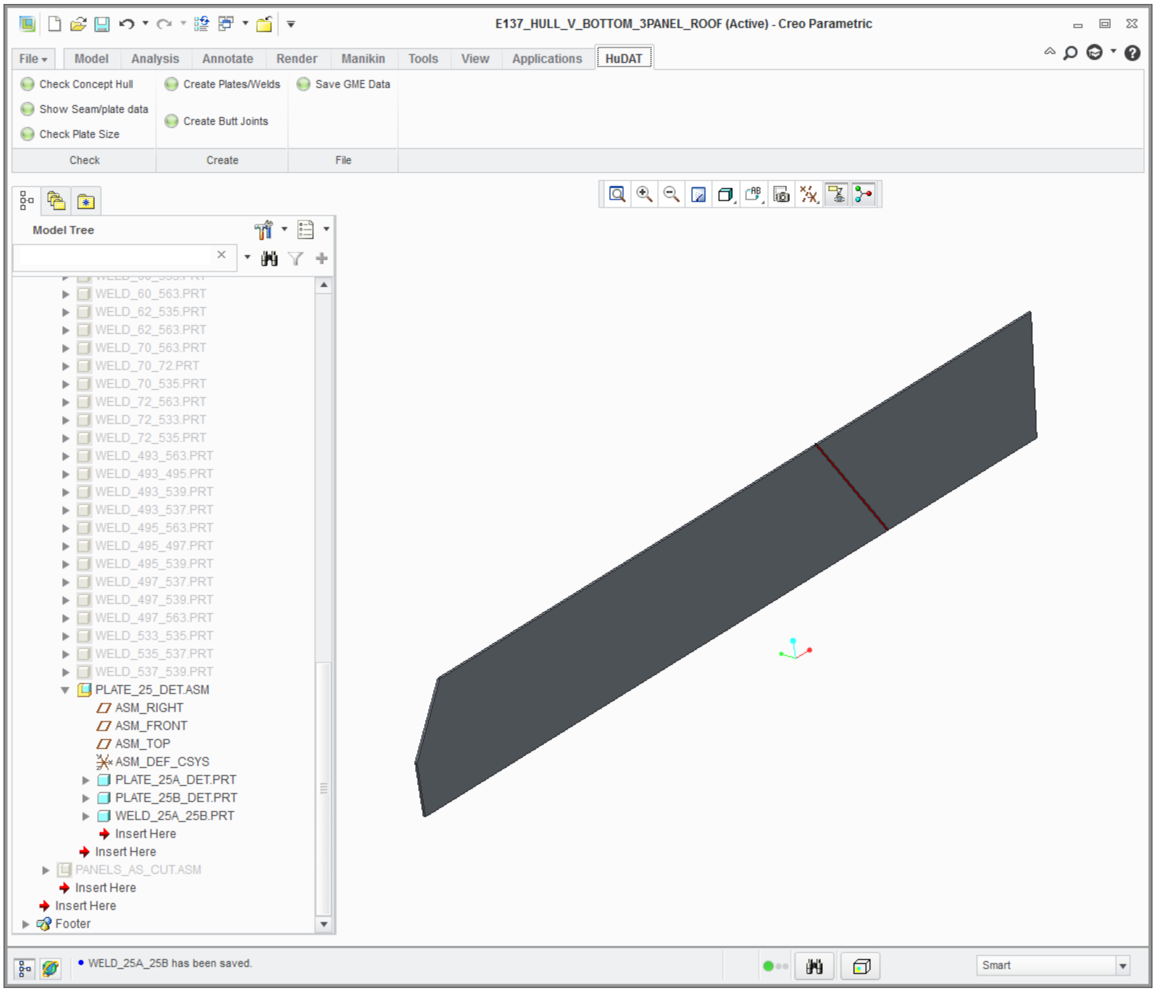


Figure 42: Model Tree After Generation of a Butt Joint Using the HuDAT Tool

Currently, if the user selects a point within two inches of an edge vertex HuDAT will assume the vertex is used as a reference. A prompt with be displayed letting the user know that the vertex will be used as a reference as shown in Figure 43.

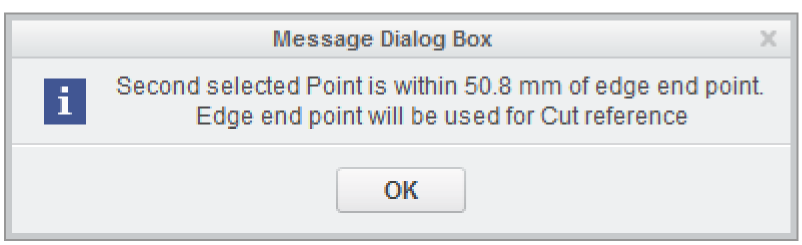


Figure 43: Dialog Box for Cut Points

NOTE:
The Butt Joint tool is sensitive to user inputs and as such, care must be taken when selecting the two points.

Current limitations include:

- Collinear edges may not be selected.
- Points may not come from the same edge.
- Cut points within two inches of an edge vertex will use the edge vertex as a cut reference. If the new cut point is collinear with the second edge that is being cut HuDAT will throw an error.
- A straight line is used to connect the first point to the second, and so cuts through non-convex regions of a plate is not supported.

2.2.13 Adding Components from Vehicle Forge Library

The "*Import VehicleFORGE Component*" on the *Internal Structure* menu on the HuDAT ribbon allows the user to import internal structure components from the VehicleFORGE Gamma website. After selecting this button, the user will be prompted to enter their VehicleFORGE Login ID and Password for authentication. Once authenticated, the user may select from either Extrusions or Plate Sheet components and will be provided a list selection box of components in one of these categories. This list of components can be found under the gamma.vehicleforge.org website under the Fang Components/PowerTrain/Engine_subsystems/RawStock Category. Figure 43 shows the VehicleFORGE interface dialog and steps to importing a component.

