SCALEXTRIC 4SCHOOLS

Make

Assemble

Setup

PTC® | ACADEMIC PROGRAM

C2-SCA-BOX-0202-1.0

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tbrotherhood@ptc.com	Suggestions for improvements and other activities would also be very welcome.
Product code	C2-SCA-BOX-0202-1.0

The following organizations share a common goal of promoting STEM subjects and endorse PTC's Education Program.

Contents

Introduction

Scalextric4Schools is an exciting Design – Make - Race challenge for middle and high schools. This booklet is of several that support the project looking in detail at the manufacture of components, assembly and setup of a Scalextri4Schools slot car.

More Information about the challenge, guides and links to order track and components can be found on the challenge web site at: www.scalextric4schools.org

Session 5: Make

The Scalextric4Schools car could be manufactured using many different techniques. For this tutorial we have focused on just two methods; laser cutting and three axis CNC machining.

Health & safety

Before using any machinery, make sure you are properly trained and comply with all safety guidance and regulations.

Car chassis

Preparing the DXF file

The chassis is made up of flat components that need to be nested together and cut from a flat sheet of 3mm cast acrylic or similar material. A dxf output from the drawing module of **Creo Parametric** is the most common way of driving 2D cutting machines like lasers or CNC millers/engravers.

The easiest method uses a **Creo Parametric** assembly of the parts lying flat which is used to create a drawing with a single view of the assembly before exporting a dxf file for cutting.

CAD Parts   **CAD Assembly**   **CAD Drawing**   **DXF export**

Export to…

DXF
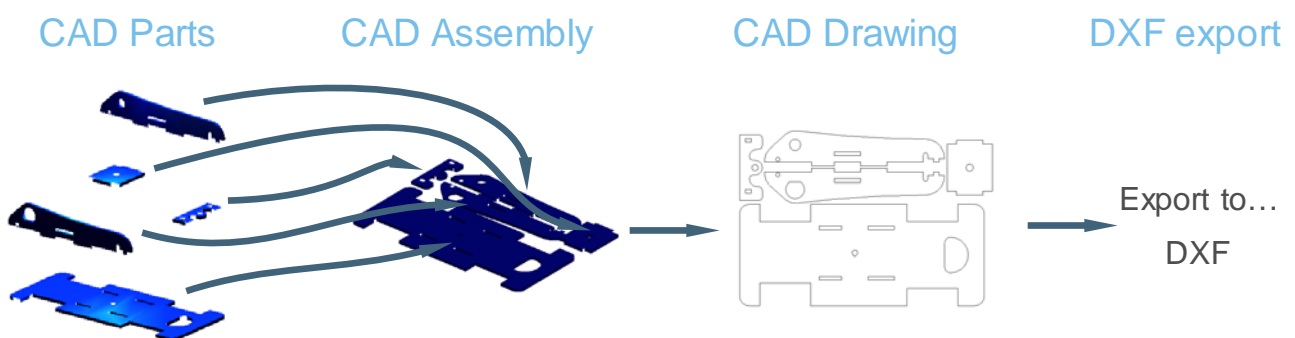
The dxf file created by **Creo Parametric** can now be imported into the software driving the laser or CNC cutter.
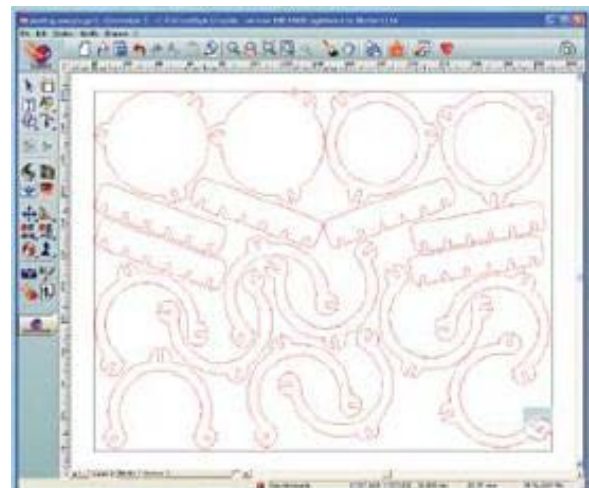
Laser cutting

Most laser cutters in schools are CO2 based and between 20w and 80w power rating. Due to variations in manufacture it is unlikely two lasers will cut at the same rate so you will need to do some test pieces to find the settings that are best for the materials you are using. Laser cutter manufacturers should provide you with settings for a range of common materials to use as a starting point.

Control of the cutting process is done using a combination of power and speed of cut. Usually these values are expressed as a percentage. Where throughput is important it is common practice to leave the power at 100% and control the cutting using speed.

For 3mm acrylic in a 40w laser at 100% power most lasers will be cutting at a speed between 3% and 8%. Higher powered lasers will cut more quickly and lower power lasers more slowly. The aim is to use a setting and speed which will just cut through the material.

On the same components you may want to engrave and cut. Where this is the case use different colors for the engraved and cut lines. Laser driver software will usually let you set different power/speed settings for each color. It is important to put the engraving color first in the machining sequence as parts are liable to move once they have been cut.

A short video showing a laser cutter in actions has been provided.

Laser-cutting.avi

CNC machining overview

The file format most often used in high schools to transfer 3D shapes for CNC machining is STL, named after the term 'stereo lithography'.

STL files represent 3D surfaces using thousands of triangular facets. If these facets are too large they will be visible on the finished object. Where the facets are small you will not notice them and curved surfaces will appear smooth and even.
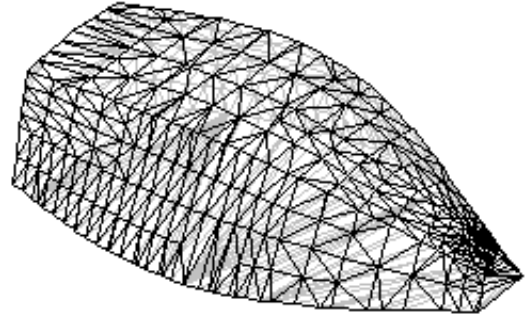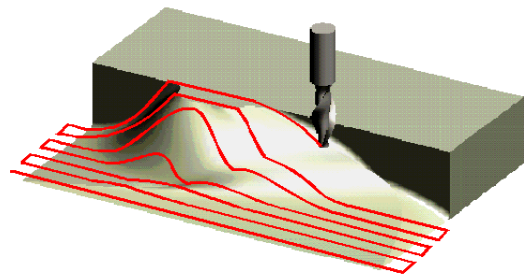
CNC machining uses a cutter rotating at high speed moving over a block to remove material.

It is customary to have two cutting strategies:

Roughing – This uses a large diameter cutter to remove a lot of material quickly.

Finishing – Uses a small diameter cutter to clean up the surface reaching into any fine detail on the model.

The surface quality of the finished object depends almost entirely on the finishing strategy and the following factors:

- Sharp cutting tools
- High cutter speed of rotation
- Smooth sideways movement of the cutter
- Small 'step over'.
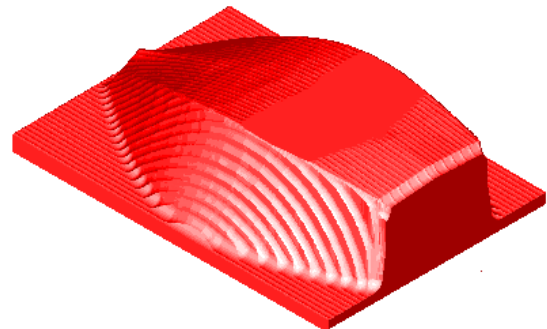
Large 'step over' = shorter cutting time

The two illustrations on the right show the difference between the course surface finish left from a large 'step over' above, and the smoother surface finish from a small 'step over' below.

Typically a step over of around 10% of the cutter diameter will give a reasonable surface finish.
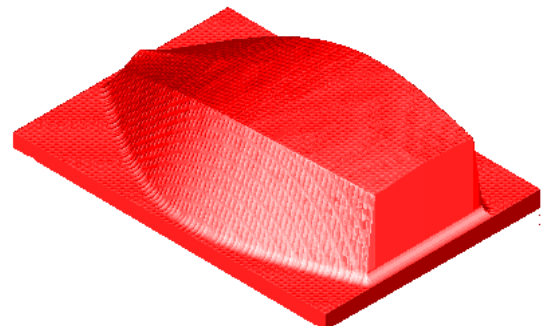
Small 'step over' = longer cutting time

CNC machining - Car Body

This is the most common method of creating the Scalextirc4Schools body and requires access to a CNC router and vacuum former.

