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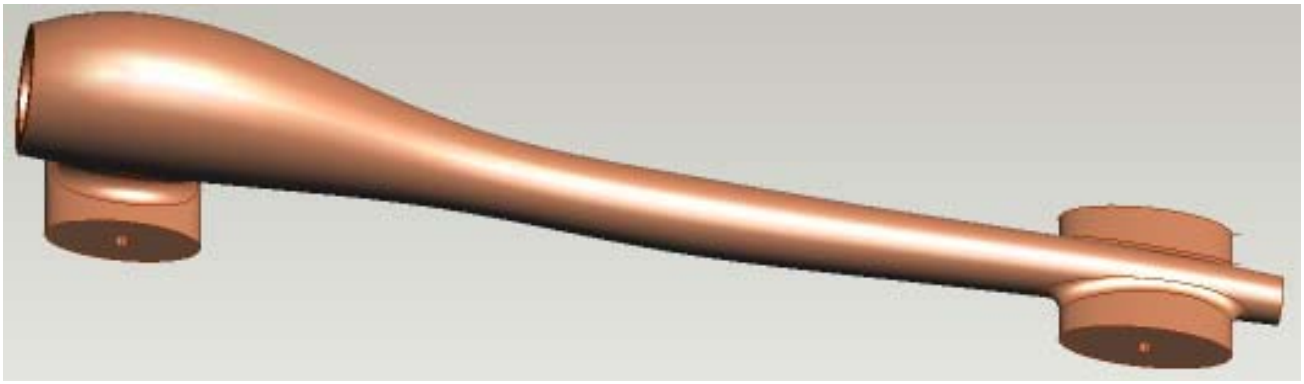
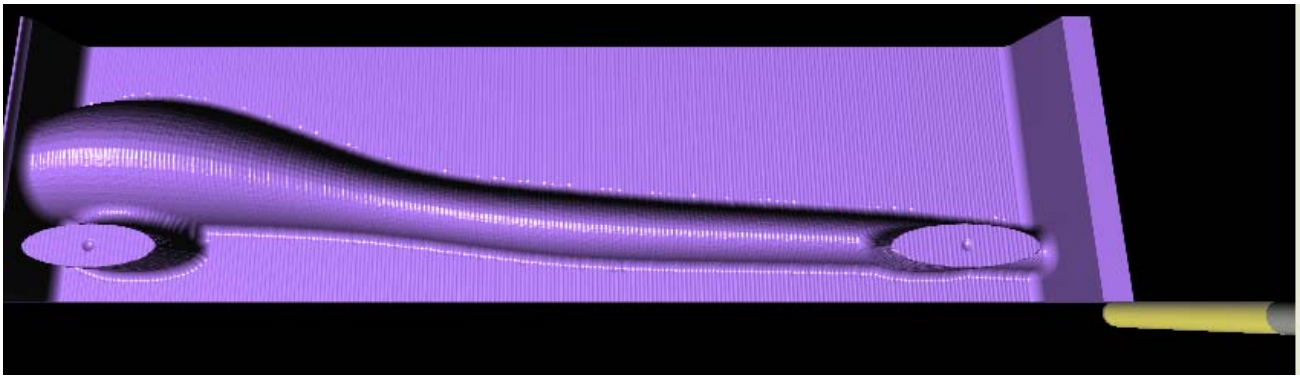
# $CO_2$ Car Design and Manufacturing





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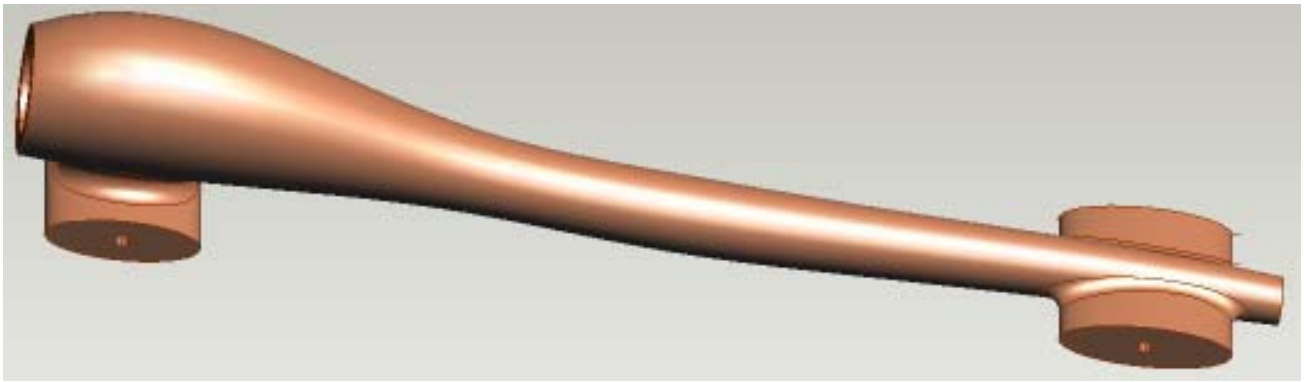
# $CO_2$ Car Design
# using
# Pro/Desktop Version 8



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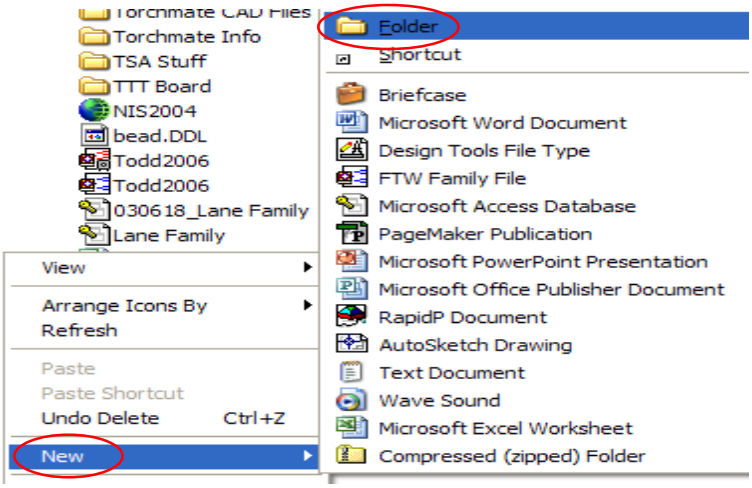
## 1 - 1: Creating a Directory to SAVE Your Files

1. To help manage files, you need to create a directory to save your CO2 files.

2. *Double-click* on the My Documents folder on your desktop.

3. Right-click, select **NEW**, and click on **folder**. Then type in the folder name using the following format ...

**<Your Last Name> CO2 files** *(example: Todd's CO2 files)*.



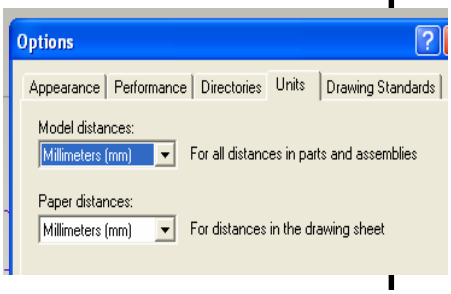

4. Close the **My Documents Window**!

**Note:** *Click* on the ☒ in the upper right corner of the screen to **CLOSE** the ***My Documents window***.

## 1 - 2: Setting up your Drawing Area

1. **OPEN** the Pro/Desktop program by selecting **START**, **All Programs** and *clicking* on PTC ProDESKTOP 8.0.

2. You may need to Maximize the screen by clicking on the middle box in the upper right hand corner of the screen.




3. Set drawing **UNITS** to **METRIC**.

   From the drop down menu at the top of your screen, **select TOOLS**, then **click OPTIONS**.

   • Select **UNITS** and change to Millimeters and **click OK**.

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4. Go to the upper left corner of the screen and select **FILE**, then click **OPEN**.

5. Select the **CO2 Car Template.des** file from the **My Documents Folder** or other location specified by your instructor.

6. Again, **maximize t**he screen by *clicking* on the middle box in the upper right hand corner of the screen.

**DON'T MISS THESE STEPS ...**

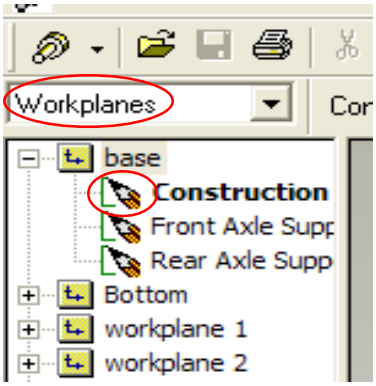
7. Before going any further, you MUST use the **SAVE COPY AS** command and save this file in the DIRECTORY (folder) you just created.

8. Save the file using the following format ...
**<Your Last Name> CO2** *(example: Todd's CO2)*.

9. Now go back up and select the **FILE** menu, *click* on **CLOSE**.

10. Again select the **FILE** Menu, *click* on **OPEN**, select the your CO2 car file and *click* **OPEN**.

11. Go to the **BROWSER Menu**, located on the left side of the screen and make sure that **Workplanes** appear, if not select the down arrow and choose workplanes..




12. *Click* on the **+** sign in front of the **Base Workplane**, then *click* on the **Construction Lines** sketch icon.

13. *Click* on the **View onto Workplane button** located in the **VIEW** menu at the bottom of the screen.

14. Information on the next page will help you better understand workplanes and sketches.

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# Workplanes and Sketches

***All objects in your design must be created on a sketch located on a workplane.***

***If we were to use traditional drafting equipment, a workplane would be like the drawing board and the sketch would be the sheet of paper.***

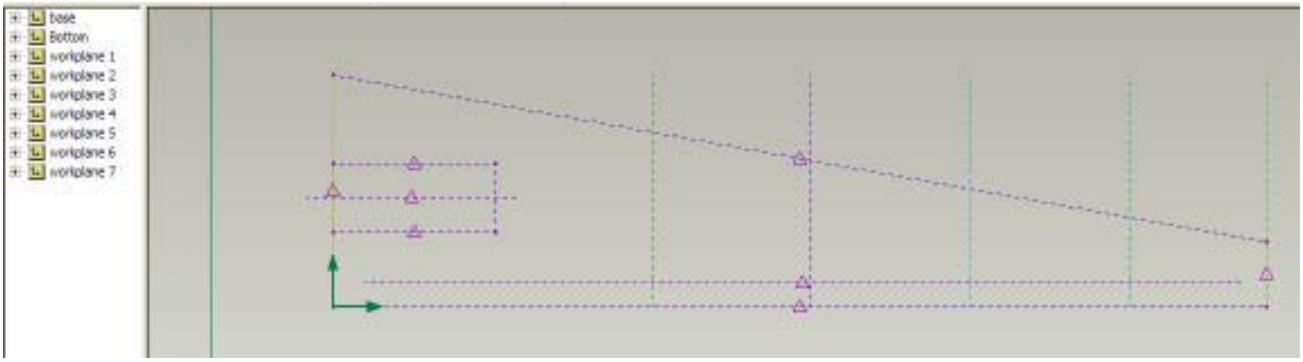
**Workplanes are designated with the workplanes icon** .

- Workplanes are like drawing boards, and they can have multiple sketches.
- The **+** symbol in front of a workplane icon means that there sketches created on that workplane.
- To view these sketches you must double-click on the + sign next to the workplane.

**Sketches are designated with a pencil icon -** .

- Sketches are like sheets of paper, you can have multiple sketches on a workplane.
- To create or modify an object, it must be placed on the **active sketch** in the design.
- To determine the **active sketch**, look for the **BOLD sketch** in the workplanes browser. **Construction sketch** is the active sketch in the example above.
- To **ACTIVATE a sketch**, *double-click* on the pencil icon located in front of the sketch you wish to activate.
- After ***double-clicking*** the icon you should see the sketch name highlight or become bold.

15. The image below should appear on the screen, if not see your teacher! *(Note: you may need to use the center scroll button on your mouse to zoom in or out. )*



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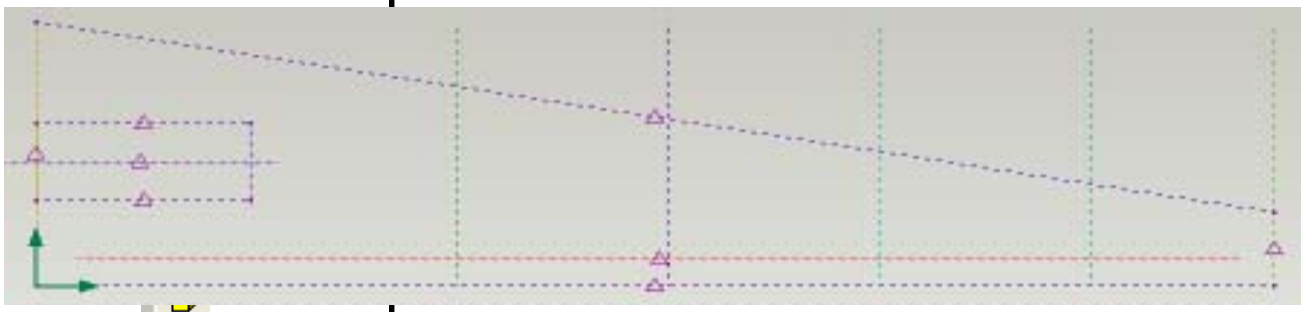
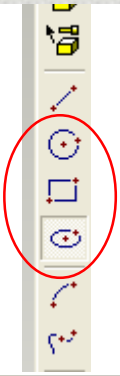
## 1 - 3: Creating the Axle Supports

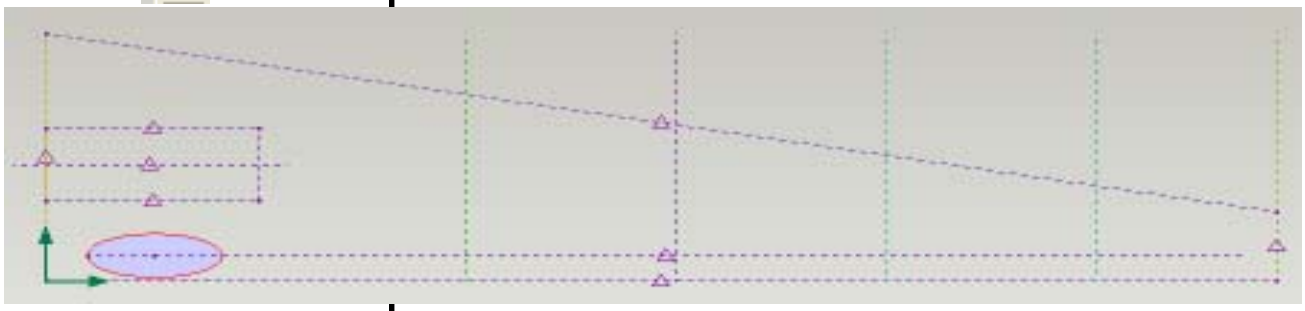
1. *Double click* on the **sketch icon** in front of **Rear Axle Support workplane** to activate that sketch. When you have correctly activated the sketch, the workplane text will appear **BOLD**.