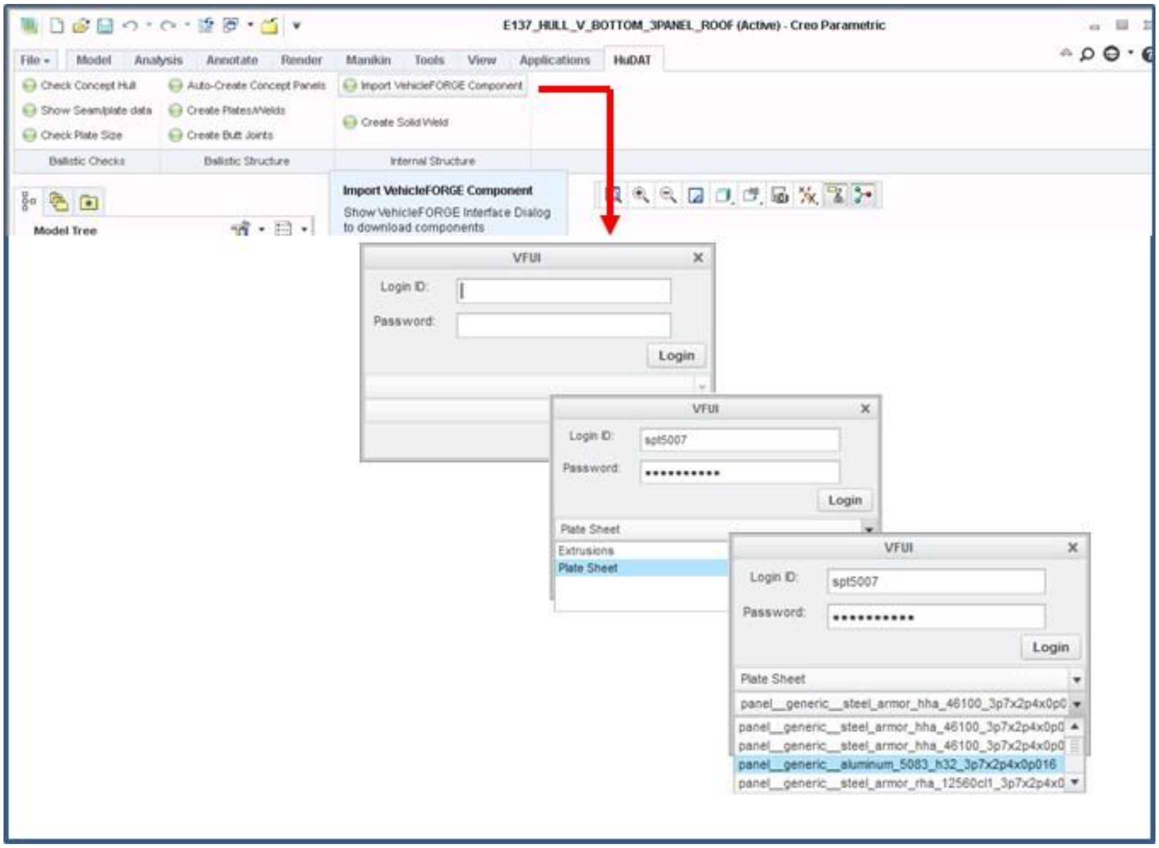


Figure 44: Importing a Vehicle Forge Component

After a component has been selected and the Import button pressed, HuDAT downloads the component zip file and places it in the Components directory. The Creo CAD files are automatically extracted, placed in the Hull CAD directory, and loaded into Creo under the Internal Structures Assembly. If the Internal Structure Assembly does not exist, HuDAT will create it. The user is responsible for positioning and modifying the part as needed to meet their design intent. HuDAT will assemble the component in the Internal Structure Assembly that was created in the HULL_DETAILED Assembly. Figure 45 shows the default location of an imported plate sheet and shows the part in the model tree.

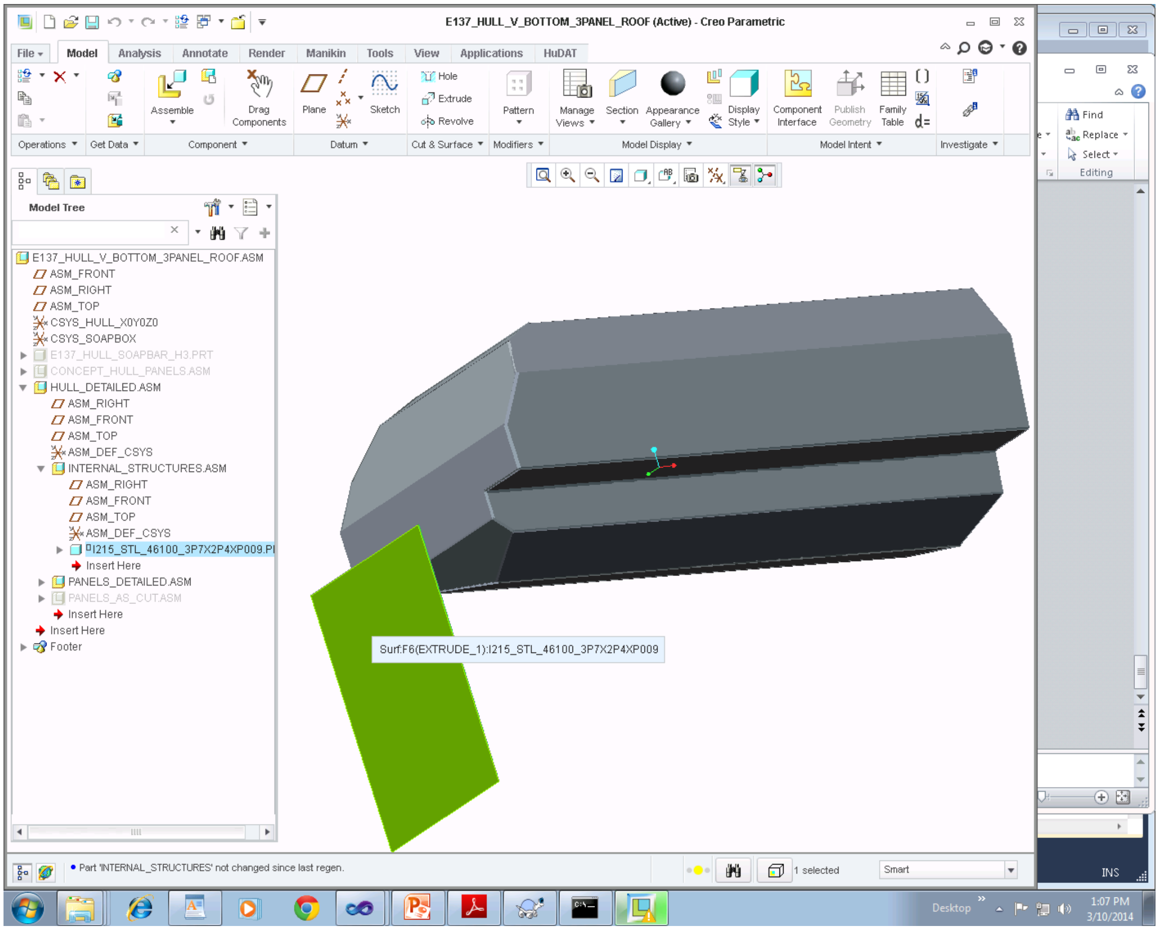


Figure 45: Vehicle Forge Component after Import

2.2.14 Creating a Solid Weld

The "*Create Solid Weld*" Button under the *Internal Structures* menu in the HuDAT ribbon tab allows the user to create a solid weld between two parts in the *Hull_Detailed*assembly. After the user has trimmed or modified their internal structure and placed it in the appropriate location, they may want to define solid welds between it and other structure. The *Create Solid Weld* button prompts the user for weld leg lengths and the selection of two surfaces. The surfaces must be solid surfaces (from solids) and may not be quilts. After surfaces have been selected and weld leg lengths have been entered, HuDAT will create solid weld geometry between the two surfaces.