The limitations for vacuum forming and 3 axis machining are very similar. Looking from above, your design must not have any undercuts that would prevent the tool reaching the surface or prevent the body mold being removed from the plastic body shell. The design featured in this tutorial has followed these rules.

This image shows the Boxford 3D GeoCAM preview screen set up for their A3 high speed router machine.

http://www.boxford.co.uk/
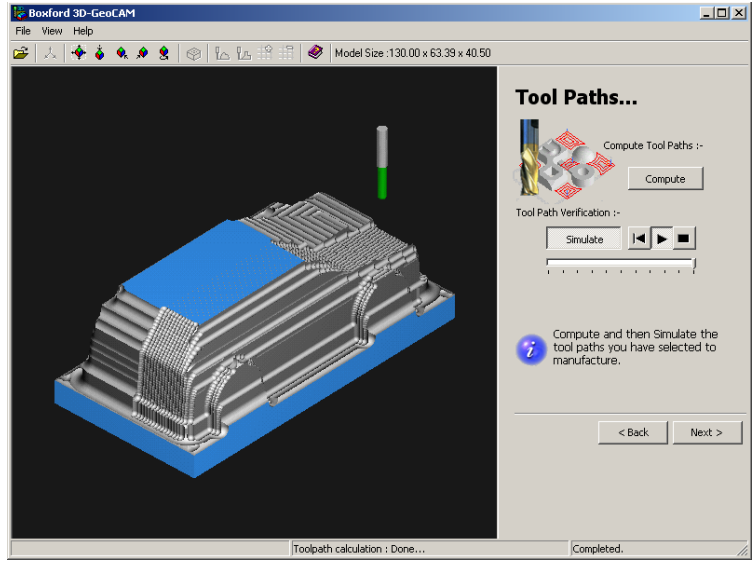
The steps in turning your model on screen into a machined part are illustrated here.
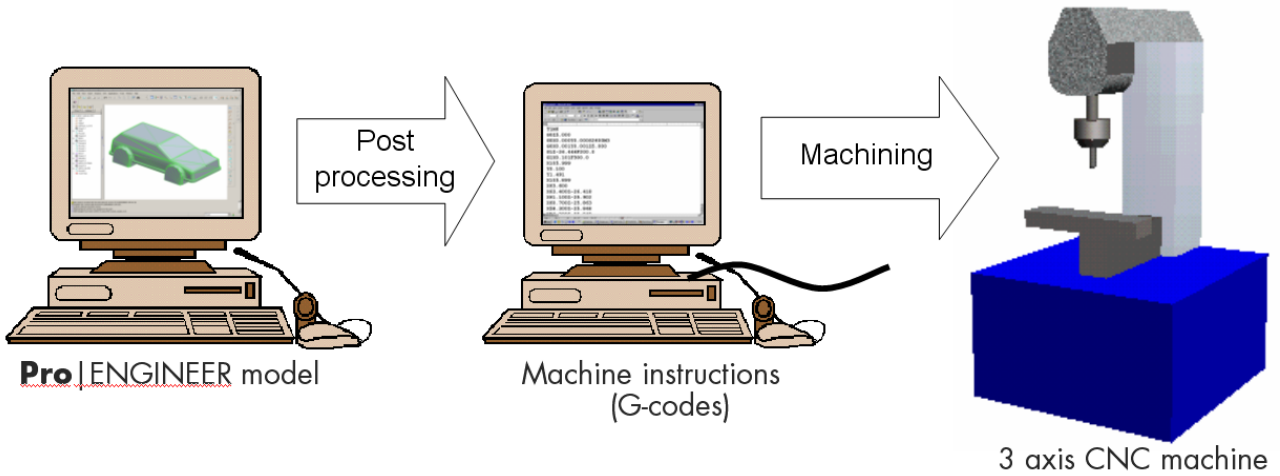
There are two main ways to post process your model;

- An STL file format and 3rd party software for your CNC machine.
- The **Pro|NC** manufacturing module in **Creo Parametric** Schools University Edition.

STL output

This uses a file format invented for the first rapid prototyping machines.

Called Stereo Lithography the process builds models using a laser to harden layers of liquid resin.

The file format uses the initial letters from the process i.e. .STL

Image - http://en.wikipedia.org
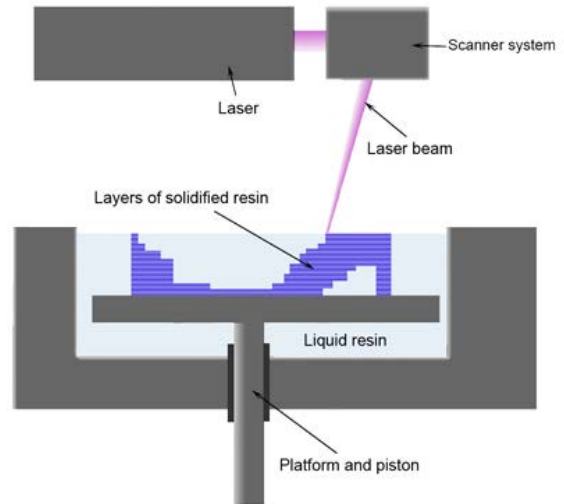
Exporting a STL file from Creo Parametric

1. Your car body mold should be on screen in Creo Parametric.

2. In the **File** menu, **Save As**, option, Click **Save a Copy.**

- In the **Save a copy** dialog, change the file Type field to **Stereolithography STL (*.stl)**.

- In the **New Name** field accept the default name then click **OK**.
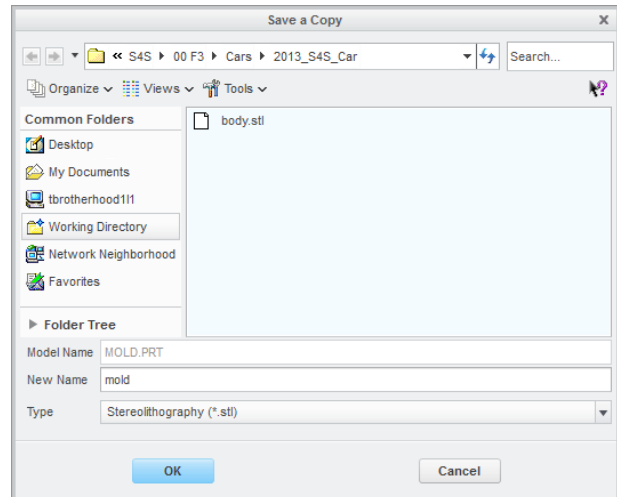
3. In the Export STL dialog, change the **Chord Height** field to **0** then hit the **Enter** key on the keyboard.

Creo Parametric substitutes a small number for the zero you typed in. **Creo Parametric** has calculated the most suitable mesh size for this model.
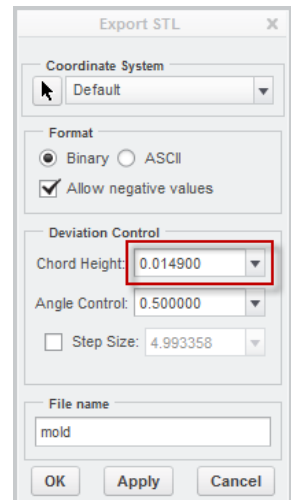
The **Creo Parametric** model will now display the facetted surfaces of the STL conversion.

The settings you entered will create a fine mesh with lots of small triangular surfaces. These will be invisible on the machined shape. The STL file for this model was 240KB.

If the Chord Height was set to 1 a course mesh like this is created.