2. Notice the RED construction line located in the image below, use it as a guide for locating the center of your axle holes. *(Line may NOT be red on the drawing screen.)*





3. Use the **Circle**, **Rectangle** and/or **Ellipse** tools located in drawing toolbar on the right side of the screen, to create the profile for your rear axle support *(see example below).*



4. Make sure that you draw your profile *within the boundaries of the car blank.*

   - Leave some room between left edge of the axle support to the back of the car, and do not go outside the boundary on the bottom of the car blank. *See example above.*

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5. To better view the drawing you may want to **rotate, pan** or **zoom**.

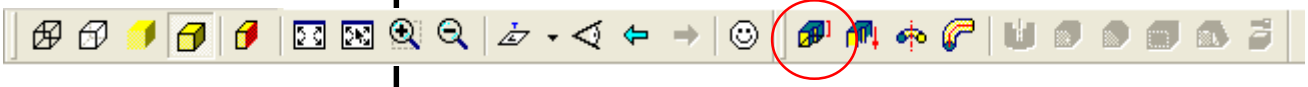
   - **Rotate** - hold the center mouse button down and move the mouse.
   - **Pan** - hold the shift key and the center mouse button down and move the mouse.
   - **Zoom** - scroll the center mouse wheel to zoom up or down.

6. Zoom in on your rear axle sketch using the center mouse wheel.

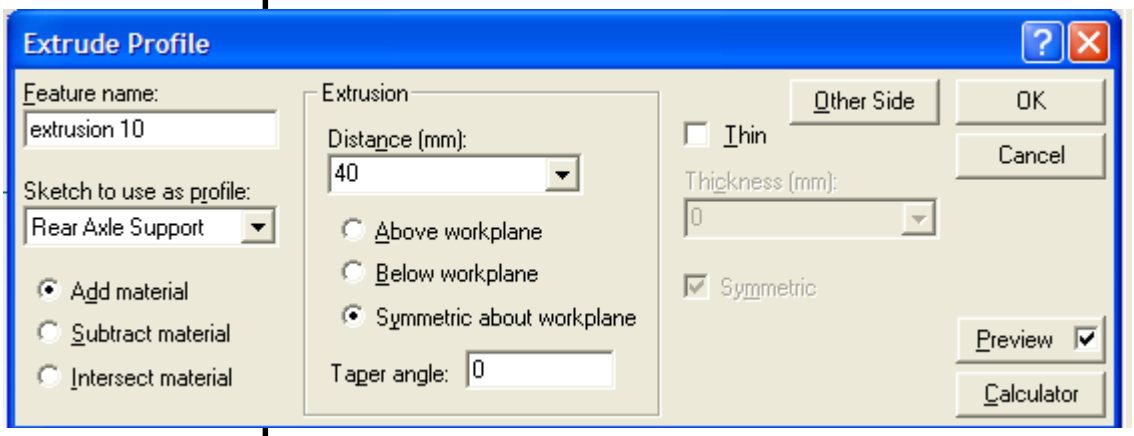
***Troubles drawing a 3.2mm diameter circle?***

*Try ZOOMING in closer, The grid size increases and decreases in proportion to the level of zoom*

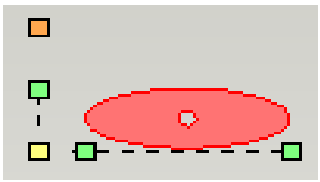
7. Select the Circle tool from the drawing toolbar, and draw a 3.2mm circle in the center of the rear axle support for an axle hole. *(See sample to the left)*



8. Select the **EXTRUDE PROFILE button** from the **features menu** located at the bottom of the screen.

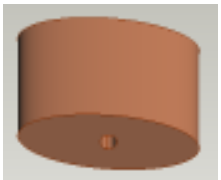



9. Click on the buttons to **Add material, Symmetric about workplane**, and type in a distance NO GREATER than **40mm**, then click **OK**.



10. You should now see the image to the left!

- To better view the extrusion you may want to use your rotate, pan or zoom commands. *See example to the right!*



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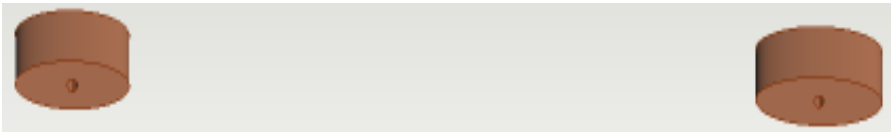
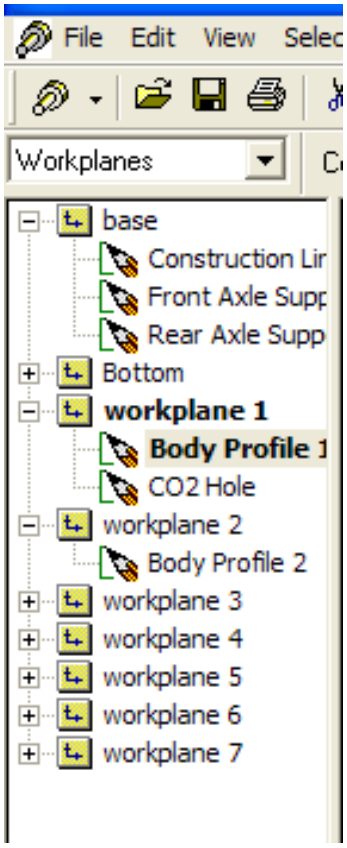
11. Now create your front axle support using the s**ame steps above**.

    - **ACTIVATE** the **Front Axle Support Sketch** and **View onto the Workplane**!
    - Select the **Circle**, **Rectangl**e and/or **Ellipse** tools and draw the support with axle hole.
    - **Extrude** to desired distance, no greater than 40mm.



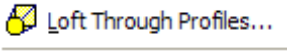
12. When completed, **SAVE your design**! Make sure you are saving it in the directory you created earlier in this activity.




## 1 - 4: Creating the Body Design Profiles

1. There are SEVEN workplanes already created to help you design your **body profile**. Each workplane has a sketch already created, named Body Profile 1-7.

***You'll see those listed on the left side of the screen under the browser window. Let's get Started!***

- You will be using the **circle** **tool**, located in the drawing tools menu to draw a circular profile on each of the seven sketches.
- You will then use the **Loft Through Profiles** command to create a continuous feature that creates material using multiple profiles.
- The **Loft Through Profiles** 

**command** is located under the **FEATURE** menu located at the top of the screen.

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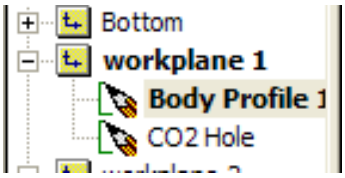
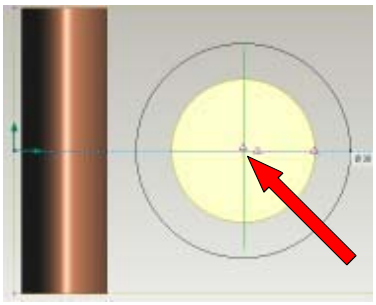



***Notice - the left side of the image below is actually the bottom view of the Axle Support!***



2. In the **Workplanes Browser**, *click* on the **+** sign in front of **Workplane 1.** ACTIVATE the **Body Profile 1 sketch** *by double-clicking* on the sketch icon.

3. ***"Click"*** on the **View onto Workplane button** located in the **VIEW** menu at the bottom of the screen.

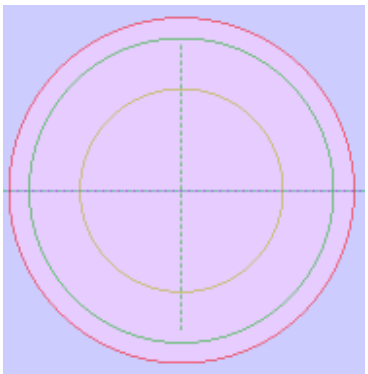
4. ***"Click"*** on the **Autoscale button** locate in the **VIEW** menu at the bottom of the screen to scale and center the design to fit the drawing window.

5. Select the circle tool from the drawing tools menu.

   - Move the cursor to the center of the existing circle, ***"click and drag"*** the cursor straight right until you see the number at the cursor reads **30mm**. *See example to the left.*

- If you make a mistake, select the **Delete Line Segment tool,** located at the bottom of the Drawing Tools toolbar.
- The cursor will look like a pair of scissors, just "click" on the object(s) you wish to delete.

6. In the **Workplanes Browser**, activate the **Body Profile 2 sketch** *by double-clicking* on the sketch icon remember you have to *click* on the **+** sign in front of **Workplane 2**, the see the sketch.



   - Again, select the circle tool from the drawing tools menu.

   - Move the cursor to the center of the existing circles ***"click and drag"*** the cursor straight right until you see the numbers at the cursor reads **34 mm**. *See example to the left.*

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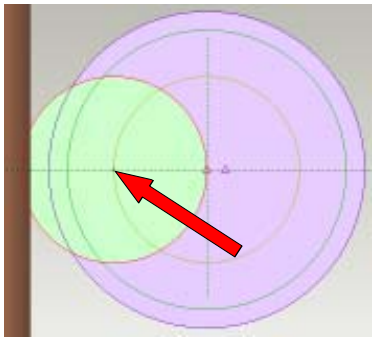
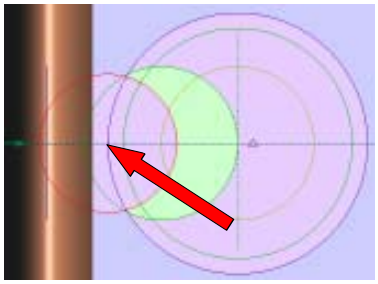


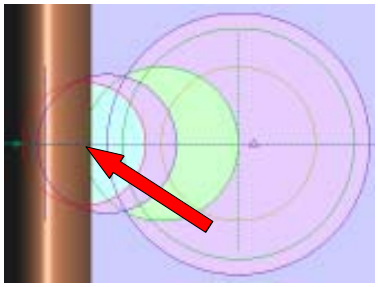
7. Using the same steps as above ACTIVATE the **Body Profile 3 sketch**, under **Workplane 3** and ***select*** the circle tool.

   - Move the cursor to the intersection of left edge of the smallest diameter circle and the horizontal center line, draw a **20mm** diameter circle.



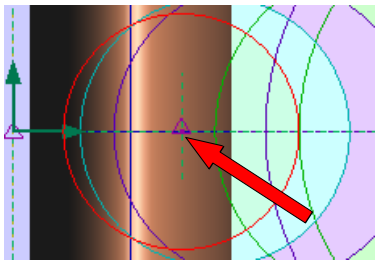
8. ACTIVATE **Body Profile 4**, ***select*** the circle tool.

   - Move the cursor to the intersection of left edge of the largest diameter circle and the horizontal center line, draw a **18mm** diameter circle.



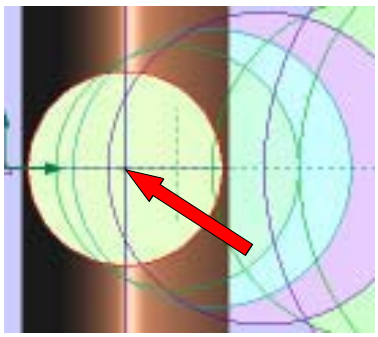
9. ACTIVATE **Body Profile 5**, ***select*** the circle tool.

   - Move the cursor to the intersection of left edge of the 20mm diameter circle and the horizontal center line, draw a **16mm** diameter circle.



10. ACTIVATE **Body Profile 6**, ***select*** the circle tool.

    - Move the cursor to the left along the horizontal center line to the intersection of the two construction lines, draw a **14mm** diameter circle as shown.



11. ACTIVATE **Body Profile 7**, ***select*** the circle tool.

    - Move the cursor to the left along the horizontal center line until you reach the **center of the axle support**, draw a **11mm** diameter circle as shown.