Figure 46 shows a plate sheet that has been imported from Vehicle Forge, trimmed and positioned coincident to the hull external panels. The figure also shows the solid weld dialog. In this dialog, the user must specify weld leg lengths and select two part surfaces where the weld will be formed. After surfaces are selected, the Weld Assist User Interface will display green check boxes to confirm good surface selections have been made. Figure 47 shows the surfaces that were selected and the weld assist dialog box updated with green check boxes.

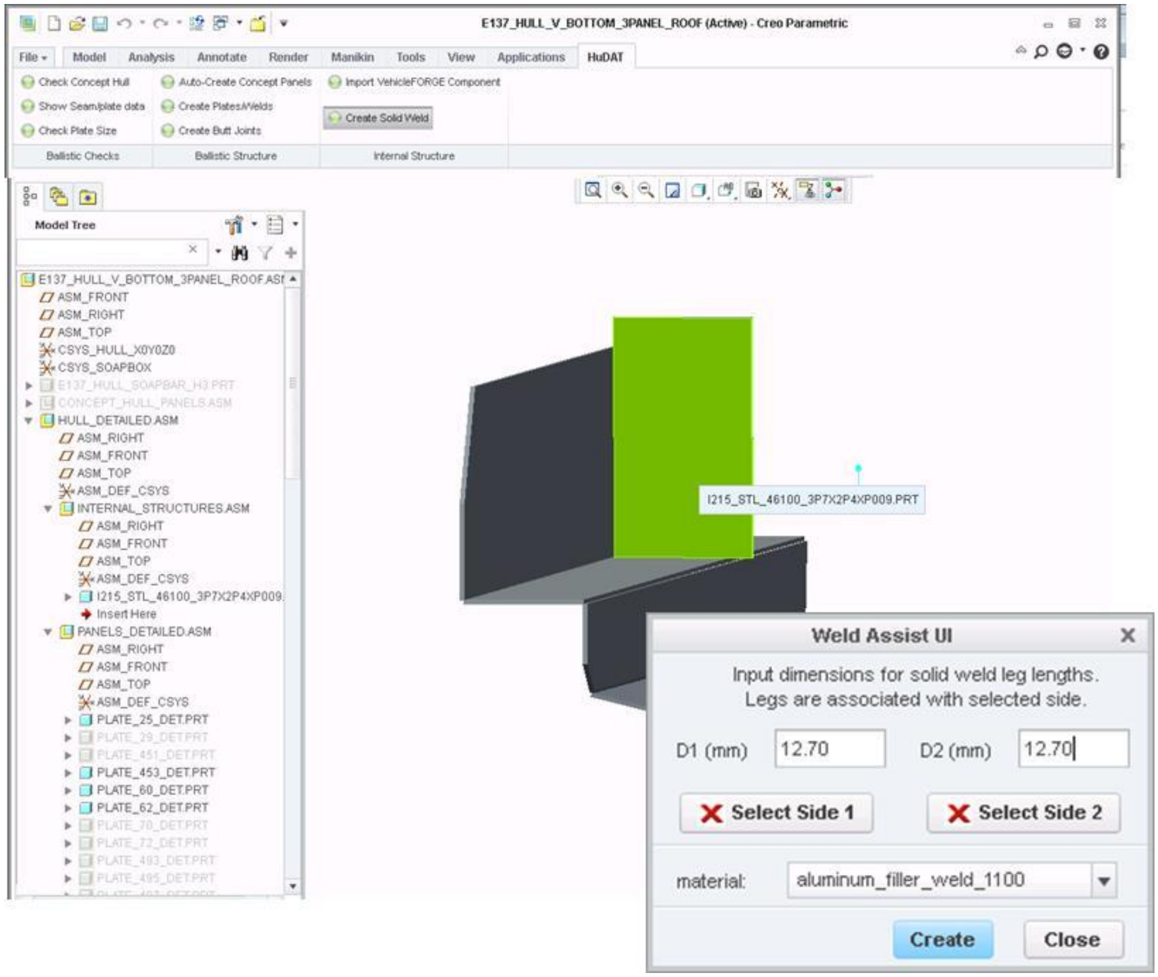


Figure 46: Use of the Solid Weld Tool

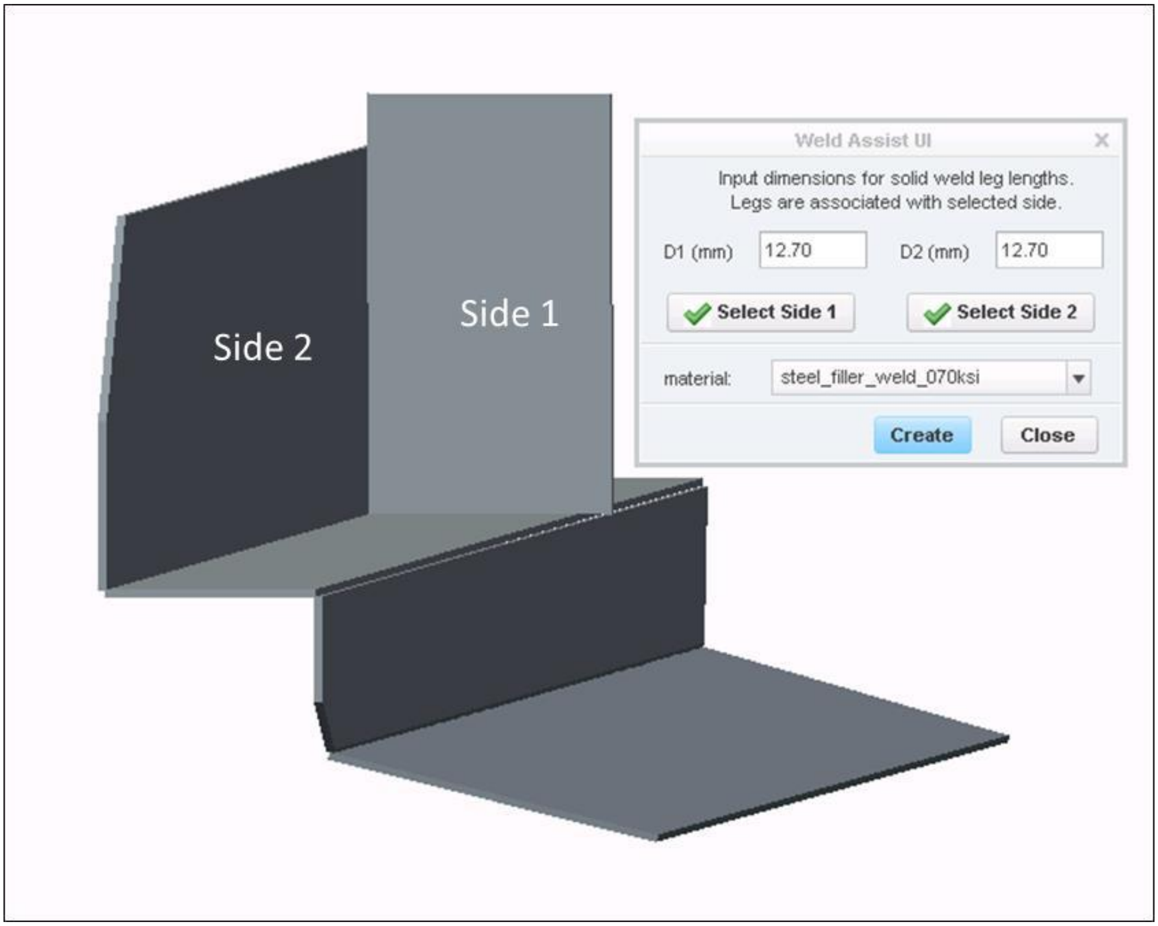


Figure 47: Use of the Solid Weld Tool - selecting surfaces

After Surface selection and weld leg lengths are entered, HuDAT will create the solid weld between the parts and place the weld component in the internal structure assembly. An example of a completed solid weld is provided in Figure 48. The weld is displayed in red.