The disk file will be smaller around 24KB but the flat surfaces will be apparent on the machined shape.
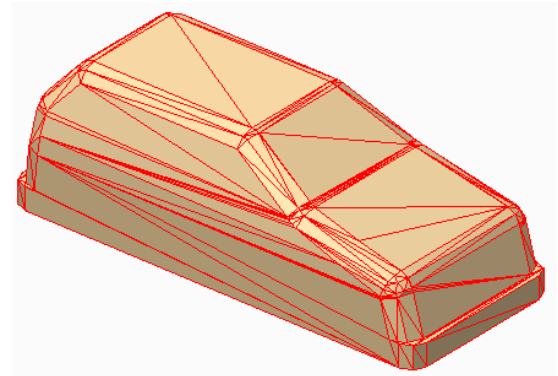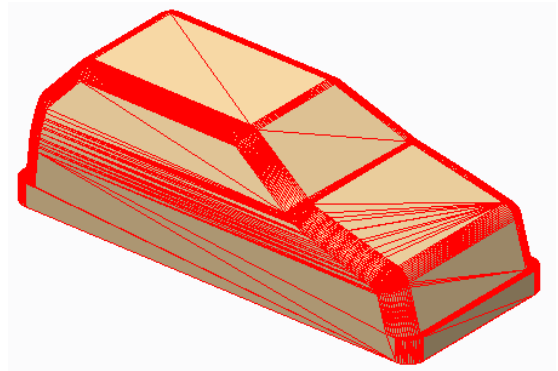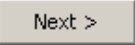
Boxford 3DGeoCAM

Boxford is a forward looking manufacturer of CNC machine tools and their 3DGeoCAM software is an advanced 3D CAM package which allows students to create optimized, gouge free, 3D cutter paths, suitable for 3 Axis CNC milling/routing machines.

CAD Models are imported in stereo lithography (*.stl) format.

Here is the opening screen with the body_mould.stl file open.
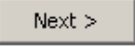
1. Click on [Next >] to move to the next screen.
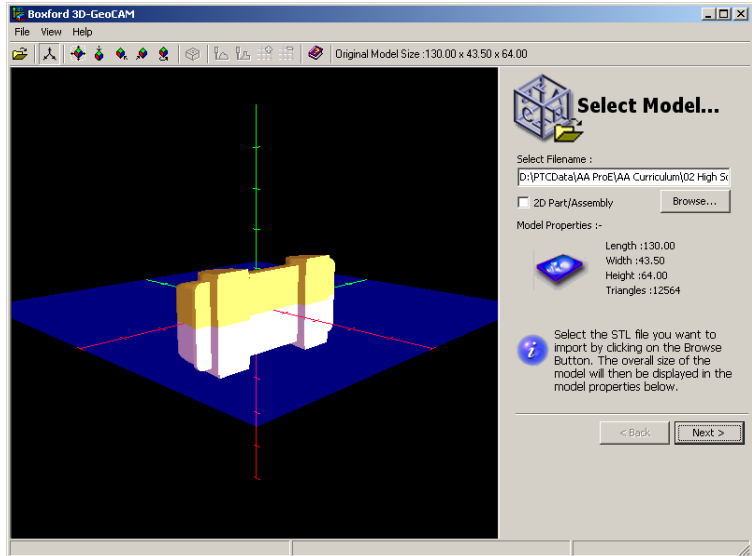
2. Click on each of the directions until the body is the right way up like this.
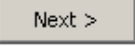
Note: The cut plane is the very thin blue line.

- Set the cut plane dimension to **3**mm by typing the value or using the slider.

3. Click on [Next >] to move to the next screen.
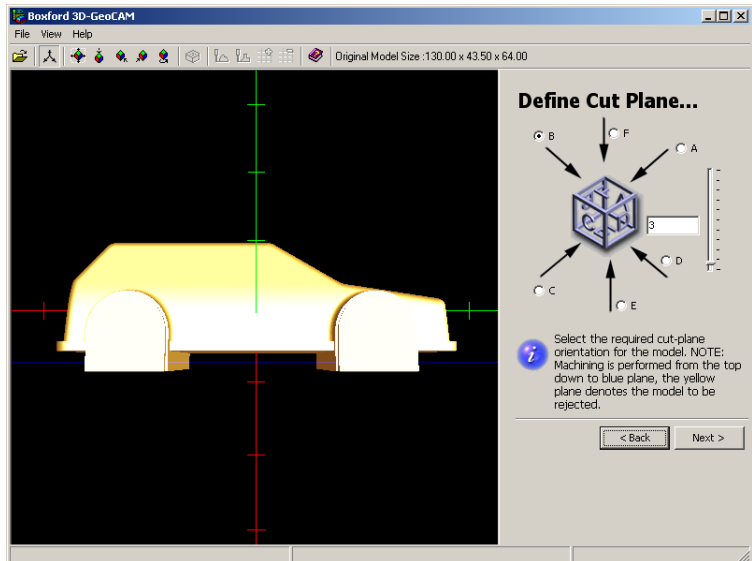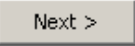
- Select the **material** you are machining.

- Enter the sizes of the material blank. A suitable blank size for the design in this tutorial is **140**mm x **70**mm x **50**mm.

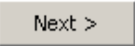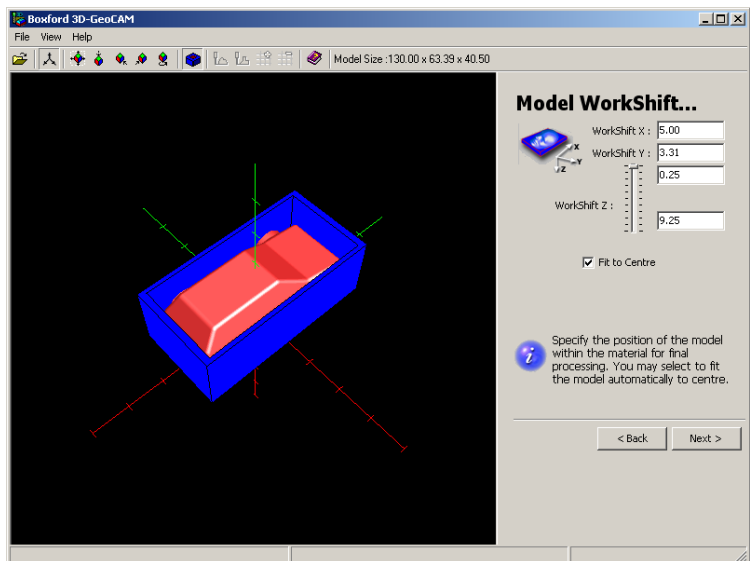4. Click on [Next >] to move to the next screen.
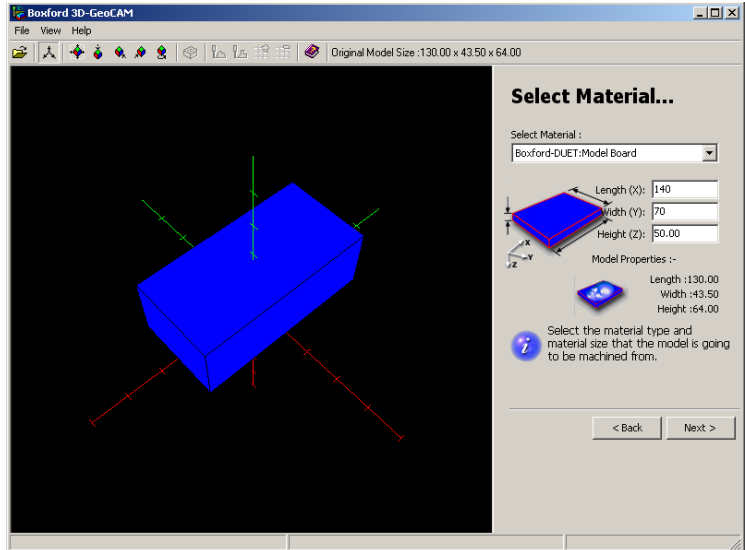
- Change the **Percent** field to **100**%