## SAVE YOUR WORK!!!!!

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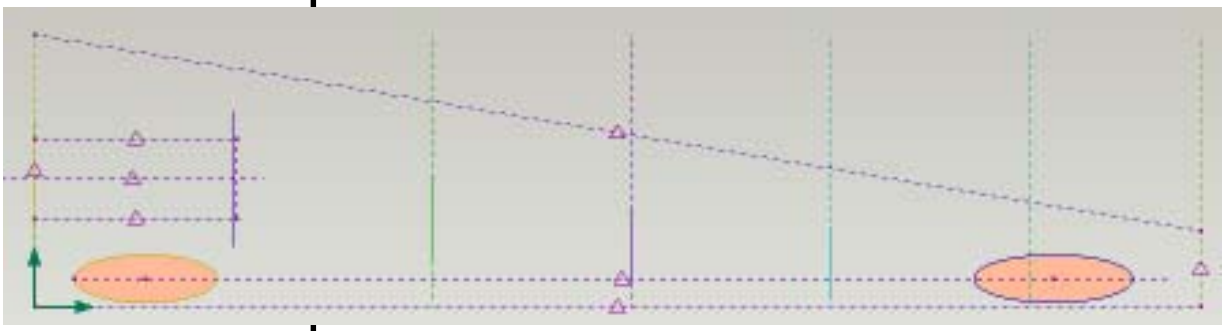
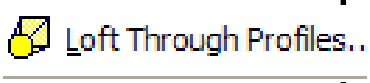
## 1 - 5: Lofting the Design Profiles

1. In the **Workplanes Browser**, *click* on the **+** sign in front of **Base.** ACTIVATE the **Construction lines sketch** *by double-clicking* on the sketch icon.

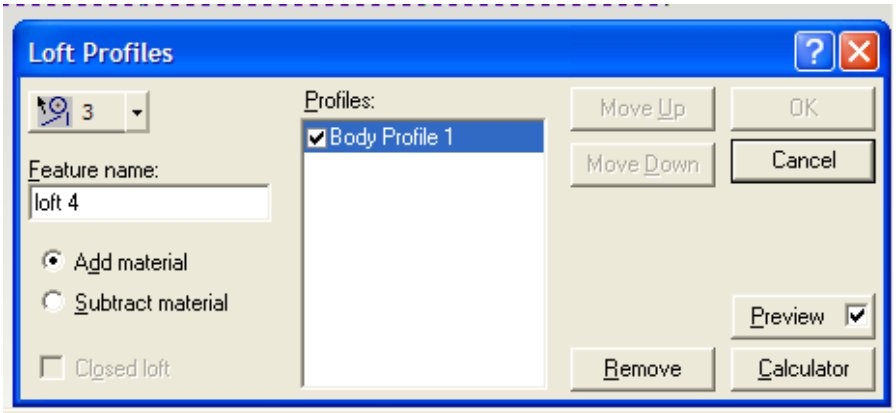
   - Click on the **View onto Workplane** button .
   - Use the **Autoscale button** if needed.



2. ACTIVATE **Body Profile 1** located in workplane 1.




3. Select the Feature menu at the top of the screen, ***click*** on the **Loft Through Profiles command.** The window below will appear.




4. Then from the workplanes browser menu, located on the left side of the screen ...

   - *click* on **Body Profile 2**
   - then **Body Profile 3**
   - then **Body Profile 4**
   - then **Body Profile 5**
   - then **Body Profile 6**
   - finally **Body Profile 7**

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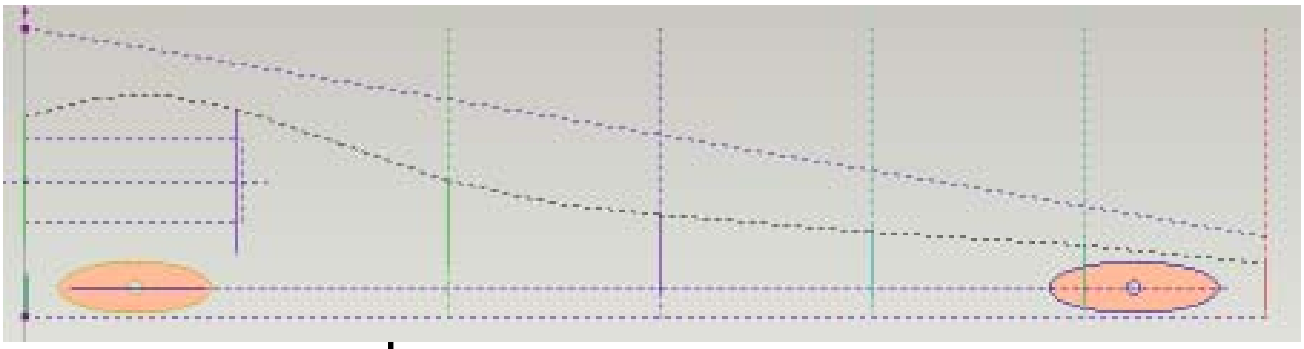
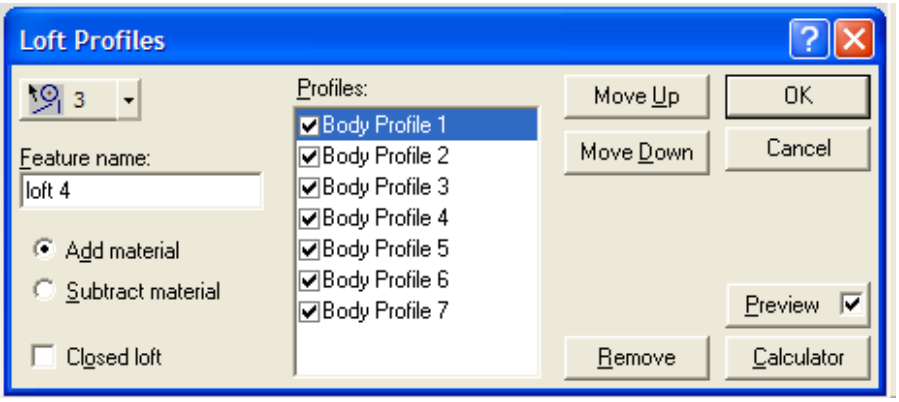
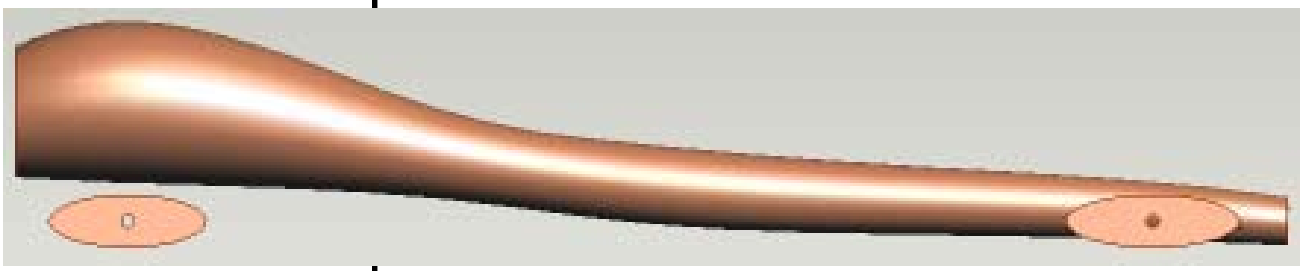


5. Make sure your profiles appear as in the window below.




6. Select the **Add Material Button**, and *click* **OK**.

7. Your body should some what resemble the design below.



# SAVE YOUR WORK!

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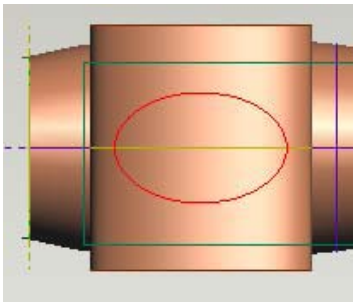
## 1 - 6: Attaching the Rear Axle Support to the Body



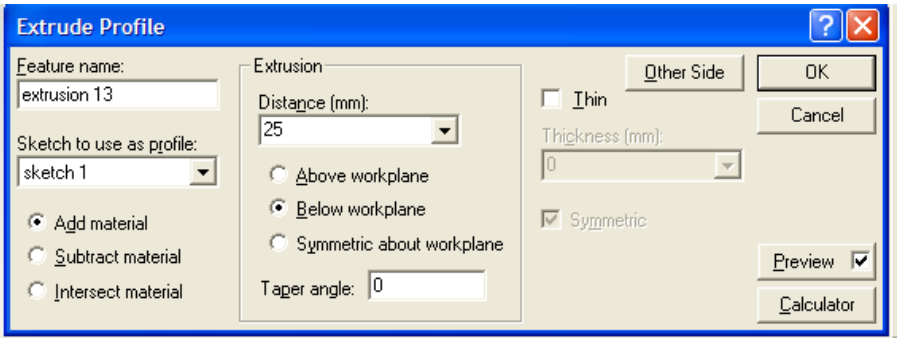
1. In the Workplane Browser, ACTIVATE **Sketch 1** in the **Bottom Workplane**.

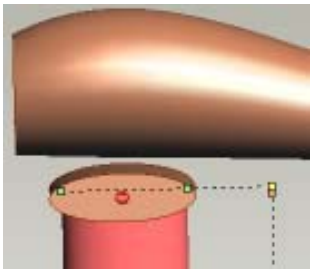
2. *Click* on the **View onto Workplane button** and Autoscale or use the zoom and rotate buttons on the mouse if needed.

3. Select the **Ellipse** tool from the Drawing Tools toolbar, and draw an ellipse over the rear axle support as shown.

4. Select the **EXTRUDE PROFILE** button from the **features menu** located at the bottom of the screen.

5. Select **Add Materia**l, **Below the Workplane**, enter a distance of 25mm and ***click*** **OK**.



6. Using the center scroll button on your mouse, **rotate** and **zoom** in on the rear axle support.

- If you see the image to the left ... you have made a mistake!

- Select the **Undo** command at the top of the screen.

- Again, select the **EXTRUDE PROFILE** button, this time make sure that you checked the **Below the Workplane** button!

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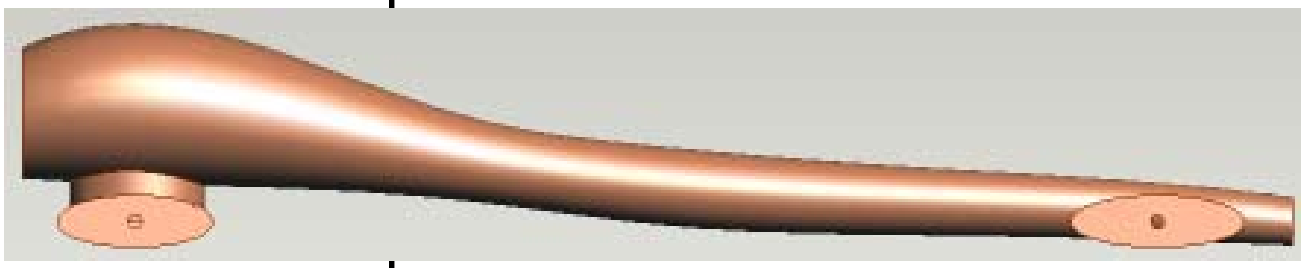
7. Your design should resemble the design below ...
   *(Remember to use your mouse buttons to zoom and rotate.)*



# SAVE YOU WORK!

## 1 - 7: Adding Rounds and Fillets to your Design

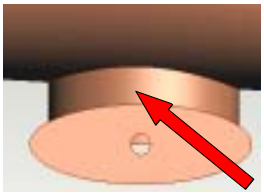


*figure 1*

1. Roll the **center scroll button** on your mouse to zoom in on the rear axle support area as shown in *figure 1.*

2. *Click* on the **select face icon** from the **select tools toolbar** located on the right side of the screen.

   - Select the **face** of the extrusion connecting the rear axle support to the body. *Notice arrow in figure 1.*
   - The face color changes when selected. *See figure 2.*

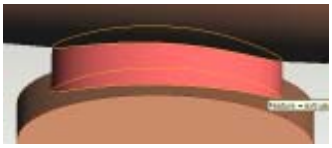
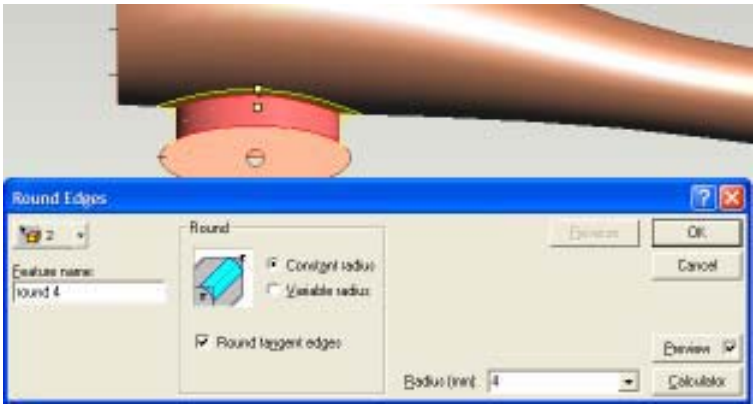


*figure 2*

3. From the Features toolbar located at the bottom of your screen select the **Round Edges tool** .




4. Enter a radius of **4mm** and *click* **OK.**

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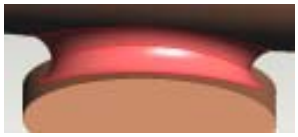
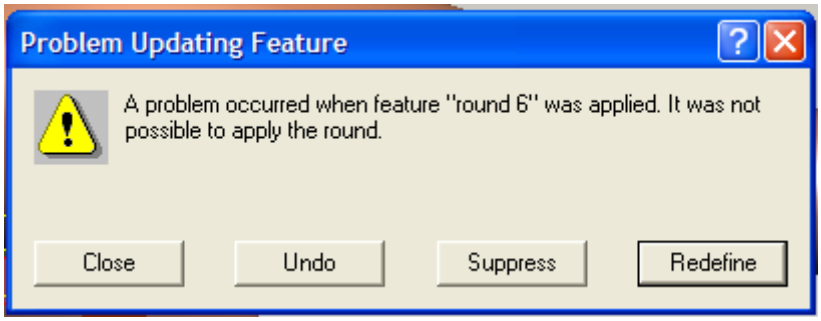


*figure 3*

5. The rear of your car design should look like *figure 3.*

6. If the window below above appears, the radius you have chose ***is to large***. You need to *click* on **redefine**, enter a radius of **3mm** and click **OK**.