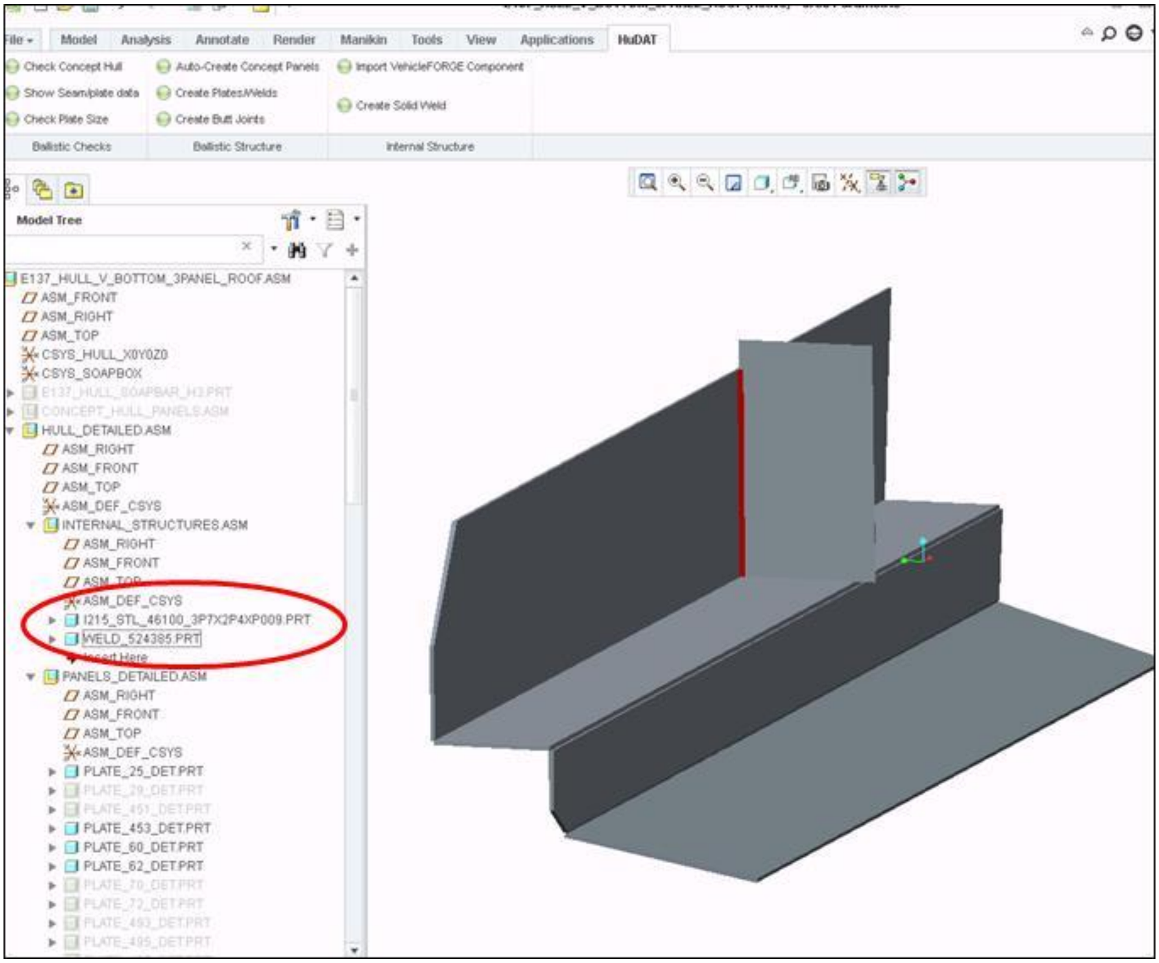


Figure 48: Solid Weld Between Internal Structure

After the solid weld is created, the Welds.XML file created by HuDAT will be updated to contain new definitions for the internal welds. Internal welds have a component class type of “WELD_CLASSB” and can be identified in the xml file by this component class value.

3.0 Release Notes

This release of includes a new button titled Auto Create Concept Panels in the Ballistic Structure command group that creates concept panels from a compliant hull soapbar part. The functionality is documented in section 2.2.5.

This release of HuDAT includes an enhanced user interface for cutting plates and creating butt joints. A slider bar input has been added to the cut point selection dialog and text is displayed to show the panel in the context of the vehicle. This is described in Section 2.2.12.