5. Click on [Next >] to move to the next screen.
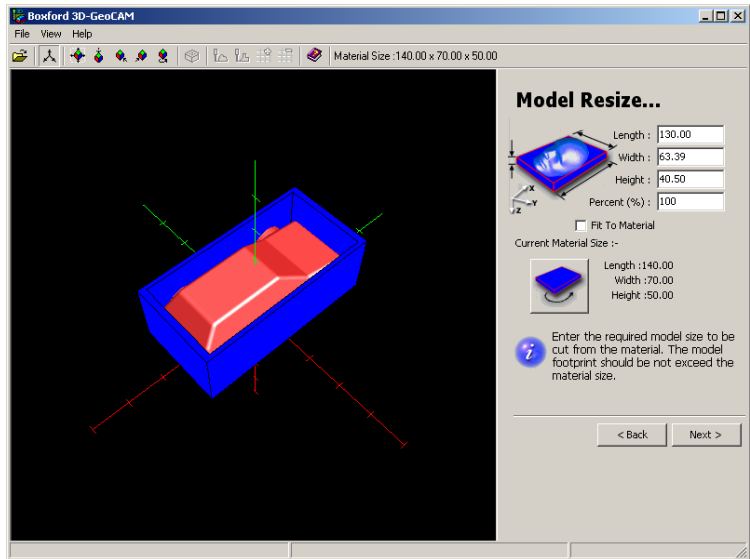
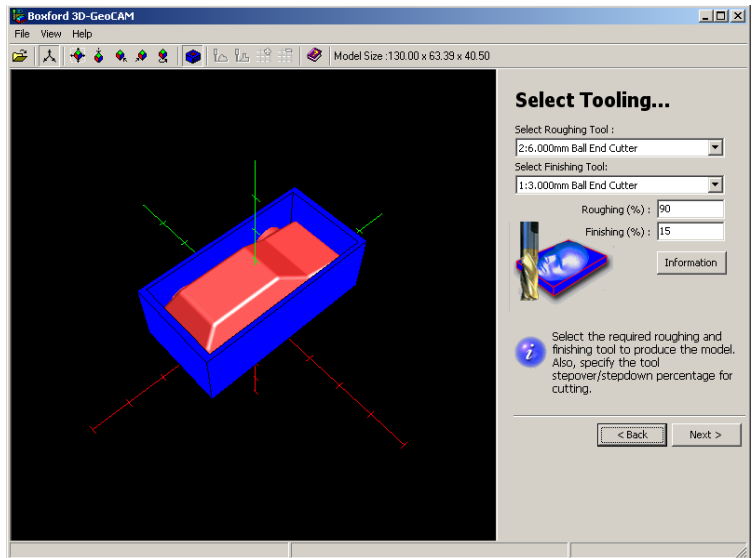- Either type in the value or move the **Workshift Z**: slider to set a value of **0.25**mm

6. Click on [Next >] to move to the next screen.

- From the lists select the tools for the roughing (**6mm Ball End**) and finishing (**3mm Ball End**) cuts.

Note your tooling may be different to this.
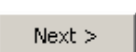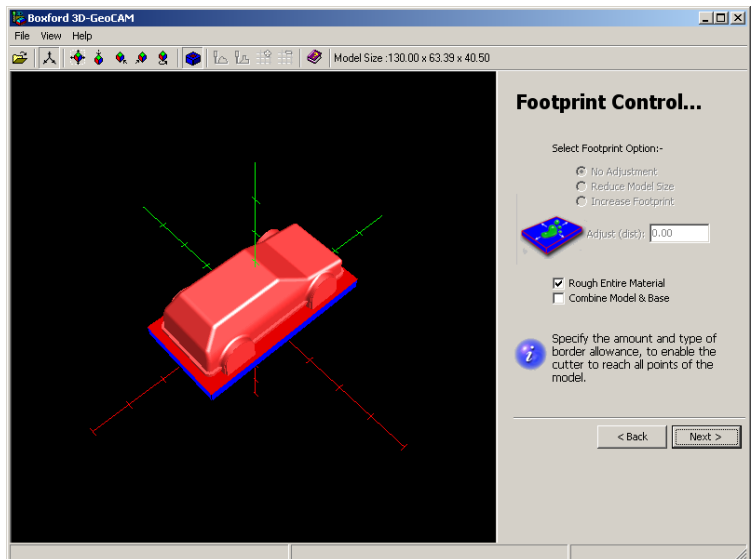
7. Click on [Next >] to move to the next screen.

Accept the default allowances.
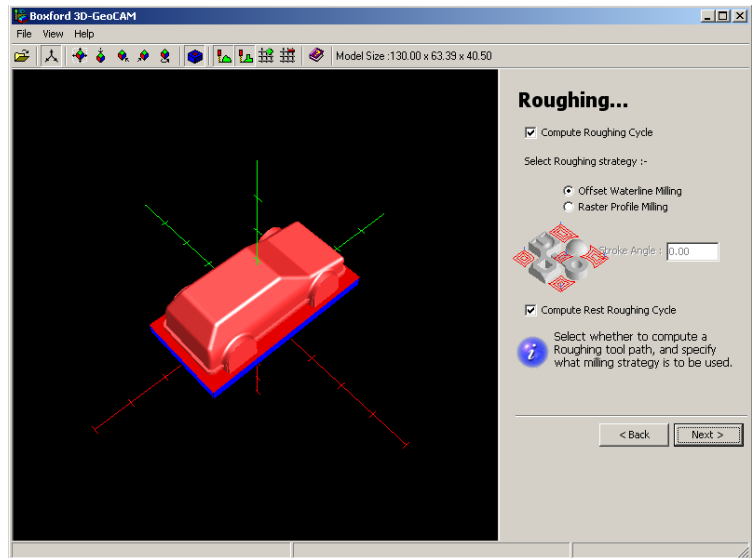
8. Click on [Next >] to move to the next screen.
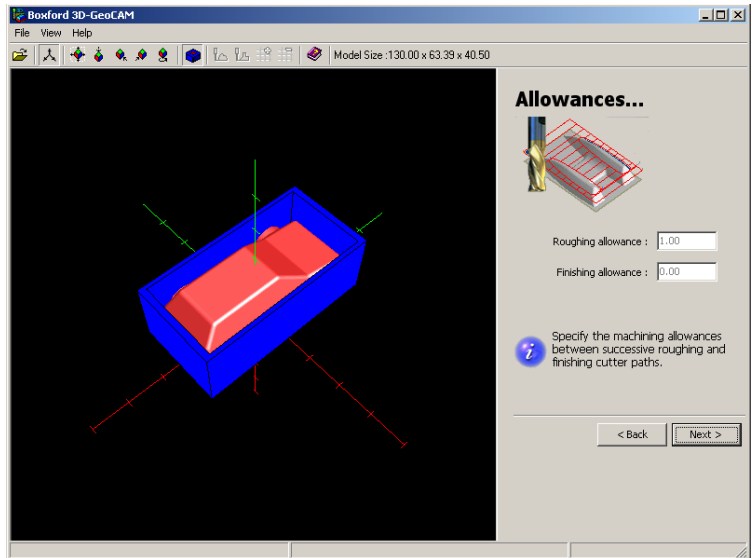
The default options will be used for the footprint.

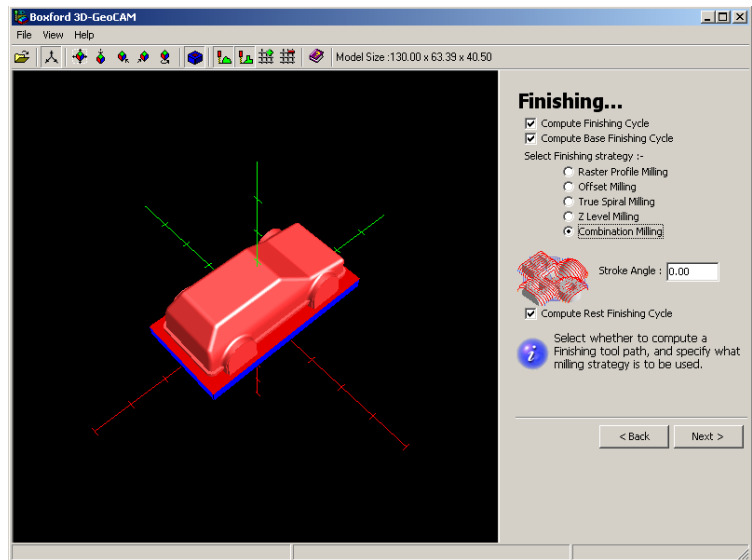9. Click on [Next >] to move to the next screen.

- Select Offset Waterline Milling.

- Tick/check the Compute Rest Roughing Cycle option.