7. Using the center scroll button on your mouse, rotate and zoom in on the front axle support area as shown in *figure 4.*

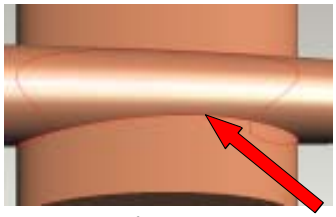


*figure 4*

8. Use **select edge command** from the **select tools toolbar**, to select the line shown in *figure 4 above.*

9. Use the **Round Edges tool** , and create a **4mm** radius. *See figure 5.*

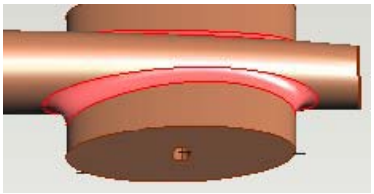


*figure 5*

10. Do the same for the other side of the front axle support if needed!

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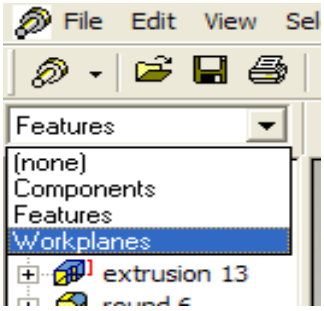
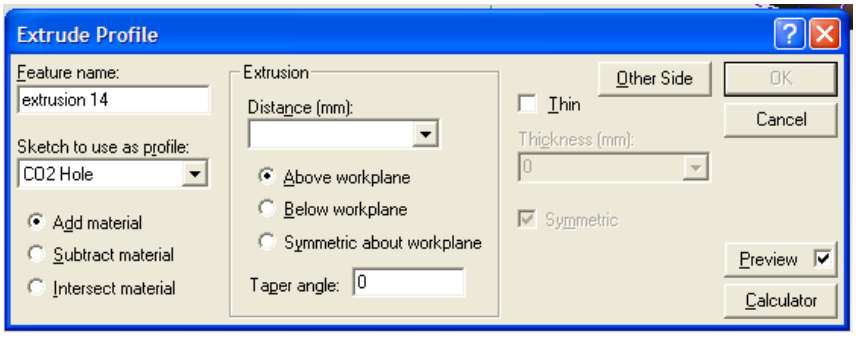



## 1 - 8: Creating the CO2 Cartridge Cavity

1. Go the browser drop-down menu and select **workplanes**.

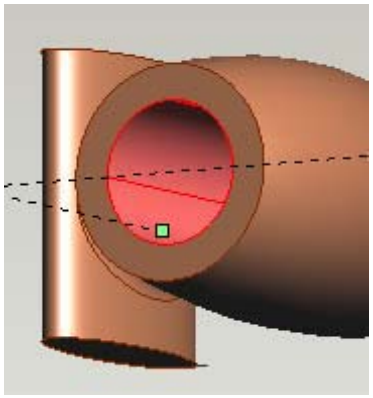
2. Go to **Workplane 1** and activate the **CO2 hole sketch**.

3. Select the **extrude profile feature** located in the features toolbar located at the bottom of the screen.




4. Select **subtract material**, **above the workplane**, a distance of **51mm** and click **OK**.

   - If you receive an error message, select **redefine** and check your settings.

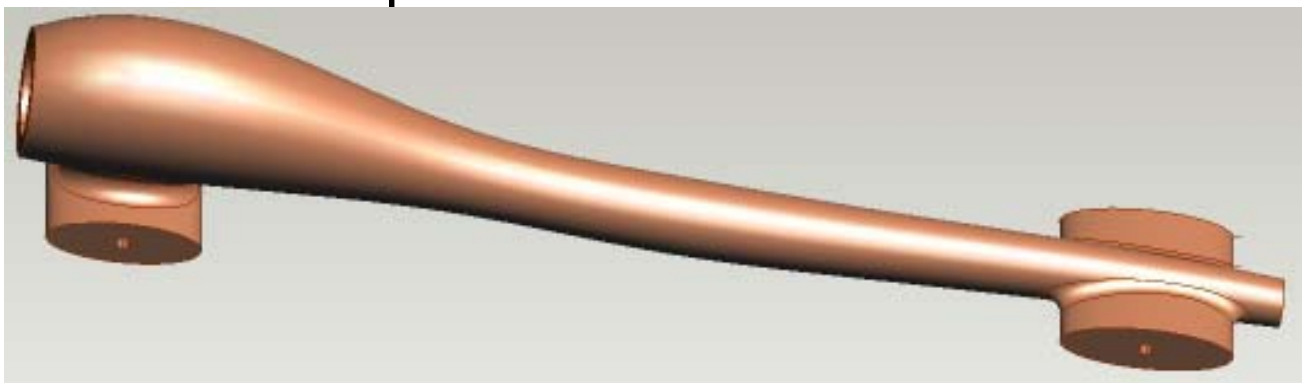


5. Make sure your extrusion removes material like the example shown to the left.

6. Make any final changes to your car and save your work.

7. When finished show your c**ompleted design** to your teacher.

**SAVE YOUR WORK!**



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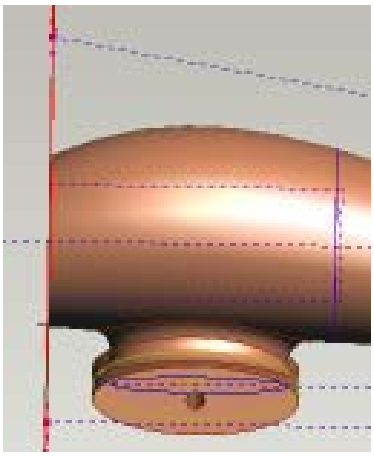
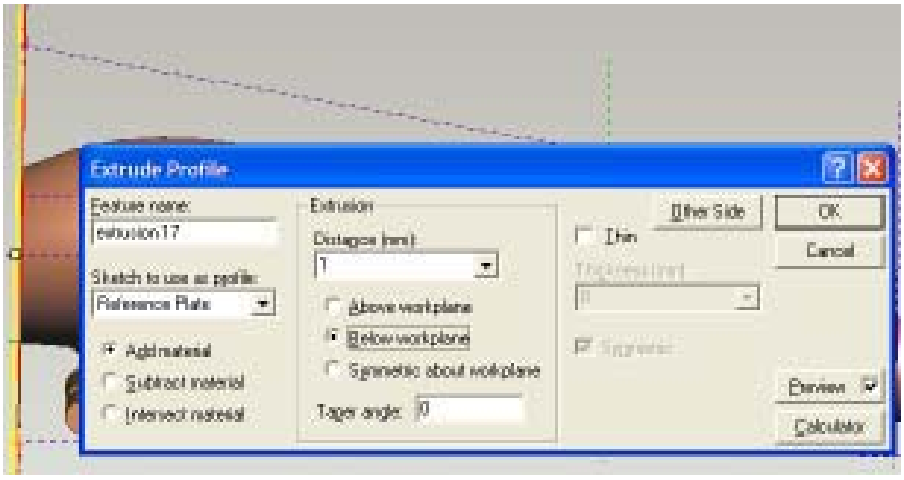
*The purpose of the **reference plate** is to locate the **center** of the CO2 cartridge hole and match it up with the machining fixture.*

## 1 - 9: Adding a Reference Plate

1. A **Reference Plate** must be added to the CO2 cartridge end of your 3D car design.
   - The reference plate is used to **help locate** the body design in the correct position (datum).
   - This makes it easier to work with the design in the manufacturing part of this activity.
   - If the same reference plane is used on all car designs, machine offsets will only need to be configured once.
2. From the workplanes browser, select **Workplane 1**, and ACTIVATE the **Reference Plate** sketch.
3. Using the appropriate mouse buttons, **scroll** and **zoom** until this image on the screen looks like the *image to the left*.



4. Select the **extrude profile feature** located in the features toolbar located at the bottom of the screen.



5. Select **add material**, **below the workplane**, a distance of **1mm** and click **OK**.
6. You have now added a **reference plate** to your car design, see image to the left.

**SAVE YOUR WORK!**

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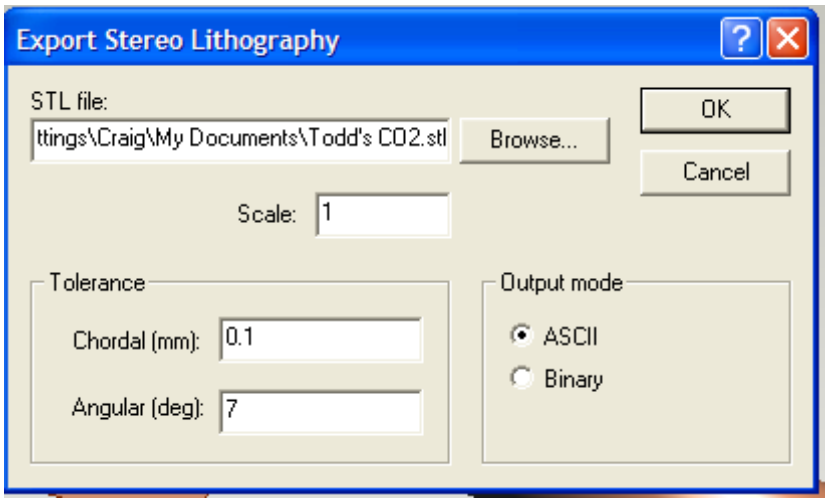
## 1 - 10: Saving Design as an STL File

1. Select **FILE** from the drop down menu at the top of the screen.

   - Select **EXPORT**

   - Click on **STEREO LITHOGRAPHY FILE**

2. Check to see that the file is being saved to your CO2 files folder.




   - Set the scale to **1**
   - Set the chordal tolerance to **0.1**
   - Set the output mode to **ASCII**
   - Click **OK**

3. You have just created a **STL file** of your CO2 Car Design which may be used later in the manufacturing of the car.

4. Congratulations ... you have successfully designed a complete CO2 Car.

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## 1 - 11: Creating a CO2 Car of your own Design

1. At this point you must see your teacher to determine if you will be required to ...

   - completely design a NEW car.
   - redesign the car you just completed.
   - move on CNC program creation.

2. If your teacher told you to proceed to CNC program creation, go to the next page.

3. If your teacher told you that you need to redign your existing CO2 Car, OPEN your Pro/D file and make the changes that the two of you discussed.

   - Upon completion, get your teachers approval of the design, create an STL file and proceed to the next page.

4. If your teacher told you that you need to create a NEW CO2 Car to a set of limitations, you will need to ...

   - get the specifications and limitations from your teacher.

   - generate some different deign ideas.

   - when ready OPEN Pro/D, open the CO2 Car template and begin creating your masterpiece!

   - upon completion, get your teachers approval of the design, create an STL file and proceed to the next page.

.

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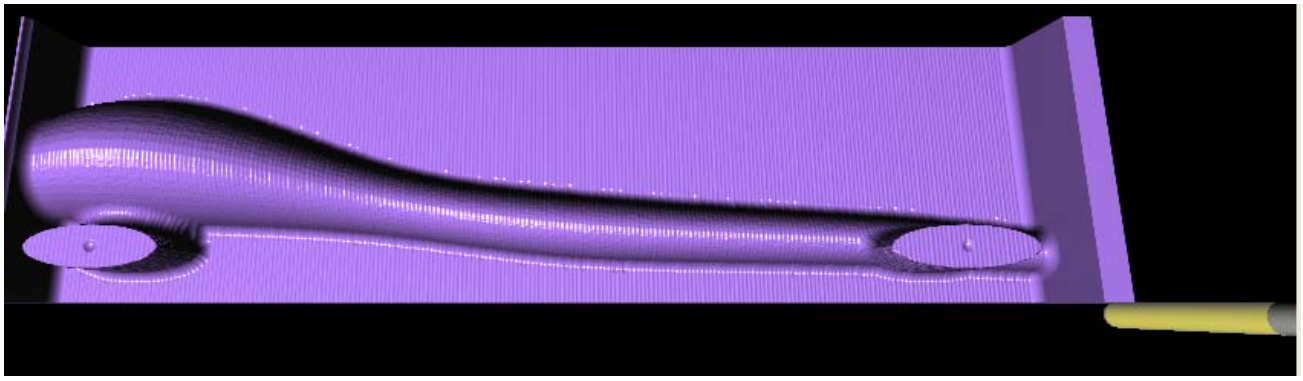
# Converting a Pro/Desktop Stereo Lithography (.stl) File to a CNC Program



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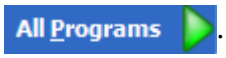
## 2 - 1: Starting the QuickCam Software

*The Denford QuickCam software is a simple to operate, wizard based software used to convert Pro/Desktop STL files into a CNC program that can be run on a CNC Router.*

1. OPEN **QuickCam Pro** or **QuickCam 3D**.

   - *Click* on the **START**

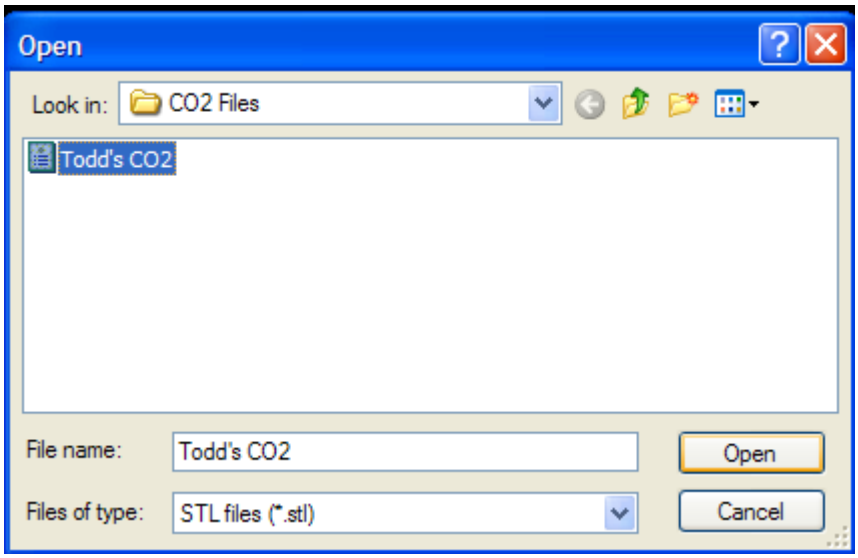
menu.
   - Select **All Programs** 

.
   - Select **Denford**.
   - Finally select **QuickCam Pro** or **QuickCam 3D**.