In this release of HuDAT the command groups in the ribbon bar have been renamed to Ballistic Checks and Ballistic Structure and the command group titled Internal Structure has been added. The Internal Structure command group contains two commands, one titled Import Vehicle Forge Components) which allows you to import raw stock components from Vehicle Forge and another Create Solid Weld which assists the user in creating a weld in the form of a solid sweep between two surfaces on two separate parts.

This release of HuDAT currently works on the following hull models that exist in the Vehicle Forge component library:

- e137_hull_double_v_3panel_roof.asm
- e137_hull_flat_bot_3panel_roof.asm
- e137_flat_3_roofflat_h1.asm
- e137_hull_v_bottom_3panel_roof.asm
- e137_hull_wing_3panel_roof.asm

Any other concept hull model that is used must conform to the concept hull requirements as described in Section above.

4.0 Limitations

HuDAT currently does not work on concept panels or hull soapbar parts which contain curved surfaces. The soapbar part must contain planar faces only and all surface edges must be linear. In addition In addition all soapbar surfaces must contain only one contour.

Currently HuDAT cannot cut or produce butt joints in any plate which has additional features such as extrude cuts or holes.

The solid ballistic welds produced by HuDAT may intersect each other at the corners or may produce gaps at the intersection points. HuDAT does not attempt to Blend or cut out/merge these solids. This geometry does not fail in HuDAT but may cause problems in other analysis test benches. The user may need to blend or perform unite/cut/merge operations on these solids to remove the intersection volumes.

5.0 Methodology for Creating Ballistic Welds

HuDAT automates the process of defining weld joints between ballistic plates of a hull. HuDAT automates and/or reduces the necessary design time for the following functions:

- Analyzing ballistic material weld compatibility
- Enlarging or reducing ballistic plate size to support the manufacturing processes needed to produce ballistic welds.
- Defining and performing edge preparation on ballistic plates (chamfers and cuts).
- Creating solid weld geometry representing the final weld bead.
- Setting plate and weld material properties and mass properties.
- Checking plate sizes against dimensional constraints which are imposed by manufacturing.
- Cutting plates into acceptable sizes and producing edge preparation for the butt joint formed.

The TACOM Ground Combat Vehicle Welding Codes for aluminum and steel define the requirements for welds for armored vehicles. These codes categorize weld requirements into four different categories, stud welding, non-critical welding, critical welding (except ballistic structures) and ballistic welding. Each weld category has a unique set of requirements for design, test and qualification with critical and ballistic welds having the most stringent requirements. Critical Welds are applicable to all weld joints where failure of the joint would likely result in personnel injury, loss of life, or a mission-critical failure, whereas ballistic welds are applicable to the joints in a ballistic structure which are critical to the ballistic integrity of the structure. The HuDAT tool creates valid weld joints that meet the TACOM requirements for ballistic class welds.

All ballistic welds must provide Complete Joint Penetration (CJP) where the weld metal must extend throughout the full thickness of the base metal in a joint. The primary purpose for the use of the CJP weld is to transmit the full load-carrying capacity of the structural components they join. Most CJP welds require a specific edge preparation, which can vary based on the thickness and material of the components joined, the configuration of the joint and the included angles between the components. Edge preparation must also adhere to constraints on the maximum and minimum component overlap, and rules which mandate that the resulting material thickness (with plate and weld) cannot be less than the less than the raw material plate thickness. These rules for edge preparation can be found in several military standards and the TACOM welding codes.

The HuDAT application embodies the geometric rules to create valid ballistic edge preparation for hulls. If HuDAT is not used to produce correct edge preparation and solid weld geometry the user must manually modify the edges of all hull panels that are joined. If starting with a set of concept panels their inside surfaces will typically represent the inner mold line of the hull. Different interface configurations may exist for the concept hull panels; for example the edges could be mitered at the corners or the panels could have orthogonal edges and only touch at the inner mold line. Figure 49 shows two examples of how concept hull panels may interface.

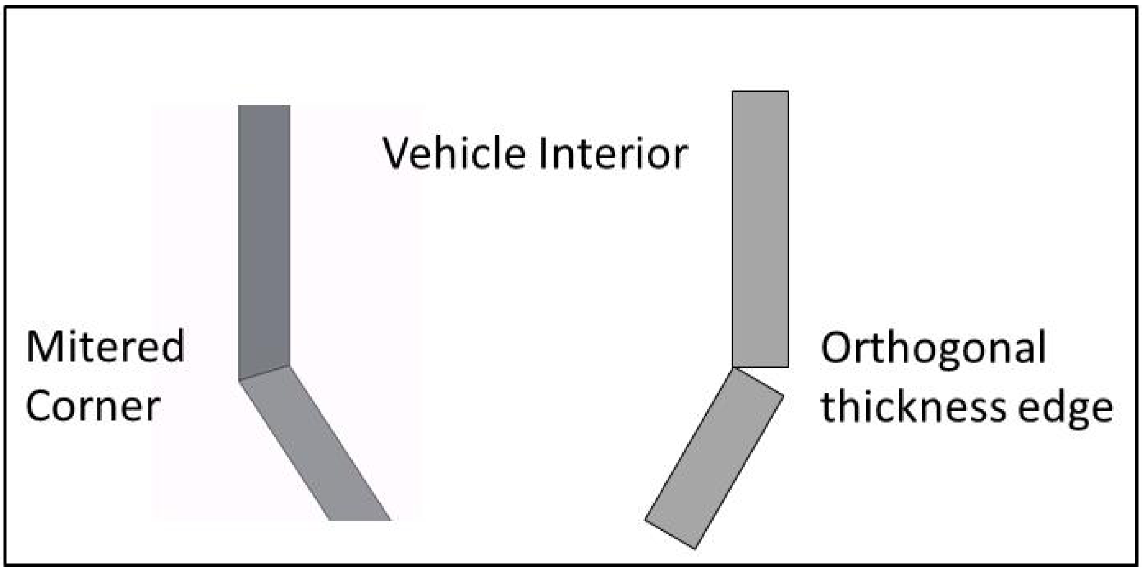


Figure 49: Examples of Concept Panel Configurations

In order to prepare the plate edges for ballistic welding, the concept panels may need to be extended or cut from their original shape to meet the guidelines for ballistic weld joins. Then the plate edge may need to be cut, or chamfered depending on the joint configuration. Figure 50 below shows an example of how the concept panels will be modified in one welding scenario for steel ballistic plates. The left hand picture in the figure shows the original concept panels with orthogonal edges touching at the inner mold line of the vehicle. In order to produce the ballistic weld in the right hand picture, plate 1 must be cut back and plate 2 must be extended. In this example plate 1 is then chamfered on both its inner and outer edges.