10. Click on [Next >] to move to the next screen.

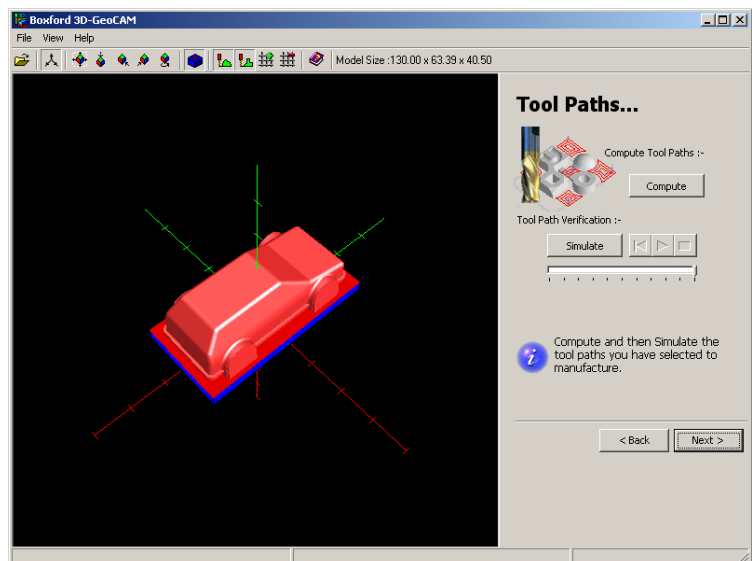- Change the Finishing options to the ones shown on the right.

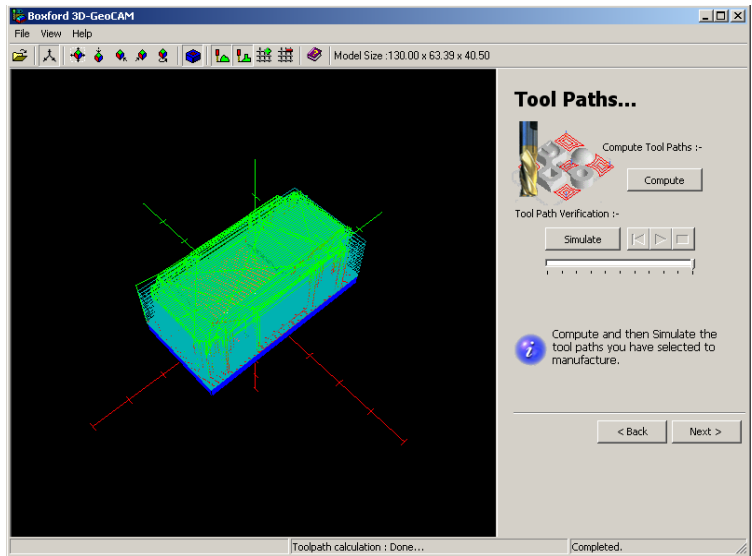11. Click on [Next >] to move to the next screen.

12. Click on Compute to start calculating the tool paths.

Note: This may takes several minutes depending on the speed of your computer. This is because 3DGeoCAM is doing some very complex mathematics.

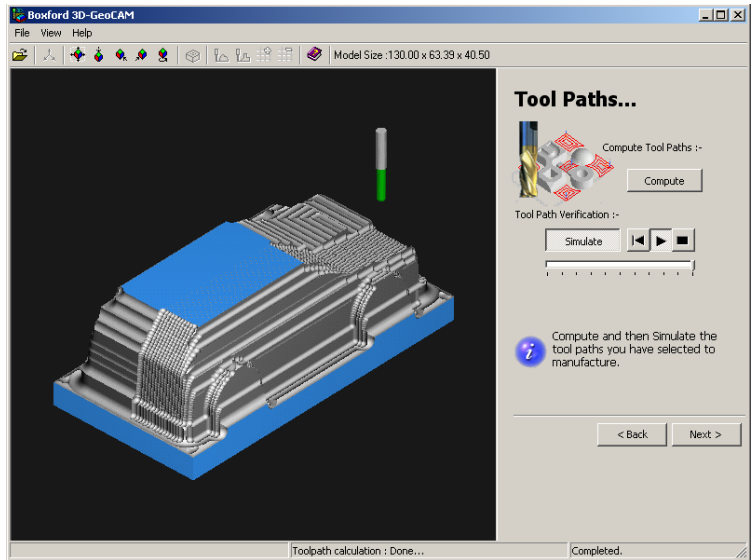13. Click on [Next >] to move to the next screen.

The model window will now display the tool paths as colored lines.

- Once the **Compute** completes, click on **Simulate** to see an accurate representation of the cutter path and resulting surface finish.

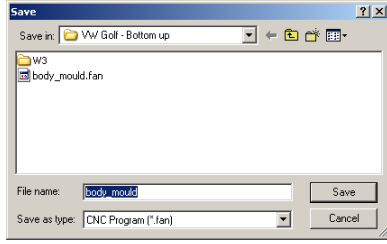The slider controls the speed of the simulation and the playback buttons allow you to replay the simulation.

Here the simulation has completed showing the quality of finish that can be expected after actual machining.

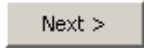14. Click on [Next >] to move to the next screen.
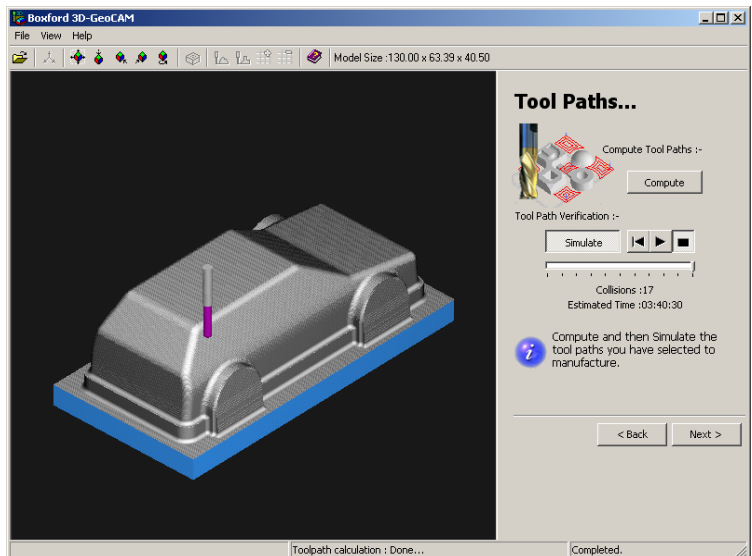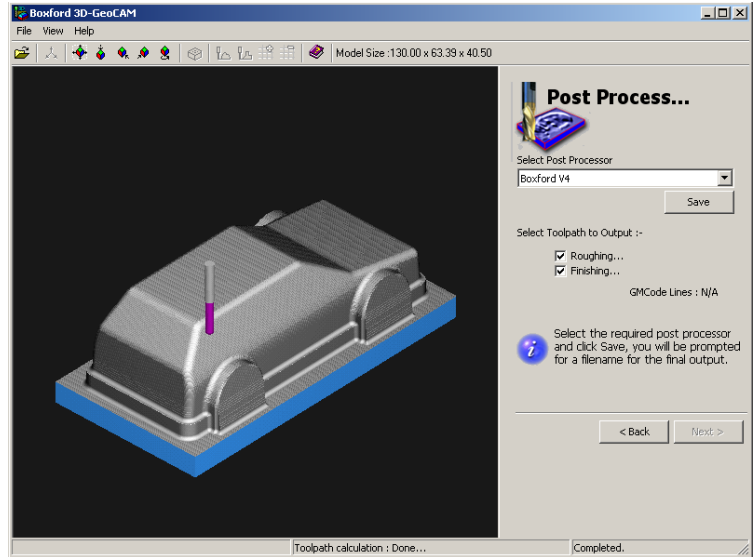
- Click on **Save**.

- Specify the folder and filename then click **Save**.

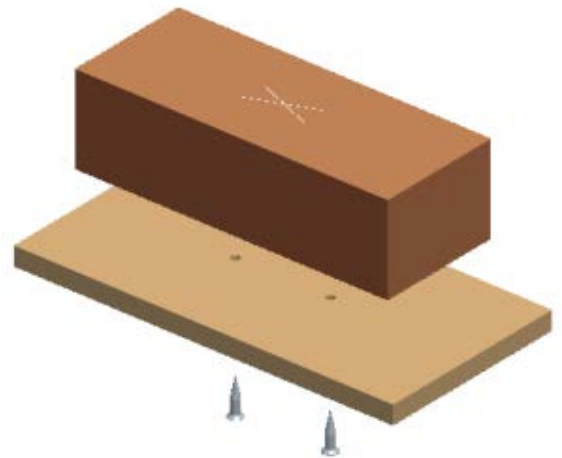15. If you are connected to a CNC machine tool, click on

 to exit 3DGeoCAM and go to the machine control software.