2. Load the **STL** (stereo lithography) file.

   - *Click* on the **3D Model**

button.
   - **Browse** for the 3D model you designed in Pro/Desktop, it should be saved in your CO2 Files directory!




   - Select your file and *click* **OK.**

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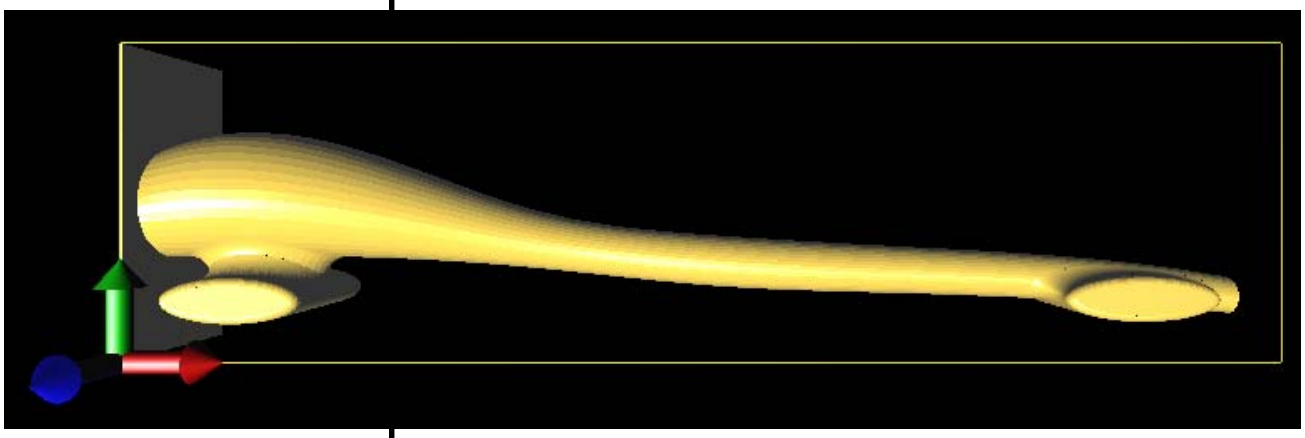
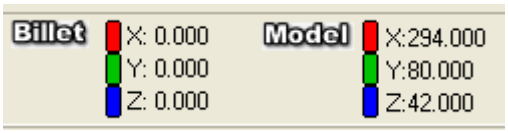
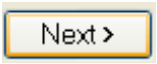
3. The image on the computer screen should look like the example shown below.



4. In the bottom right corner of the screen, there is a box that gives the dimensions of your Model.

5. If the dimensions on the screen **DON'T** match those shown below, there is a problem with your 3D design, and see your teacher NOW!




6. If they are correct *click* **NEXT**  to move to the next screen.


## 2- 2: Manipulating the VIEW

1. Use the **buttons** and **scroll wheel** on the mouse to change the view on the screen.

   - *Click and hold* the left mouse button while moving the mouse to **rotate** the view, try it!
   - Use the *center scroll* wheel to z**oom in and out**, try it!
   - Hold both the *left and right buttons* to **pan** the view. Try moving the object around the screen!

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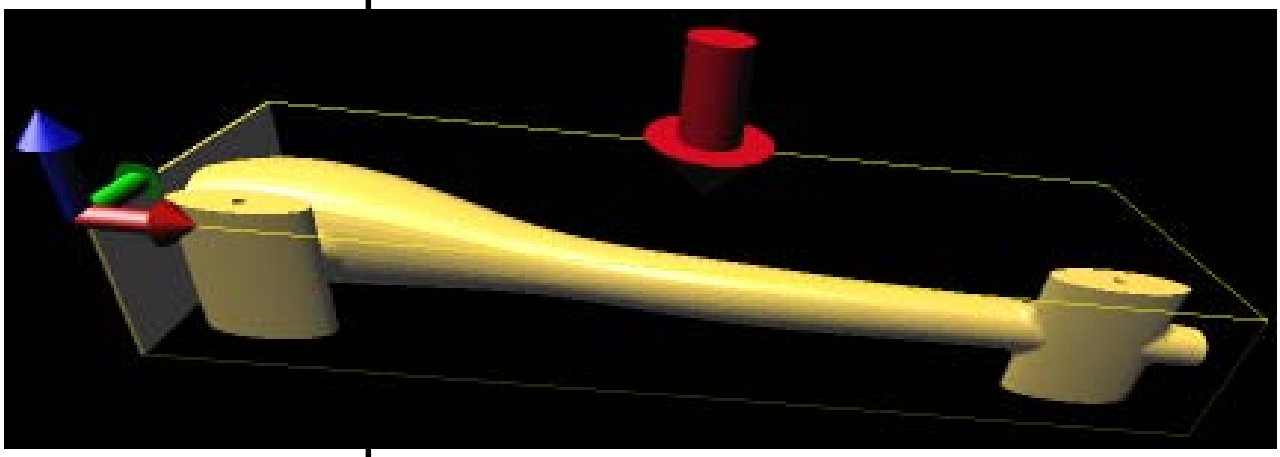
*The "Orientate Model" screen allows you to change the orientation of the 3D design within the CNC machine.*

## 2 - 3: Orientating the Model

1. Because you used the CO2 Car Template to create your CO2 Car Design, your car will import in the correct orientation.
   - X=0, Y=0, Z=0
2. Use the **mouse buttons** to orient the model as shown below.



3. Notice the LARGE RED ARROW, this represents the direction of the cutting tool.
4. *Click* the **NEXT** Next > button to move to the next screen.

## 2 - 4: Setting the Cutting Depth

*The "Set Cut Depth" screen allows you to determine how far into the model to cut.*

1. The default option for this screen is set to cut to the centre of the model.
   - The Z cut depth will read -21.000
2. Because we are using a radius cutter for machining, we are going to **lower this value** by the radius of the cutter to prevent a ridge being left around the car.

3. Set the new value to **-24.000** .
4. *Click* the **NEXT** Next > button to move to the next screen.

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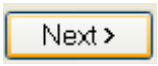
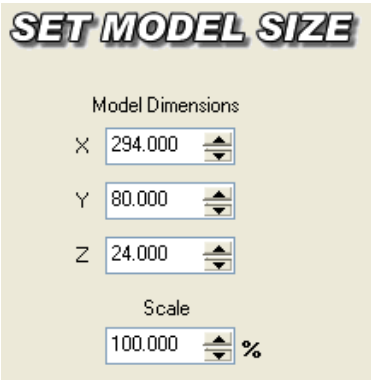
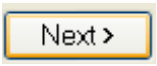
## 2 - 5: Setting the Billet Size

1. This screen allows you to set the size of the material that will be used, make the following changes ...
   - Set X to 305.00
   - Set Y to 80.00
   - Set Z to 42.00
2. After making the changes, *click* the **NEXT** 

button to move to the next screen.



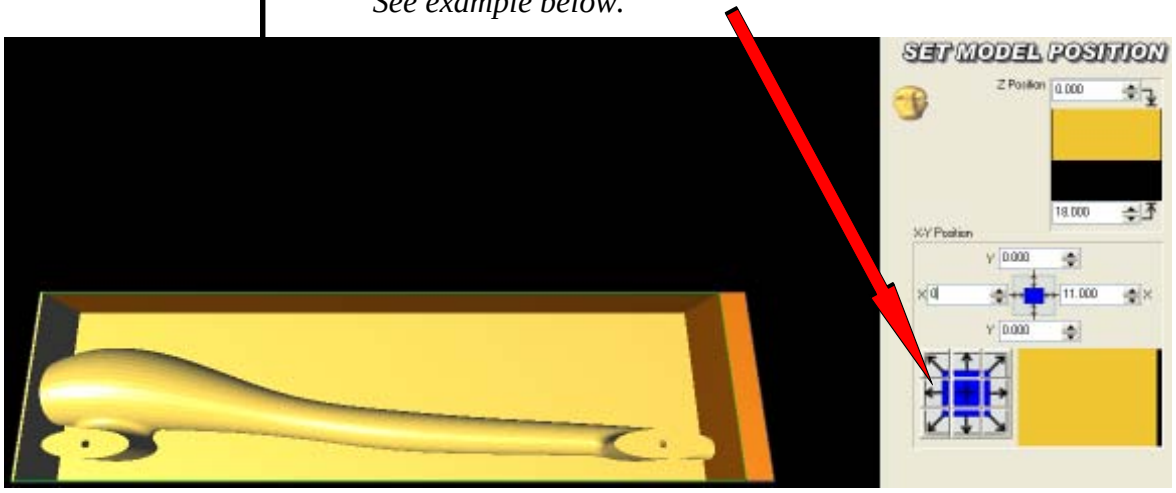

## 2 - 6: Setting the Model Size

1. The scale **MUST** be set to **100%** when making CO2 Cars.
   - If it is NOT set at 100%, **change it now**!
2. *Click* the **NEXT** 

button to move to the next screen.

## 2 - 7: Setting the Model Position

1. This screen allows you to position the 3D model within the billet. material.
2. The **Z** and **Y** positions will **not change.**
3. Move **X** left to 0.000 by *clicking* on the **center left arrow**. *See example below.*



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4. This change will allow for the room needed to hold the billet in the machining fixture.

5. *Click* the **NEXT** Next > button to move to the next screen.

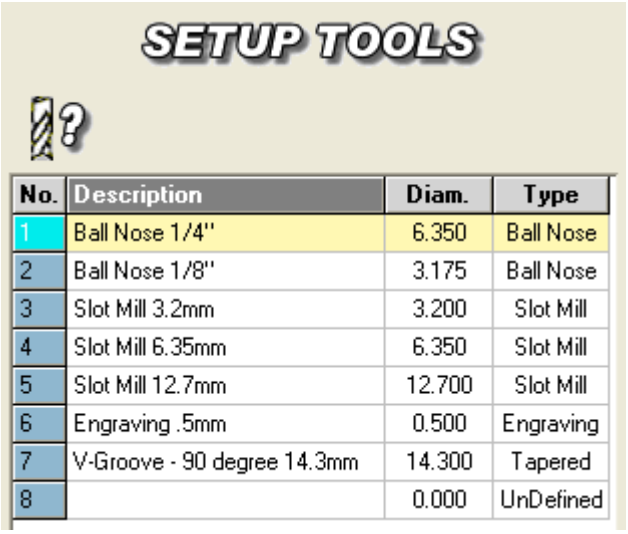
## 2 - 8: Setting the Boundary

1. No changes should be made in this screen, make sure that **model** is selected and that **X** and **Y** are set to **0.000**.

2. *Click* the **NEXT** Next > button to move to the next screen.

## 2 - 9: Setting Up Tools

1. Select the **Ball Nose 1/4"** cutter from the tool library, see below.




| No. | Description | Diam. | Type |
|---|---|---|---|
| 1 | Ball Nose 1/4'' | 6.350 | Ball Nose |
| 2 | Ball Nose 1/8'' | 3.175 | Ball Nose |
| 3 | Slot Mill 3.2mm | 3.200 | Slot Mill |
| 4 | Slot Mill 6.35mm | 6.350 | Slot Mill |
| 5 | Slot Mill 12.7mm | 12.700 | Slot Mill |
| 6 | Engraving .5mm | 0.500 | Engraving |
| 7 | V-Groove - 90 degree 14.3mm | 14.300 | Tapered |
| 8 | | 0.000 | UnDefined |

- If this tool does not appear in the library, see your teacher.

- Do NOT make any changes to the tool library without teacher supervision.

2. *Click* the **NEXT** Next > button to move to the next screen.

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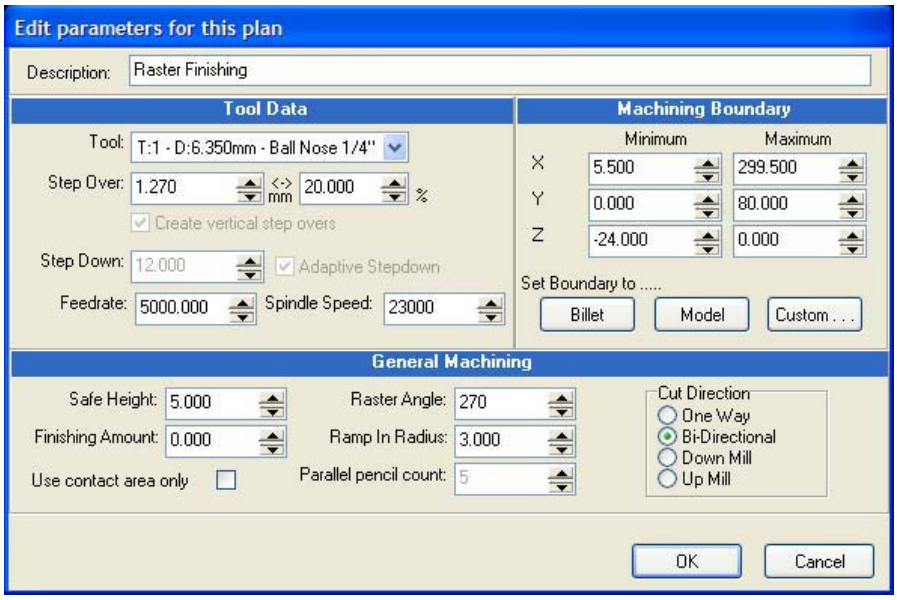
## 2 - 10: Adding Machining Plans

1. *Click* on **ADD** Machining Plan**.**


2. Select **Raster Finishing** .

3. Edit the **plan parameters** as shown below ...

   - Step over - set at **20.00%**
   - Feed Rate - set at **5000.00**
   - Spindle Speed - set at **23000**
   - Raster Angle - set at **270** *(90 for QuickCam 3D users)*




4. When changes have been made, click **OK** and the **tool paths** will be calculated.

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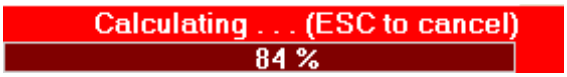
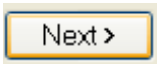
4. After you *clicked* OK, you will have to wait a minute or so while the software **calculates the toolpaths**.