The values for plate extensions or cut backs and the chamfer or extrusion cuts on the panels are calculated by HuDAT and geometric operations are performed to create the correct panel shape. HuDAT creates these plate extensions by extracting the concept plate inner surface contour and extending or retracting each edge the calculated value. Then HuDAT generates an extruded solid from the modified inner surface contour, the concept plate thickness is used for the extrusion value. After the extruded solid plate is created, HuDAT will chamfer or create additional cuts on the plate edges to create the correct geometry.

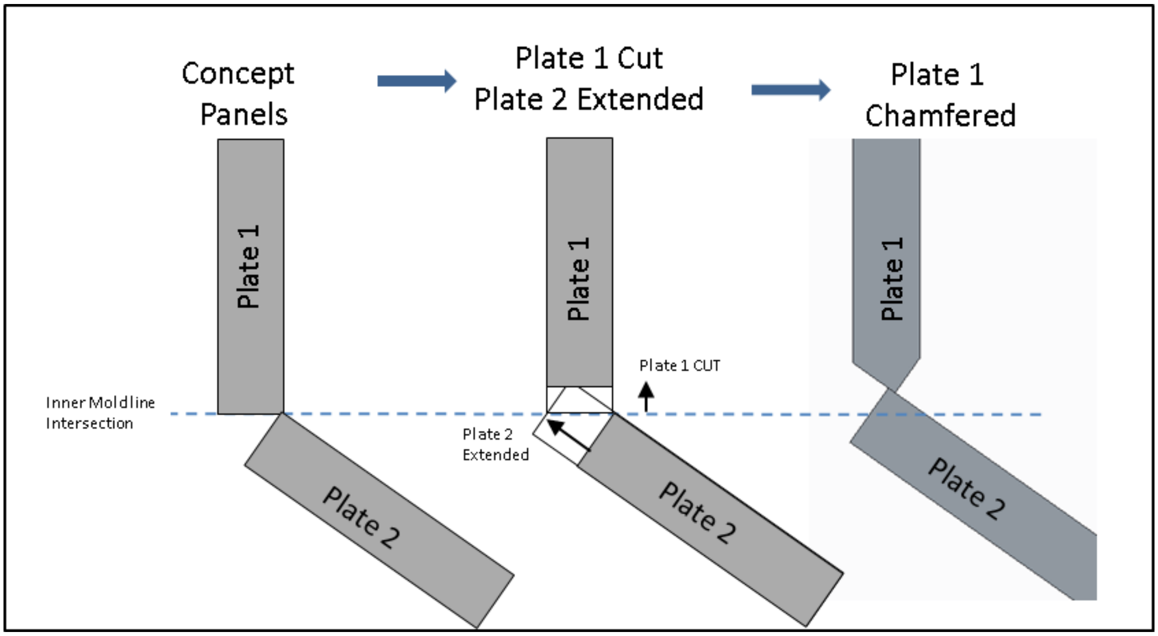


Figure 50: Transition from Concept to Detailed Plates (Steel)

The transition from concept plates to detailed plates will be different for each joint configuration an1 is dependent on the plate material, the plate thickness and the included angle. Figure 53 below shows another example of the transition from concept panels to detailed panels for an Aluminum ballistic weld. Rules for aluminum ballistic welds are different than steel and you will notice different edge preparation between Figure 50 and Figure 51. The first picture on the left of figure 51 shows mitered concept panels. The middle figure shows stock plates with orthogonal edges that are cut to a specified dimension. The middle picture of Figure 53 represents the “as cut” panels for manufacturing. To obtain the final edge preparation in the third figure, HuDAT first created chamfers on the plate 1 edges and then cut a square extrusion away from plate 2 to create the ballistic steel edge geometry.

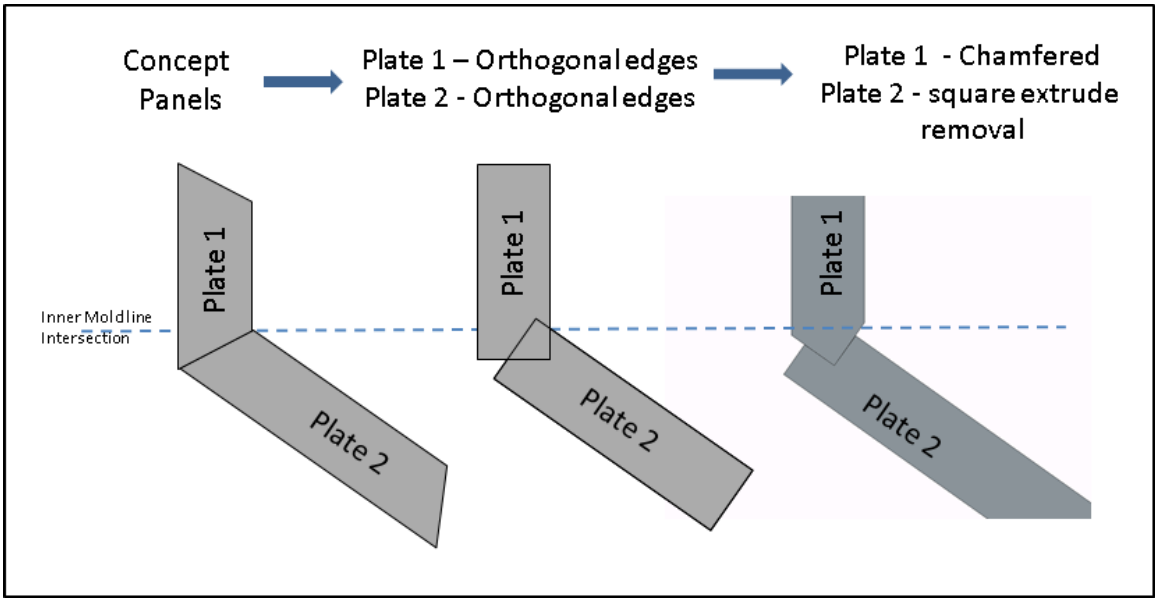


Figure 51: Transition from Concept to Detailed Plates (Aluminum)

As mentioned previously, HuDAT generates a set of "AS CUT Panels" which represent the plates as they are cut from stock. If the user chooses not to use HuDAT they will need to provide the manufacturing assessment tools with plate models that are cut to the necessary dimensions. The values for the plate extensions and cut backs, the edge chamfers and the edge cut extrusions are dependent on the joint geometry and material. Various examples of valid edge preparation for different scenarios is provided in Figure 52 thru Figure 55. To reproduce these ballistic welds the user should reference the TACOM welding codes.