Work piece

16. Cut a piece of wood to the dimensions you used earlier in the Select Material section of 3D GeoCAM.

- Attach the work piece on to a sacrificial base. Here we have used 10mm (3/8") MDF and two short screws up into the work piece.

- Making sure both surfaces are clean and free from dust, use double sided tape to fix the sacrificial base across the bed on the Boxford router. Make sure this is firmly attached and will not come loose during machining.
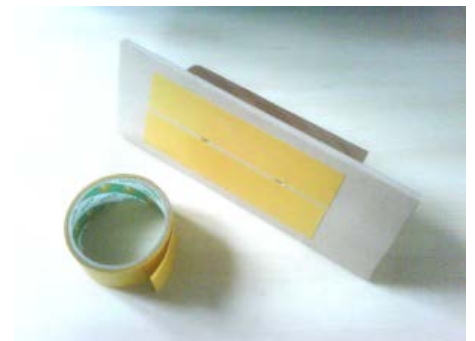
CNC cutting - suggestions

- Do not exceed the physical limitations of your machine. Experience will enable you to identify problems, listen for the machine laboring or cutting fresh air. Changes in sound are often the first indication something is going wrong.

- If you are using wood to make molds, the grain may cause rough surfaces. This example was cut with a brand new HSS tool.

- Speed versus quality

- Physical limitations of machine

- Listen for machine laboring.

- Strength of tool.

- Cutting direction and wood grain

Session 6: Car assembly

You can manufacture the car in lots of different ways, from a variety of materials. We explain some of them here.

Tools

These tools are needed to assemble the car.

1. Soldering iron

2. Electrical solder (fluxed)

3. Electrical screwdrivers (hex & slot)

4. M4 tap and wrench

5. 6mm drill with wood spacer

6. Pliers

7. Wire strippers

8. Hacksaw blade

9. Glass paper

10. Bench vice – Not shown
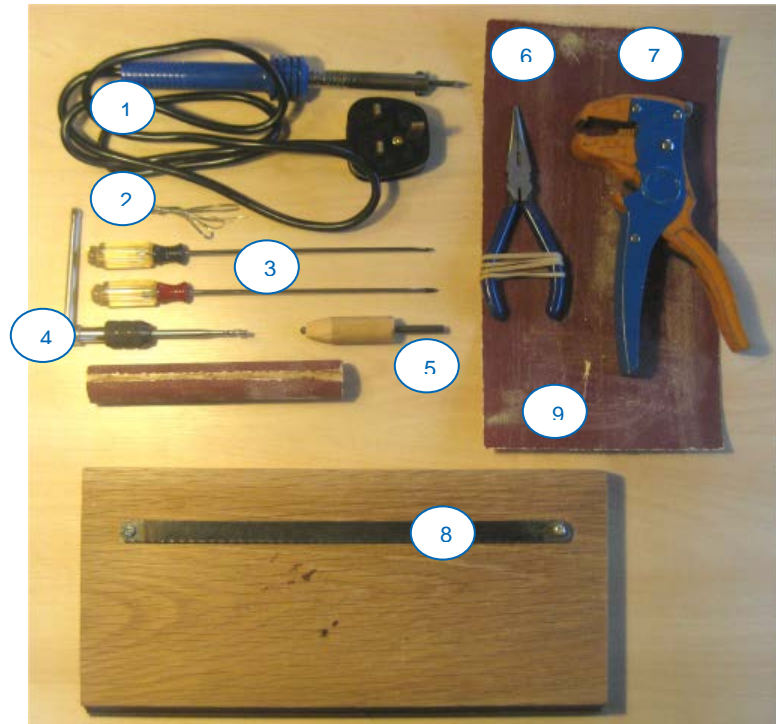
Chassis

We've designed the car chassis for the tutorial with the intention of cutting it from 3mm cast acrylic. Laser cutters produce very accurate components, with polished edges, directly from the dxf files.

Alternatively, the chassis components can be cut with a CNC mill/engraver. However, you may need to be redesigned to accommodate the diameter of the end mill/slot drill tooling.

We provide an alternative assembly and drawing for this procedure.
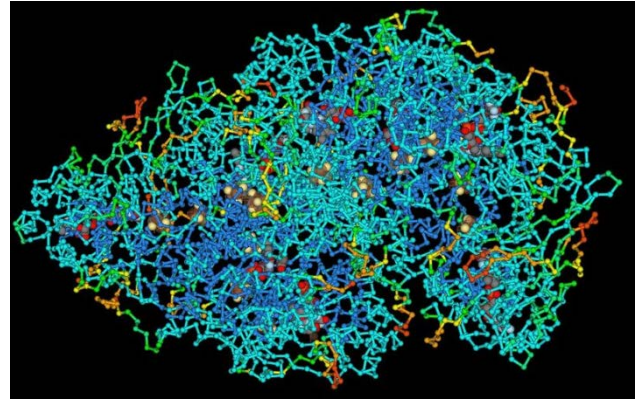
Body – Vacuum formed

The body will be vacuum formed over a CNC machined mold. A dense timber is suitable for the mold or you can use a specialist machining polymer like Ureol™

Thermo-plastics

Thermoplastics become soft when heated. They can be molded and remolded easily making them ideal for school projects.

Thermoplastics consist of long molecular chains with hardly any regular structure.

There are many thermoplastics available including; acetal, acrylic, nylon, polycarbonate, polyethylene, polystyrene.

http://en.wikipedia.org/

The Technology Student web site has a very clear explanation of vacuum forming.

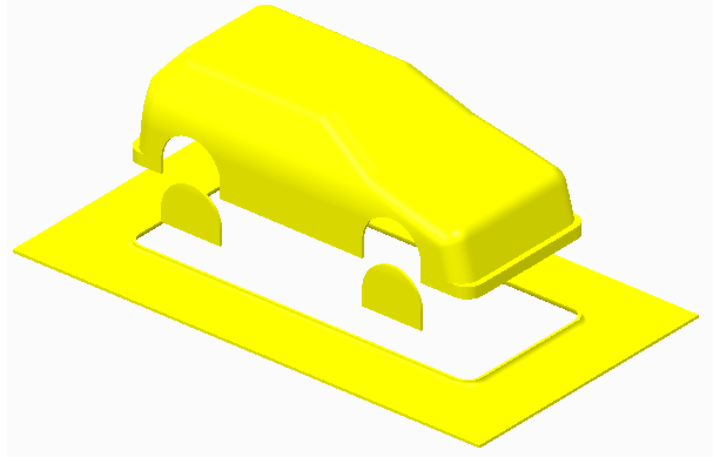http://www.technologystudent.com/equip1/vacform1.htm

Tip: From Gary Smith at Boxford - Dust the mold with talcum powder. It acts as a "release agent" and the formed HIPS plastic comes off the mold much easier.
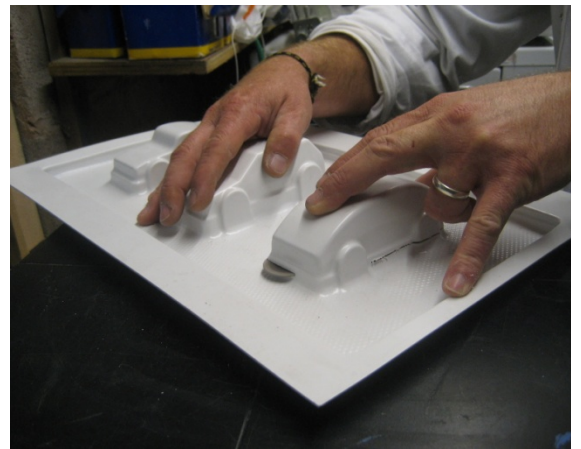
Thanks Gary!

Trimming the body molding

After molding, the formed sheet has material that needs to be removed.

1. A "Gerbil" trimmer is the easiest way to separate the car body form the formed sheet. In the picture at right, the blade of an RJH machine is set to trim the body.