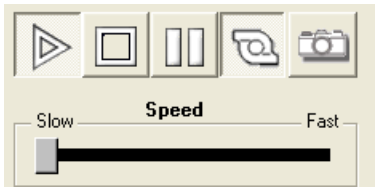



5. When the t**oolpaths have been calculated**, you will see them as lines on the model. *See below!*

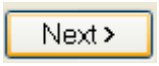
6. The plan will appear in the **Machining Plans** list.

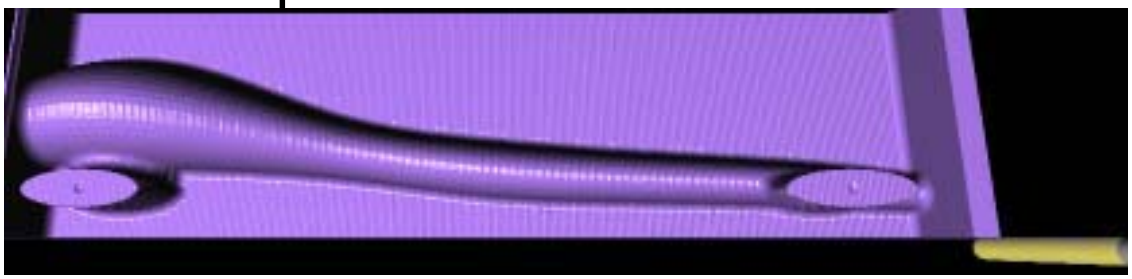
7. *Click* the **NEXT**  button to move to the next screen.


## 2 - 11: Simulating the Toolpath




1. Press the **PLAY** button to start the simulation.
   - To speed up the simulation adjust the slider.
   - The faster the simulation,the poorer the resolution.

2. *Click* the **NEXT**  button to move to the next screen.

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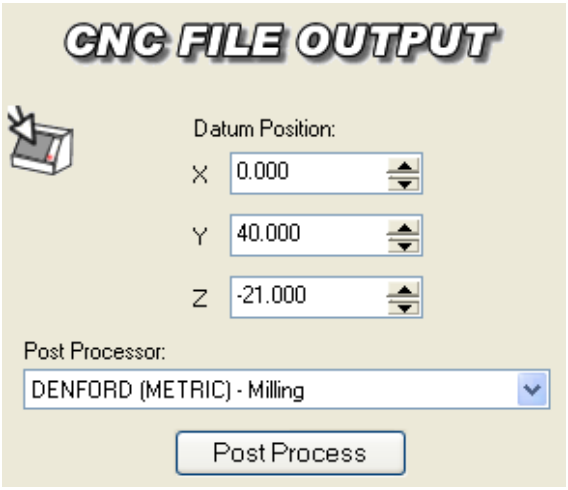
## 2 - 12: CNC File Output

1. Change the **Datum Positions** as follows ...

   - X = 0
   - Y = 40mm
   - Z = -21mm




2. This will move the **DATUM** to the center of the CO2 cartridge hole in the Balsa wood billet.

3. Make sure DENFORD (METRIC) - Milling is selected as the **Post Processor**.

4. Select **POST PROCESS**.

5. When the **Save As** window appears, select **Your CO2 Files folder** and save using the following format ...

**DON'T FORGET THIS ...** → **<Your Last Name> CO2 Right Side** *(example: Todd's CO2 Right Side)*

6. *Click* **SAVE** ... **VR Milling** will automatically open. ***See your teacher!***

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# $CO_2$ Car Manufacturing using VR Milling V5

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*You will be using a software package called **VR Milling V5** to control a **Denford CNC Router** to manufacture the CO2 Car you designed earlier in **Pro/Desktop**.*

***VR Milling** is software package that allows full editing and control of CNC (computer numerical control) files, either off-line or on-line.*

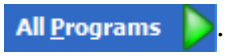
*Before going any further you **MUST** make sure that the Denford CNC Router has the CO2 Car/F1Car fixture mounted in the router. If this is not done, see your teacher for help!*

## 3 - 1: Starting VR Milling V5

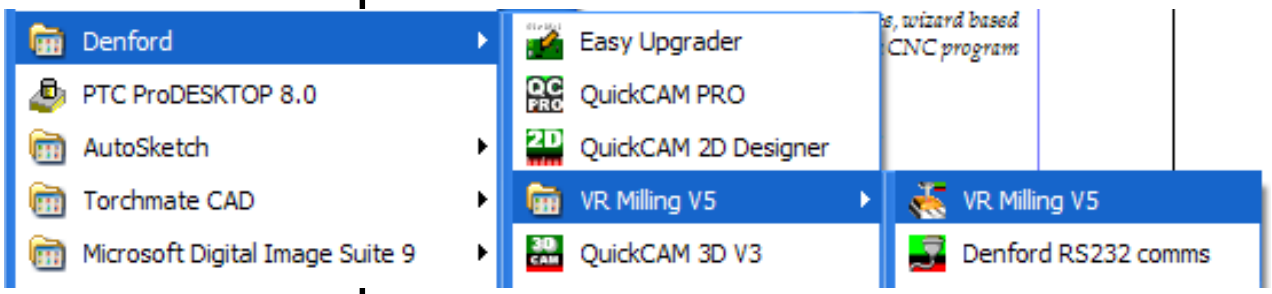
1. OPEN **VR Milling V5**.

*If the machine does **NOT CONNECT** see your teacher!!!!!*

- *Click* on the **START**

menu.
- Select **All Programs** 

.
- Select **Denford**.
- Select **VR Milling V5**, then **VR Milling V5**



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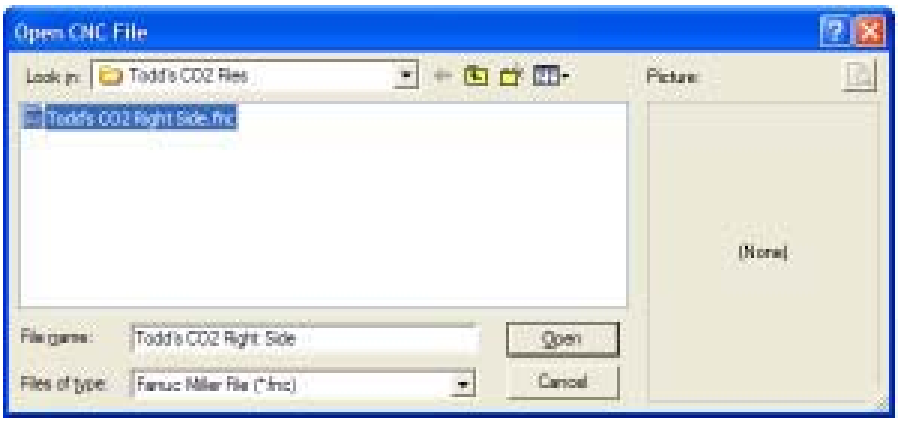
## 3 - 2: Loading the CNC File

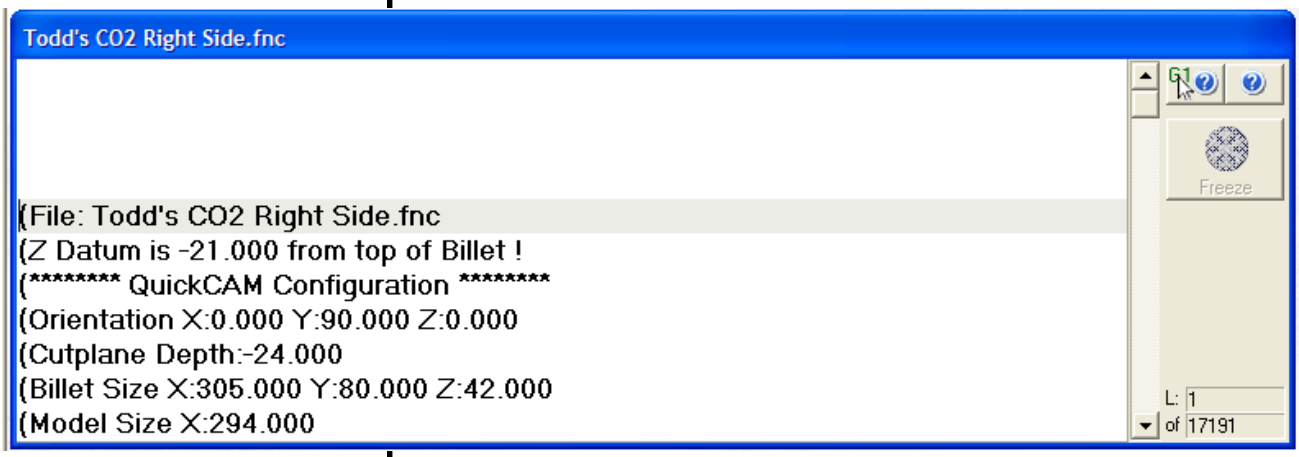
1. Click on the FILE menu at the top left of the screen

   - *Select* **OPEN.**
   - **Browse** for the file your save earlier in QuickCam, it should be saved in **Your CO2 Files** directory!
   - Remember you saved it as <Your Last Name> CO2 Right Side. *(Example: Todd's CO2 Right Side)*
   - The file will have the extension letters **".fnc"**.




   - When you have **found** and **selected** the file, *click* **OPEN.**

2. The contents of the CNC file will now be displayed in the **EDITOR** window. *See below!*



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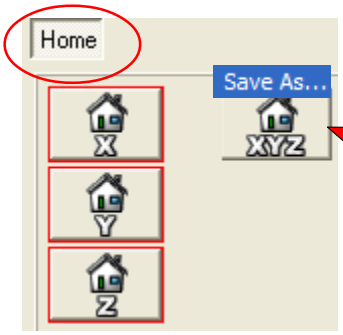
## 3 - 3: Selecting and Homing the Real Machine

1. From the toolbar on the right side of the screen, select **REAL MACHINE** .

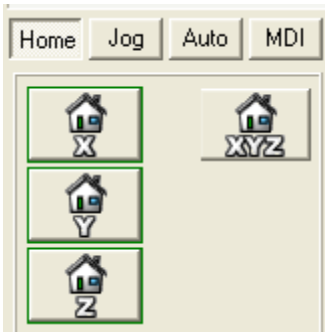
2. Once the connection has been successfully established , the machine **Control Panel** window will appear.




3. Notice, ONLY the **HOME TAB** Home appears.

   - *Click* on the **Home All** button to home all three machine axis.

   - After HOMING, the **Jog**, **Auto** and **MDI** tabs become available. *See below!*




## 3 - 4: Move the Machine Head and Fit the Cutting Tool

1. In the **control panel**, *click* on the **JOG** Jog tab to select Jog mode.

2. Click on the **Jog button** to change between **Continuous** and **Incremental modes.** *Try it!*

   - To change the position of the cutting tool **quickly**, use Jog Continuous mode.

   - To change the position of the cutting tool **incrementally**, use Jog Incremental mode.

3. Notice how the **number changes** below the Feed Control Knob when you switch between the two modes!

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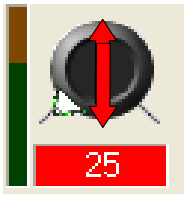
*Jog Feed Control Knob*

***This is next step is very important for you to understand, after reading through the information below, see your teacher for a quick review!***

4. Feed Rate is controlled by the **Jog Feed Control Knob**.

   - The value is shown in the **readout** below the control knob.
   - To change the **Feed Rate**, ***click on*** *and* ***drag*** the Jog Feed Control Knob **up** and **down**.




   - *Watch the feed rate values change as you move the mouse up or down!*

5. The **four cursor (arrow)** keys and the **Page Up** and **Page Down** keys on the keyboard are used to control the **X**, **Y** and **Z** axis.

   - ← moves the tool **LEFT** on the X axis.
   - → moves the tool **RIGHT** on the **X** axis.
   - ↑ moves the tool **BACKWARD** on the **Y** axis.
   - ↓ moves the tool **FORWARD** on the **Y** axis.
   - **Page Up** moves the tool **UP** on the **Z** axis.
   - **Page Down** moves the tool **DOWN** on the **Y** axis.

- Take 5 minutes to practice jogging the tool around the work area in **Continuous** and **Incremental** modes.
- Also practice changing the **jog feed rate**.
- It is important that you feel comfortable with these controls before moving on!