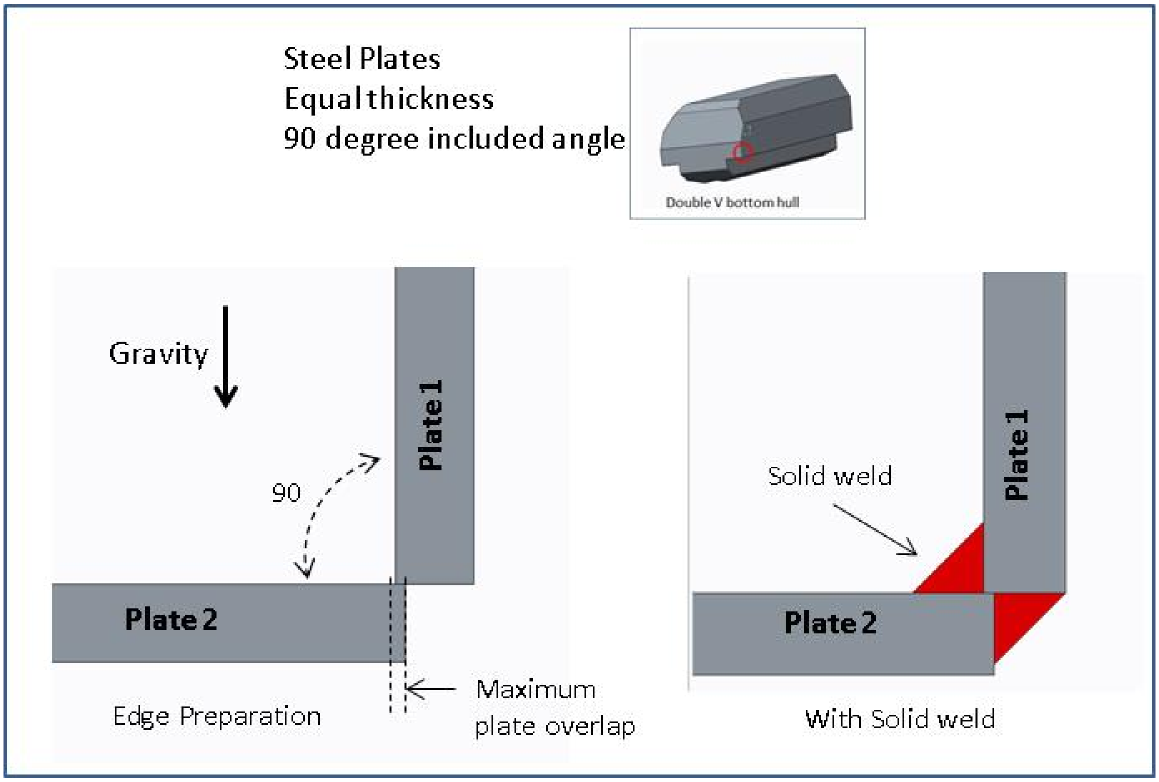


Figure 52: Edge Prep and Solid Weld Example 1

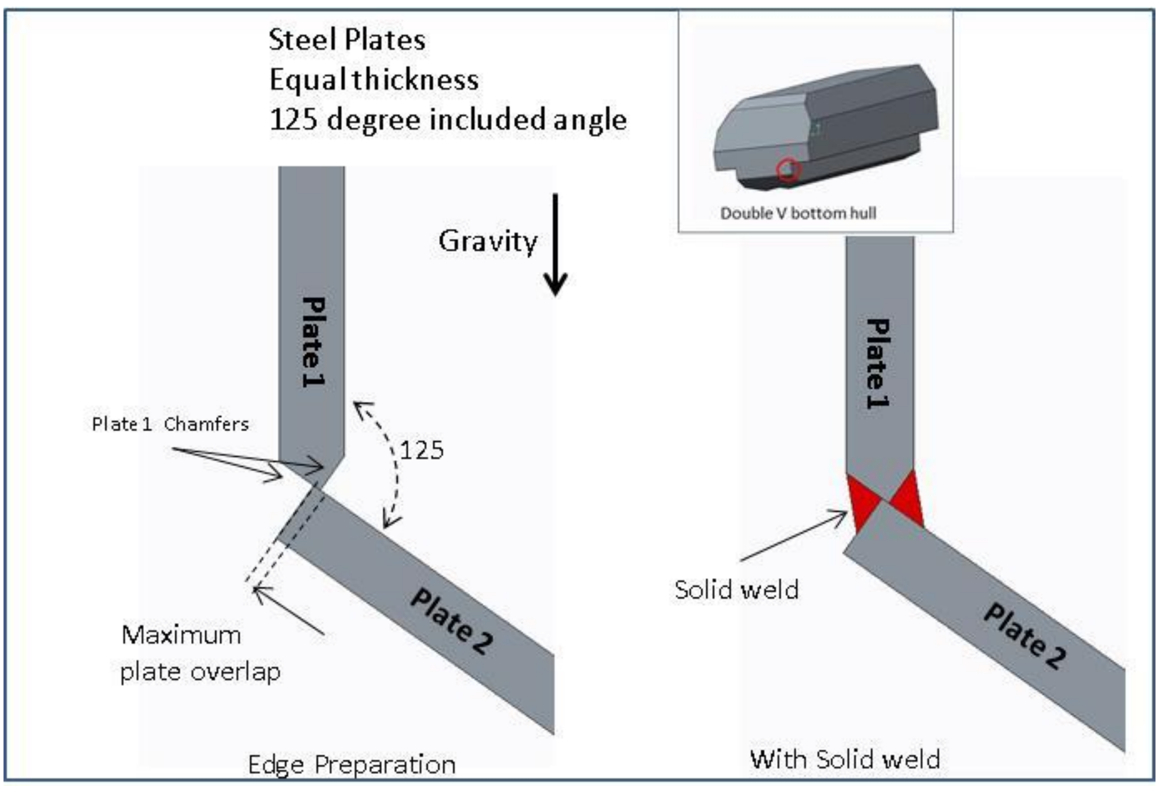


Figure 53: Edge Prep and Solid Weld Example 2

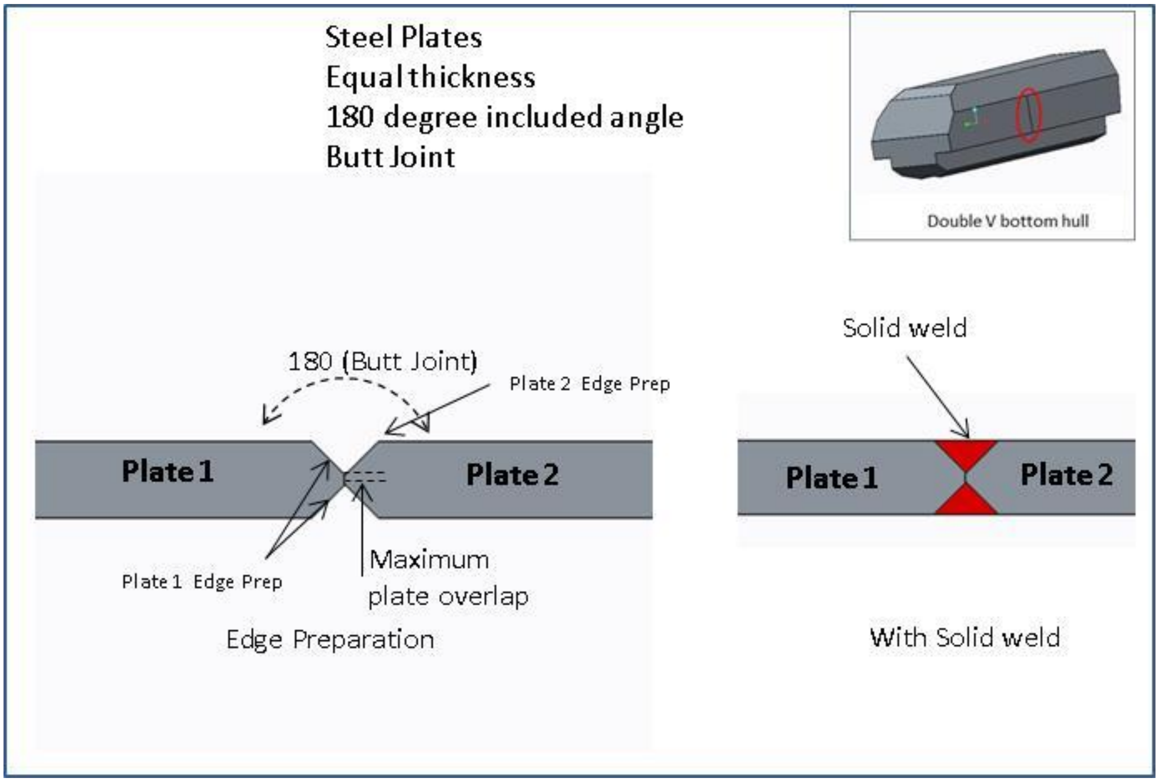


Figure 54: Edge Prep and Solid Weld Example 3

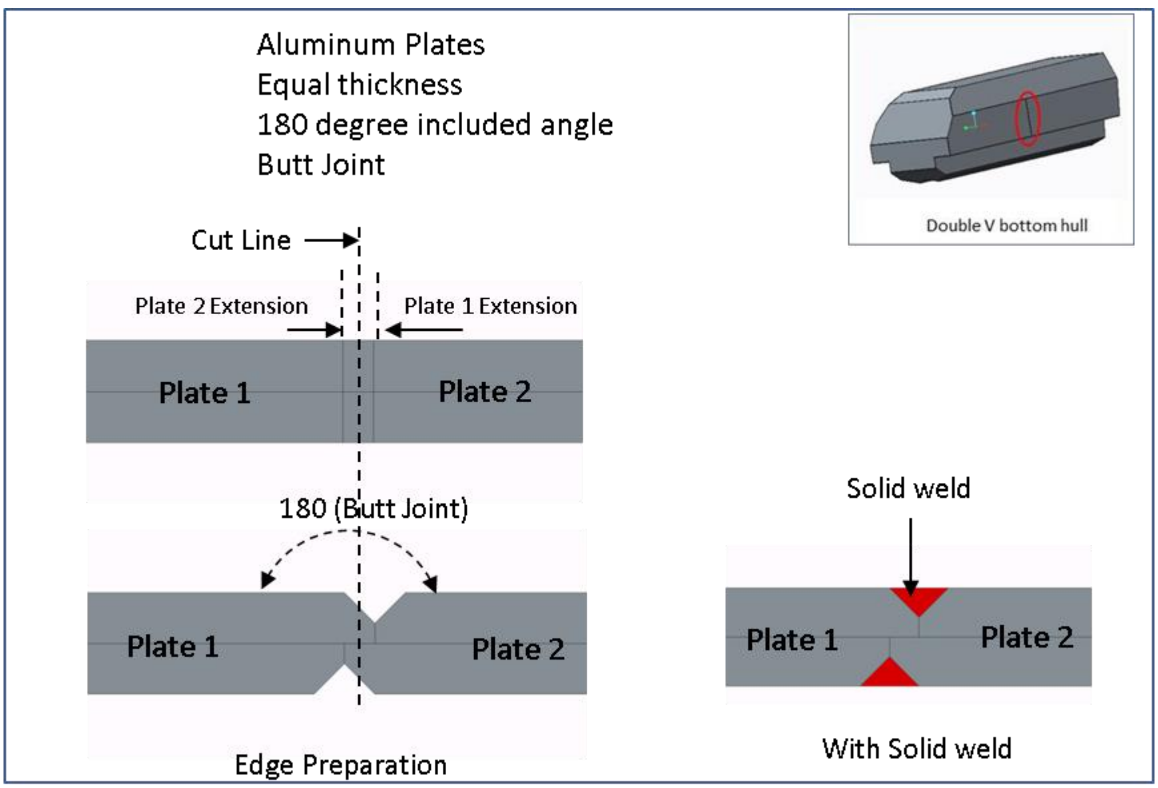


Figure 55: Edge Prep and Solid Weld Example 4

In addition to automating edge preparation, HuDAT creates solid weld geometry along the weld seam that represents the weld filler material after manufacturing. This is necessary to feed analysis test benches which rely on accurate mass properties and solid materials. If the user chooses not to use HuDAT they will need to create a solid extrusion or sweep along each weld seam that represents the geometry of the final weld. Figures 52 thru 55 also show cross sectional views of the solid welds that are formed between two plates for each type of weld configuration.

After HuDAT is executed on the concept hull, the user can use HuDAT to check the dimensions of the detailed panels to determine if they meet manufacturing limits. HuDAT can also be used to cut plates and create Butt Welds along the cut line. This is done by using the “ButtJoints” button in HuDAT. If HuDAT is not used for this process the user must determine which plates need to be cut to meet manufacturing limits, then proceed to cut each plate one or more times, produce valid edge preparation and produce solid welds along the cut line. An example of a butt joint and weld is shown in Figure 54 and 55.