2. If you don't have access to a powered trimmer, a hacksaw blade screwed onto a base, with washers offsetting it slightly above the base, works well.
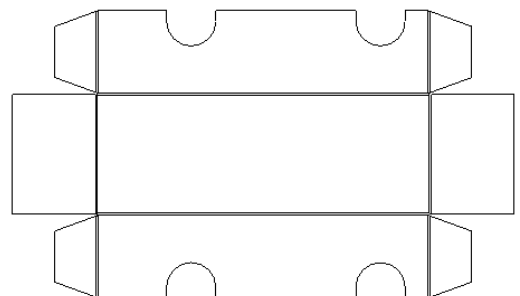
    08 body-saw.avi

3. The body edges are then easily smoothed on a piece of glass paper.

    08 body sand.avi

To remove the wheel arches, you will need to mark their outline on the shell. To help, we have created a template that fits snuggly over the shell.

4. Print out **Wheel_arches_template.drw** at 100% size onto thin card, fold and glue.

5. Place the template over the car body and, with a fine tipped pen, mark the outline of the wheel arches.

    09 arch-marking.avi

6. Remove most of the wheel arch material using a Dremel or a pair of curved nail scissors.
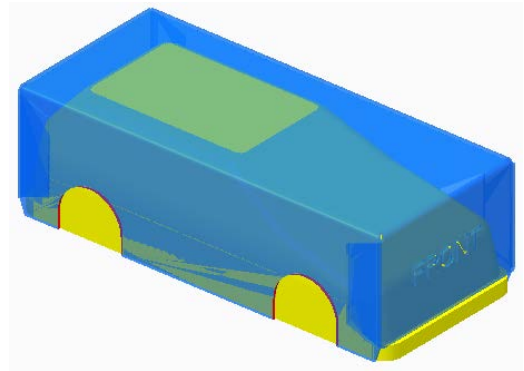
    10 arch-cut.avi

7. Use fine abrasive paper to remove burrs and sharp edges.

Here, abrasive paper is wrapped around a dowel, to smooth the curve inside the wheel arches.
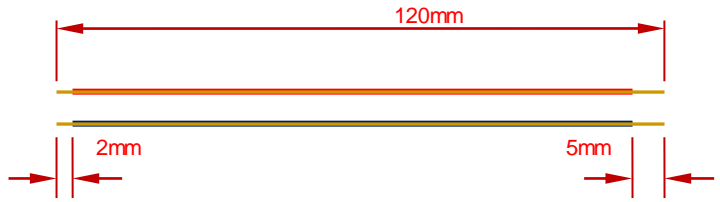
Check regularly so you don't go past the marked line.

    11 arch-sand.avi

Component preparation

Soldering the wiring

1. Cut two 120mm lengths of thin, flexible, multi-strand insulated wire.

2. Strip 2mm of insulation from one end of each wire and 5mm from the other end.

3. The ends of the wires should be twisted and tinned with solder

4. Have your instructor/mentor tin the crimp sockets with solder then attach the wires to the small brass contacts.
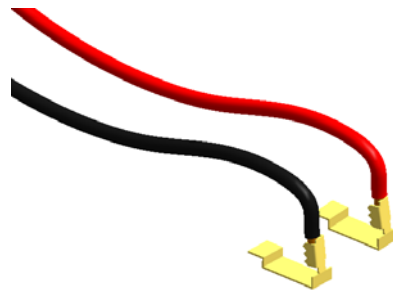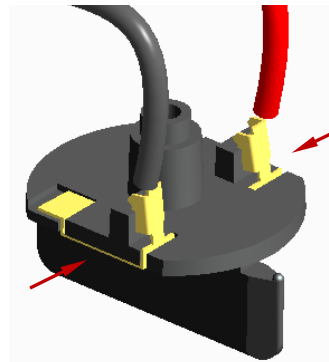

5. Make sure neither the wire nor the solder extend below the "crimp ears."

Wire and solder must not come below this point
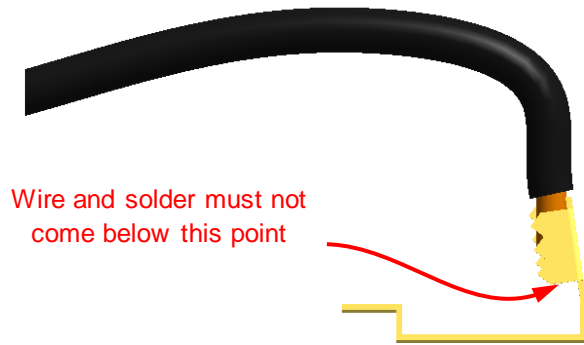
Slot guide contacts

6. Slide the contacts into either side of the slot guide.

Braid holder

7. Locate the braid holder. Make sure the holder has the curved bumps pointing upwards.

8. Fold one of the braids around the holder as shown by the red arrow.

9. Repeat for the second braid.
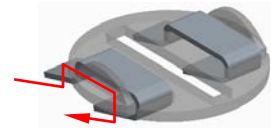
10. Tilt the braid holder as shown below and slide it over the rear of the slot guide body.

11. When the braid holder reaches the end of the slot, tilt it up until it's horizontal.

12. Gently push the braid holder towards the rear of the slot guide body until it clicks and reaches the stop
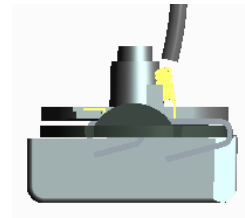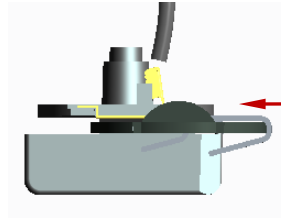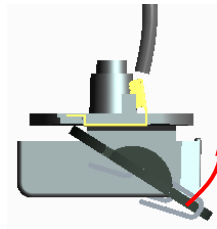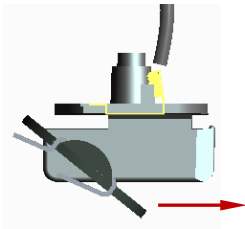
Assembly

The instructions that follow explain how you can assemble the components supplied by Scalextric with the chassis components you have manufactured.

Rear axle

1. Identify the axle that has ridges around its center; this is the rear axle.

2. Using a vice and sleeve, carefully push the white plastic contrate gear along the rear axle until it covers the center ridges.

Do not put wheels on the rear axle at this time.

Note: A 22mm long section cut from a clear ball-point pen barrel works well as a sleeve.

Sleeve
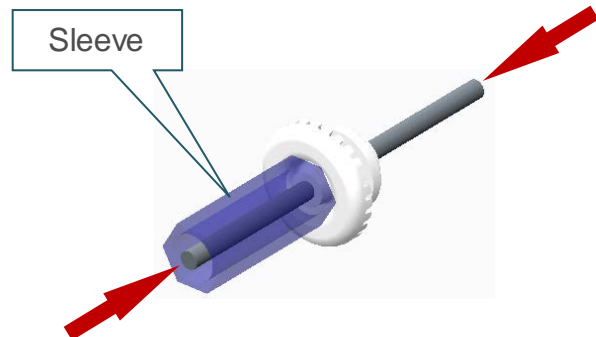
Front axle

3. Use a bench vice to push **one** wheel onto the other axle. Stop as soon as the ridged portion of the axle disappears into the wheel.

4. Use a bench vice to push another wheel onto the front axle. Stop as soon when the knurled portion of the axle disappears into the wheel.

Caution: Do not apply excessive force with the vice, as this could bend the axle.
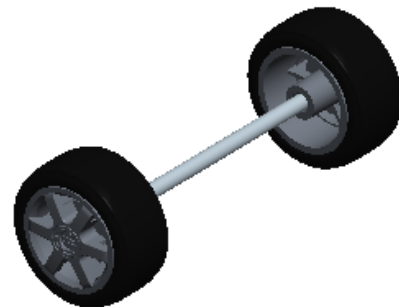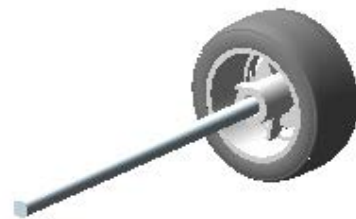
Motor and pinion

5. With the vice and the same sleeve from Step 4, squeeze the small white pinion, circular end first, onto the motor shaft. Stop when the gear is half way along, covering the ridges in the shaft.
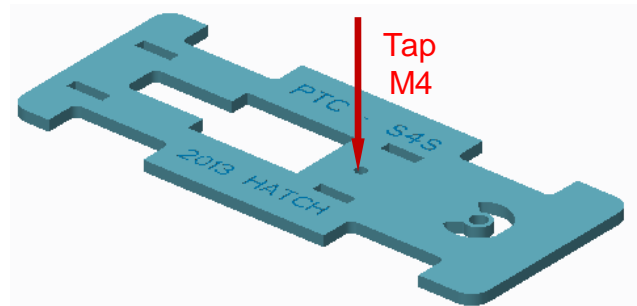
Caution: Do not apply excessive force with the vice as this could bend the motor shaft.