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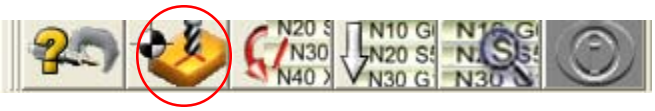
## 3 - 5: Selecting the Work Offsets

*Offsets are the distances the cutting tool needs to travel, from it's* ***HOME*** *position to the point from which the program starts in X, Y and Z.*

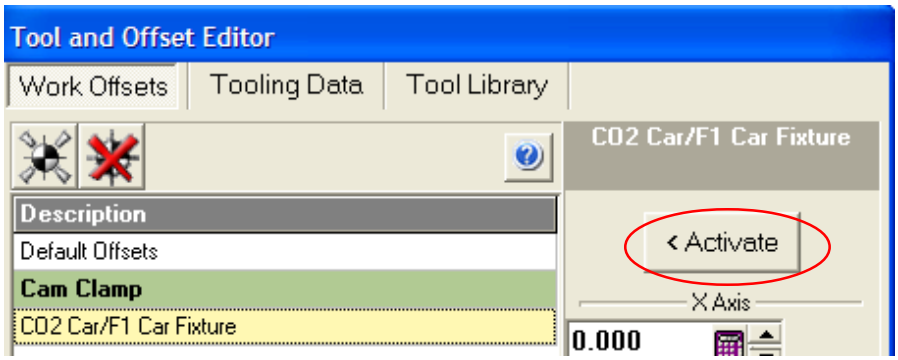
1. The offsets for the CO2 Car/F1 Car have already been set for you by your teacher.

2. You will just have to select the **correct offset** and ACTIVATE it.

   - *Click* on the **Tool and Offset Editor** button located at the bottom left of the screen.

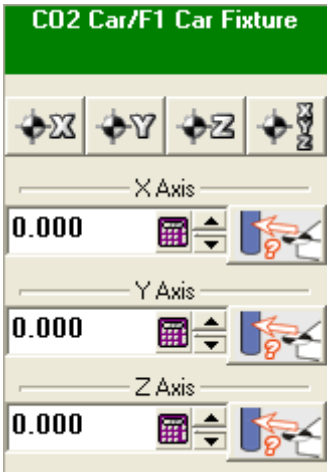


3. When the window below appears, select the **CO2 Car/ F1 Car Fixture**, then *click* ACTIVATE.




4. The window below will now appear, the offsets you see below ***will be different*** that those currently in your tool editor window!

*Your teacher will have the* ***correct offsets*** *for you to see posted above or around the router,* ***if not see your teacher now!***



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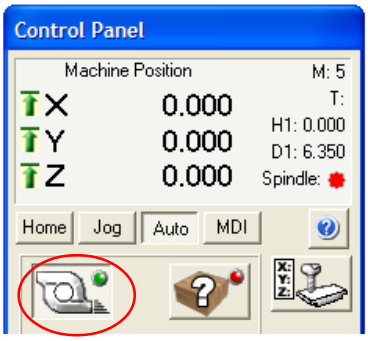
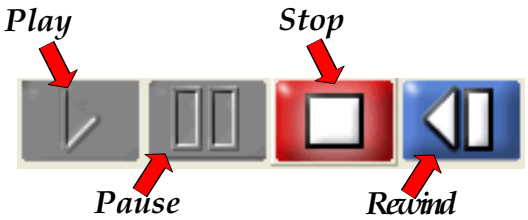
*Tool is to CLOSE to billet, Jog the tool **up** to clear the billet!*




5. CLOSE the **Tool and Offset Editor** by *clicking* on the **Tool and Offset Editor** button located at the bottom of the screen.

## 3 - 6: Run the Program

1. Before **RUNNING** the program HOME ALL the axis, and make sure the cutting tool is clear of the billet.
   - If NOT, use the **cursor**, **page up** and **page down** keys to move the cutter clear of the billet!
2. Select the **HOME TAB** Home in the control panel.
3. *Click* on **HOME ALL** , wait for the homing process to finish.
4. Click on the AUTO TAB Auto.
5. Select TURBO MODE , make sure the little light is green and not red.
   - This will greatly reduce large 3D object machining times.
   - It will usually make the machine perform with a smoother motion.
6. The program is now ready to **RUN**.
   - Do you have a billet installed in the CO2 Car/F1 Car fixture.
   - Is the 1/4" Ball End mill installed?
7. If ALL setups are **OK, go** to the **File Control** toolbar located at the bottom of the screen.



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8. *Click* on the **STOP** button, followed by the **REWIND** button.

   - This will ensure that the program starts from the beginning.

   - ***DO NOT*** *click* **PLAY** until you read through the next section **3-7: Monitoring the Machining Process**!

9. *Click* on the **PLAY** button to start the program.

   - The program will begin to run.

10. A message will appear asking you to change to tool number 1, *you should have already installed the 1/4" Ball End mill.*

## 3-7: Monitoring the Machining Process

1. It's time to set back, LOOK and LISTEN ...

   - Keep your hands by the red **EMERGENCY STOP** button at all times.

   - Make sure that the tool does not run into the CO2 Car/F1 Car Fixture.

   - Listen to the ***sound of the machine***, if the cutter is laboring, you may want to use **feed rate override knob** on the front of the machine

   - If you see extreme vibration you make want to reduce the feed rate.

*TIP:*

- *To gain more control you may want to use the FEED RATE OVERRIDE KNOB on the front of the router to reduce the feed rate when first starting a program.*

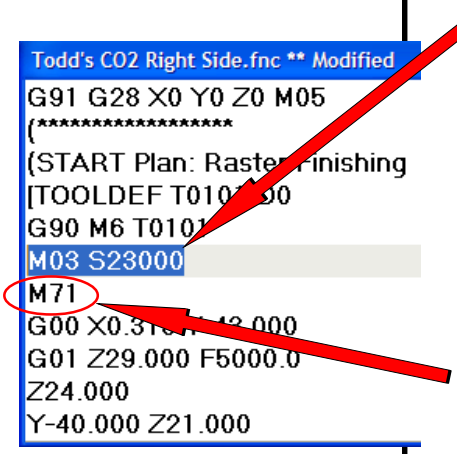
- *After you are happy with the way to tool is cutting you may increase the Feed Rate to 100%.*

2. You are now ready to begin machining!
   - *Click* **PLAY** and **OK**.
   - The **spindle will start**, and the program will begin to run!

# Enjoy the Show!!

## 3 - 8: Creating the CNC File for the Opposite Side

1. When machining is finished, you will need to create the **CNC file** for the **left side** of your car.
2. In order to do this you are going to MANUALLY EDIT the original CNC program, by inserting a line of "code" that activates the MIRROR command.
3. Go to the **EDITOR**, use the *scroll wheel* on the mouse to scroll down the screen until you see the line **MO3 S23000**.
   - Note the **"S"** value depends on the type of CNC machine being used, *so this value may be different in your program!*
4. *Click* the cursor at the end of this line, then press the **ENTER** key on the *computer keyboard* to add a new line.
5. Now type - **M71**, this is the ***"code"*** defining the **mirror in the Y axis command**.
6. *Click* on the **FILE** File menu at the top of the screen.
7. Select **SAVE AS** Save As... . DO NOT select **Save** by mistake.
   - Selecting SAVE by mistake will result in OVER-WRITING the original file!



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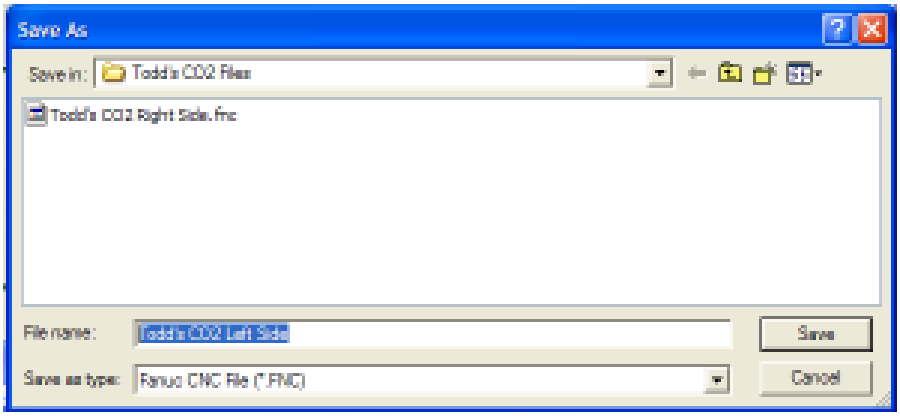
8. When the **SAVE AS** screen appears ...

   - Make sure Your CO2 Files folder is where it is being SAVED!

   - In the file name, change the word LEFT to RIGHT. ***(Example: Todd's CO2 Right Side)***




## 3 - 9: Drilling Axle Holes

1. This is a good time to **drill the two axle holes**.

   - The body still has a flat side to reference from.

   - The small dimple shows where the holes are to be located on the machined side of the billet.

2. See your teacher for **specific instructions** how and where to drill your CO2 axle holes!

*Dimples that can be used to accurately locate the position for axle holes.*

*Flat base that can be used to as a reference base to accurately drill axle holes.*

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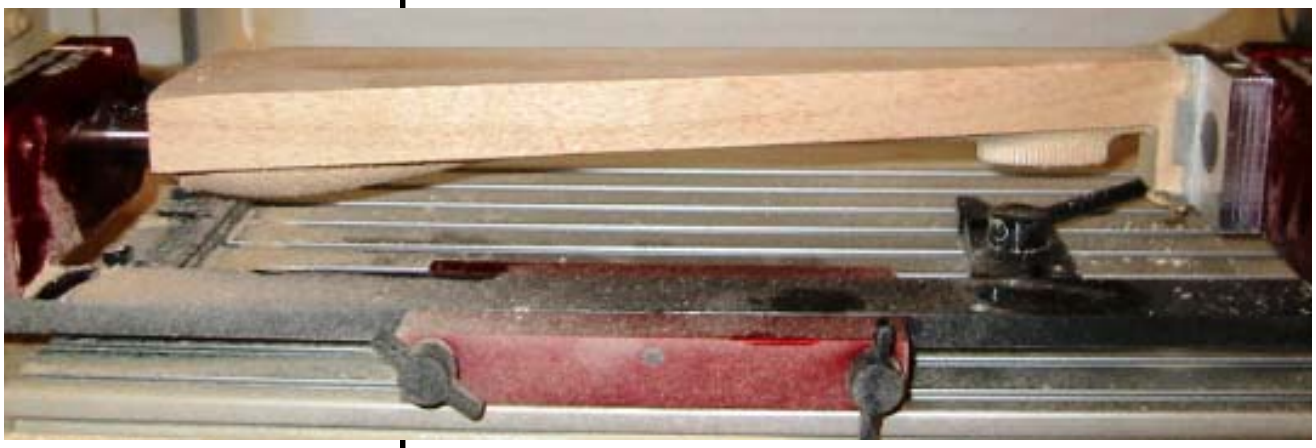
## 3 - 10: Rotating the Billet in the CO2 Car/F1 Car Fixture

1. Physically **rotate** the Balsa wood billet in the fixture by **180 degrees**.



- Billet will usually have to be removed to do this!
- Procedure will vary depending fixture that you are using!
- If you are have trouble ***ASK your teacher for HELP***.

2. Make sure that **ALL** knobs and screws are **tight** before proceeding.

## 3 - 11: Machining the "LEFT" side of the Car Body

1. Make sure that the **VR Milling** software is loaded and that you have the file loaded for the **LEFT** side of your car!
2. The machine should be set to the **ALL HOME** position.
3. Click on the **AUTO TAB** to enter the auto mode.
4. Click on the **STOP** button, followed by the **REWIND** button.

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- This will ensure that the program starts from the beginning.

4. Click on the **PLAY** button to start the program.
   - The program will begin to run.
5. Again a message will appear asking you to change to tool number 1, you should have already installed the 1/4" Ball End mill.
6. Sit back watch and listen to the machine **RUN**, keep your hand by the Emergency Stop button!
7. Your **finished design** should look some what like the one below!

# Congratulations!

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# Teacher Resource Pages

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# Tips and Hints Needed to Teach this Activity Successfully

*To have success in teaching this activity we have put together some tips and hits to help you have success as a teacher.*

*This document by it self it will NOT promise instant success for your students. There are still many places where you will have to teach your students concepts NOT included in this document. (Examples: safety, basics of design, aerodynamic principles, tolerances and limitations, etc.)*

*It is very important to have dialog with your students through out this activity to make sure they have an understanding of the concepts being covered.*

## 4 - 1: General Tips

1. Before you can even begin you must find to file **CO2 Car Template.des** and copy it in the **MY Documents folder** on ALL of the computers that you will have students working on.

2. Your students will be required to create a directory called **<Your Last Name> CO2 files** *(example: Todd's CO2 files)* to save all the files related to their CO2 Car. This directory can be located on the hard drive, network, floppy drive, USB drive, etc.

3. It is important that students save ALL files created in this activity in this folder. This will make your and your students lives much easier when trying to find and edit files. When finished students should have FOUR different files saved in this directory, see below.
   - Pro/Desktop file - **Todd's CO2.des**
   - Stereo Lithography file - **Todd's CO2.stl**
   - CNC files - **Todd's CO2 Right Side.fnc**
     **Todd's CO2 Left Side.fnc**

4. It is VERY IMPORTANT that you work through this activity completely before trying it with students. By doing this you will find the following ...

5. Is the CO2 Car Template located in the My Documents folder?
6. How well do you know how to run and trouble shoot Pro/Desktop?
   - What will be the simplest way for students to install the CO2 billet?
   - Are the tool and material libraries set up correctly.
   - Do you know how to correctly install and setup a cutting tool?
   - Is the CO2 fixture set up correctly?
   - When and how do I want students to drill axle holes?
   - Where are the places your students will have problems?
   - Where will you need to spend extra time teaching concepts to your students?

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## 4 - 2 : Pro/Desktop and CO2 Design Tips

1. It is very important that you spend some time teaching Pro/Desktop basics before starting this activity. Pro/D can be a very simple program to use, BUT if you have never been exposed to it, Pro/D can be very intimidating.

2. It would be a could idea to cover the following before starting this activity: workplanes, sketches, drawing tools, features tools, select tools, editing, etc.

3. It will be a very important to have a complete understanding of the loft feature tool in this activity.

4. This activity will guide every student step-by-step on how to design the exact same CO2 car in Pro/D.

5. We recommend that you have every student follow step-by-step how to complete the first car, upon completing that design give your students a set of design parameters and limitations that they must follow to design a second car of there own design.

6. Discuss design possibilities, such as changing profile shapes, affects of aerodynamics, and machine limitations.

7. After students have successfully created or modified a SECOND car that passes your inspection, you may let them move on to CNC file creation part of this activity.

8. You can create your own set of CO2 car limitations or obtain them from your state or National Technology Student Organizations (TSA).

9. It is important that you DONOT allow students to design something that is impossibe to manufacture.

10. You will be using a 1/4" ball end mill (6.35mm), make sure it can reach all areas inj the design.

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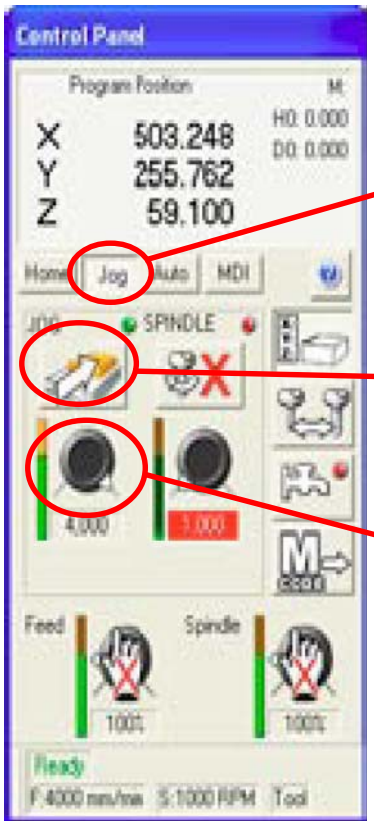


## 4 - 3: Moving the Machine Head and Fitting the Cutting Tool

1. The position of the machine head (the cutting tool) can be manually controlled using Jog mode. In the "Control Panel" window, click the **"Jog" tab** to select Jog mode.

2. To change the position of the machine head quickly, click the [Jog] button until a straight arrow is displayed, signifying 'Jog Continuous' mode.

3. Click and drag the Jog Feed control knob to the top of the scale. The feedrate value is shown in the readout below the control knob.

4. The four cursor (arrow) keys, and the [Page Up] and [Page Down] keys on the keyboard, are used to control the X, Y and Z axes. Press and hold the appropriate key to move the required axis.

5. To change the position of the machine head incrementally, click the Jog button until the image changes from a single arrow to three small, stepped arrows, signifying Jog Step Mode.

6. Click and drag the Jog Feed control knob to adjust the increment. When you press the cursor keys the cutter will move by the amount set.

7. Jog the machine head to an appropriate position, then, fit the cutting tool. The procedure for this will vary depending on the machine type. See the machine manual for more detailed information on this procedure.

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## 4 - 4: Installing the CO2 Car/F1 Car Fixture

*The easiest method of holding the balsa wood billet in your CNC router is by using a fixture. Once set into position, the fixture allows billets to be accurately placed, offering the potential for small scale production of CO2 cars.*

1. The alignment fork on the left of the fixture fits into the CO2 cartridge hole in the balsa wood billet. The tapered end of the billet is tightened against the bracket on the right side of the fixture.

2. It is essential that the jig is installed square (ie, at 90°) to the machine axes. When fitting and adjusting the position of the jig, use an engineers square with any available reference edges. Since the balsa wood billet is revolved 180° inside the fixture, any inaccuracies will be multiplied by two.

3. It may be possible to position the jig so the cutter can never hit the right side bracket (ie, the bracket lies outside the effective movement area of the cutting tool).

4. Fit the balsa wood billet in the jig as shown.

## 4 - 5: Creating a Work Offset for the CO2 Car/F1 Car Fixture

*Offsets are the distances the cutter travels, from its 'Home' position to the point from which the program starts in X Y & Z. Now you are going to create an offset for the center line of the CO2/F1 Fixture. You will create a new offset, name it, and then set the X,Y and Z values.*

***It** is possible to store a number of offsets and swap between them for different jobs.*

1. Click on the **Tool and Offset Editing button**

2. Select the **Work Offsets Tab**.

3. Click the **"New Work Offset" button**.

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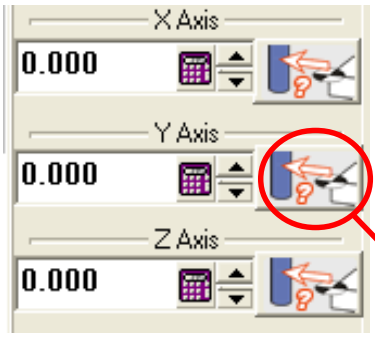
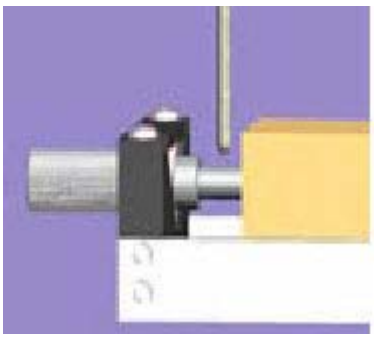




4. Click on the 'blank' offset that has been added to the list and type in **CO2 Car/F1 Car Fixture** for the description of the new offset.

5. Click the 'Activate' button

to activate your new offset. The NEW offset is now active. NOTE, it highlighted in green.

6. Select the **jog continuous mode button** , move the tool a few millimeters away from the alignment shaft.

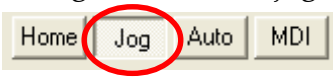
7. Touch onto the alignment shaft at its smallest diameter. The fixture shown to the left is 12mm, other models may have a different diameter.

8. Select the **jog step mode button** for fine incremental movements and jog the cutter until it just touches the alignment fork. Place a thin strip of paper between the cutter and the alignment fork to help detect precisely when the cutter touches the fork.

9. With the cutter in the above position click on the **Set datum offset from Current Position (Y axis) button**.

10. Click the **Y Minus button** to indicate the correct side of the alignment fork the cutter is positioned.

11. Type in **9.175**, the sum of the radius of the alignment fork and the radius of the cutter (6 + 3.175 = 9.175). Click **OK** when done.

12. Click the **Jog tab** to go back to the jog mode.



13. Using the **jog keys**, move the tool towards you and away from the alignment fork. Use the 'Page Up' key to lift the tool above the fork, ensure that the tool is above the fork before proceeding to the next step.

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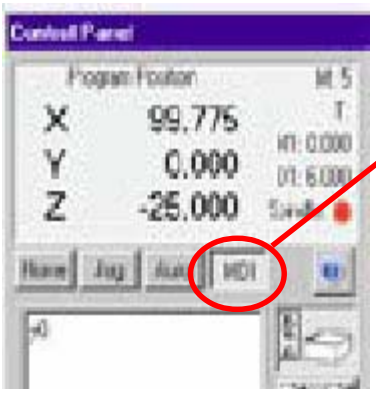
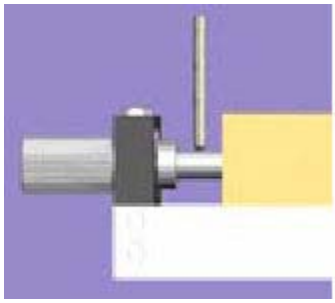
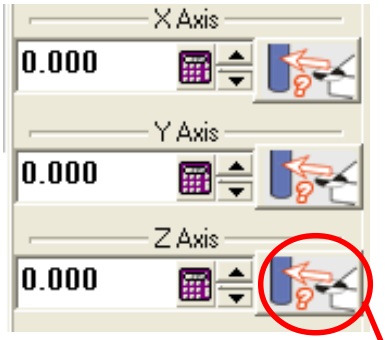



14. Click on the MDI tab in the control panel and type Y0 *(zero not the letter O)*

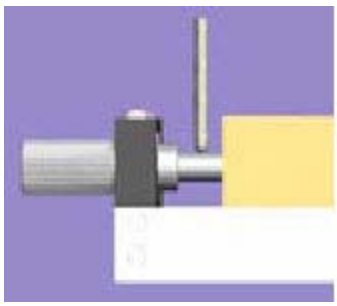
15. Press Play on the file control.

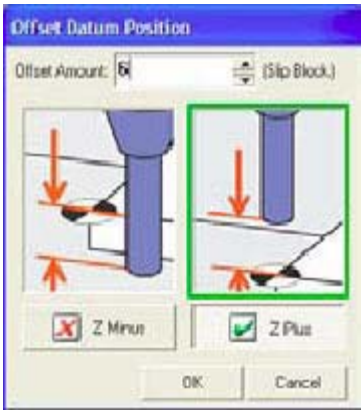


16. The cutter will move to the Y position set previously. This should be directly over the centre of the location fork, if not the Y offset is incorrect, repeat the previous operation.



17. Using the jog keys in **jog step mode** , bring the nose of the cutter down so it just touches the section of the alignment shaft where the diameter is 12mm as shown.

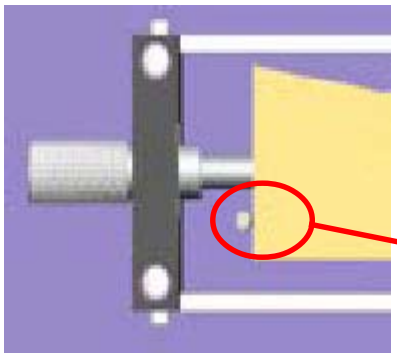





18. With the cutter in the above position click on the **Set datum offset from current position (Z axis) button**.

19. Click the Z Plus button to indicate which side of the alignment shaft the cutter is positioned.

20. Type in **6mm,** the radius of the alignment shaft. Click the **OK** button when done.



21. Click the 'Jog' tab to go back to jog mode.

22. Using the jog keys, move the cutter so it just touches the side of the balsa wood billet.

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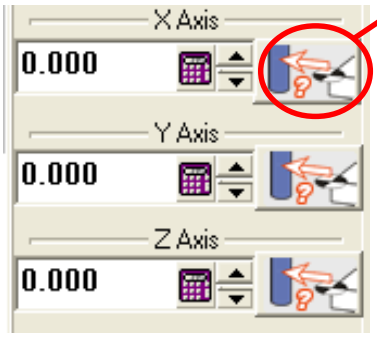


23. With the cutter in the above position click on the "Set datum offset from current position (X axis)" button.

24. Click the X Minus button to indicate which side of the billet the cutter is positioned.

25. Type in **2.175** here. (The cutter radius - 1mm) We deduct 1mm to account for the datum plate.

26. Click the **OK** button when done.

27. You have now successfully setup the CO2 Car/F1 Car fixture. It is a good idea to machine severals cars yourself before turning students loose on the machine.

**When machining there are a few things to remember …**

- Ensure the cut plane is at least the cutter radius below the center line.
- Always ensure the car is located in the bottom left hand corner of the billet.
- Never cut a car unless you are sure the bore is in the correct position. **DO NOT MAKE THE PART as damage to the fixture may result.**
- With QuickCAM 3D set the raster angle to 90. With QuickCAM Pro set the Raster angle to 270.
- Always check that the tool path does not pass down the ends of the billet and collide with the fixtur

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## 4 - 6 : Troubleshooting CO2 Car/F1 Car Fixture Setup

**Why does my car have a ridge down the middle after it has been cut?**

- *Problem 1* - If the ridge is only evident on the top of the car then the cutter may have not passed beyond the center line and has left the tool radius visible.

- *Solution 1* - Set the cut plane more than the cutter radius below the center line of the model and ensure the Z offset has been set when positioning the model in the block.

- *Problem 2* - The tool fitted to the machine is a 6.35mm Cutter and the tool selected in the tool library is 6mm. This will cause the tool to be offset and create a ridge 0.35mm in size even when the offset is correct.

- *Solution 2* - Ensure the correct tool is loaded in the library and selected (edit the library if required)

- *Problem 3* - The machine offset in Y locates the center of the bore in the car. This is the Y zero coordinate and is the point about which the car is indexed to cut the second side. If there is a step on both the bottom and the top of the car then measure the amount of the step.

- *Solution 3* - The Y offset should be changed by half of the measured ridge. Open the tool offset window and write down the Y offset. Manually change the value by half the step measurement then make another car. Once you have a car with no ridge make sure you record the offset.

**Why does my car have a ridge down its length that is bigger at one end than the other?**

- *Problem* - The fixture fitted to the machine is not correctly installed, most likely the fixture is NOT parallel to the machine table..

- *Solution* - Align the fixture correctly following the instructions in the help tutorials.

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## 4 - 7 : Contact Information and Disclaimer

**Need further help?**

You can contact Denford Customer Services for further help developing and machining your 3D solid models. Before contacting Denford for support, please read your hardware and software manuals and check the FAQ section on our website - www.denford.co.uk

When you request support, please be at your computer and CNC machine, with your hardware and software documentation to hand. To minimize delay, please be prepared to provide the following information:

- CNC Machine Serial Number (from the machine ID panel).
- Registered user's name / company name.
- The CNC machine control software name and version number.
- The wording of any error messages that appear on your computer screen, if applicable.
- A list of the steps that were taken to lead up to the problem.

Please note that on-site visits by our engineers may be chargeable.

**Denford Contact Details:**

Denford Inc.
815 West Liberty Street
Medina, OH 44256
1-800-866-9750

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