Sleeve
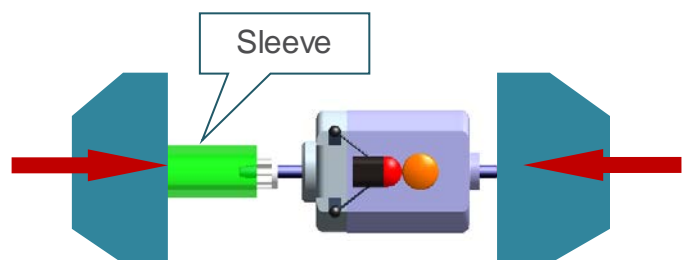
Slot guide
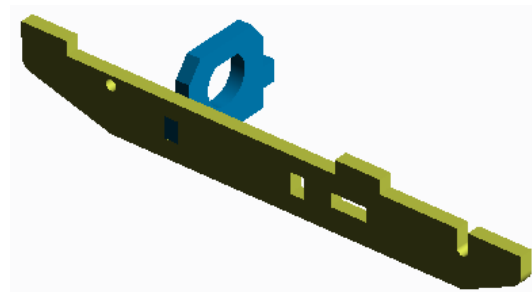
Chassis preparation

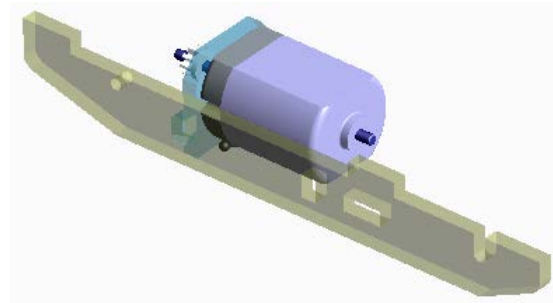6. Use an M4 tap to cut a thread in the center hole of the chassis base.

Tap M4

Chassis assembly

The initial chassis assembly will be done upside down.

7. Take one of the side frames and fit it to the rear motor frame, making sure to orient the flat portion of the motor frame hole upwards.
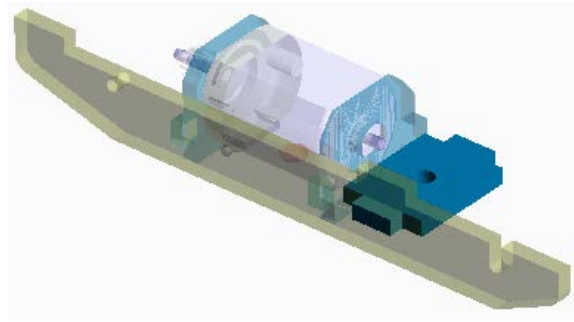

8. Insert motor into side frame with the wire connections facing downwards.
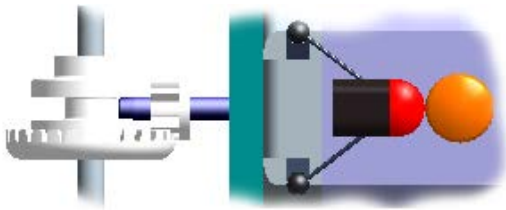

9. Place the front motor frame over the boss at the end of the motor, and slot the motor frame into the side frame.
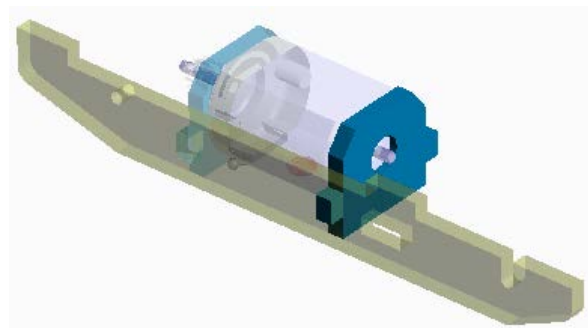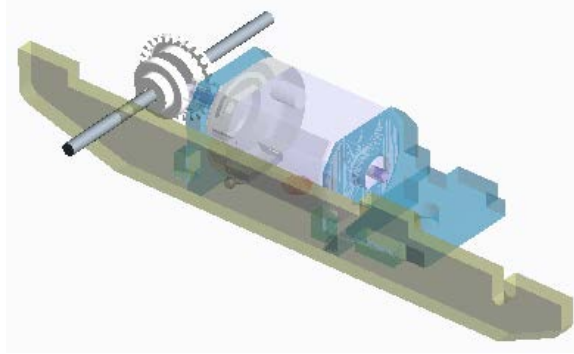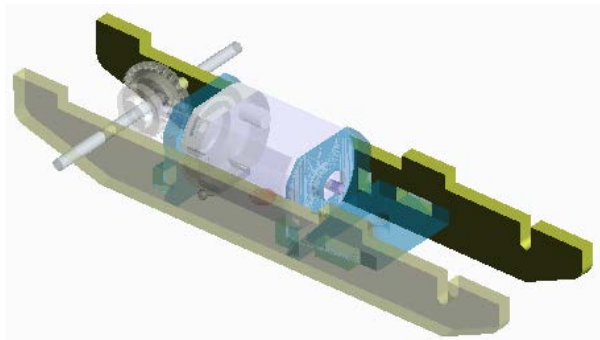
10. Insert the center plate into the side frame.

11. Insert the rear axle through the hole in the side frame and make sure the contrate gear on the rear axle engages with the motor pinion.
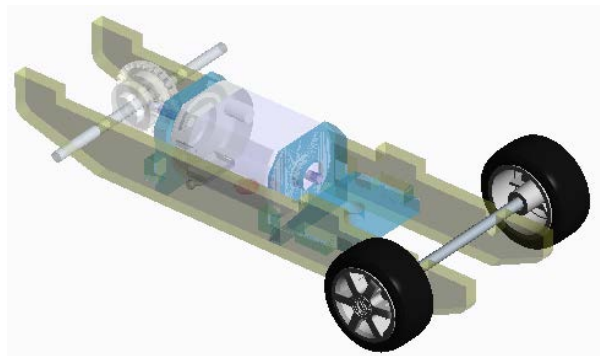

19 chassis-base.avi

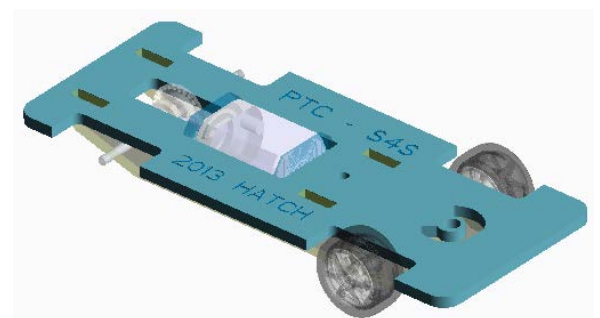

12. Add the second side frame.

13. Insert the front axle sub assembly into the slots at the front of the chassis side frames.
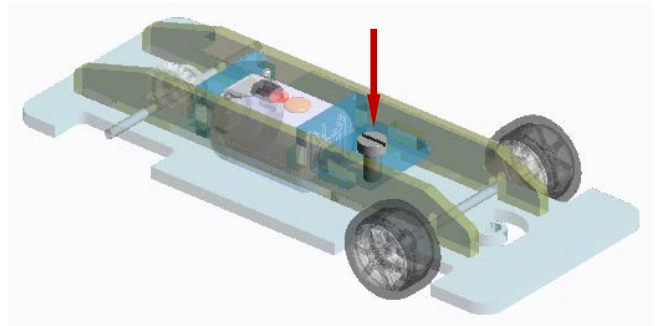

14. Place the chassis base engraved text upwards over the assembly making sure all the components locate properly.

15. Check the axles are located correctly and rotate freely

16. Turn the assembly over and secure with an M4 x 10 machine screw.

17. Thread the wire ends up through the hole in the front of the chassis.

18. Locate the slot guide boss into the hole.
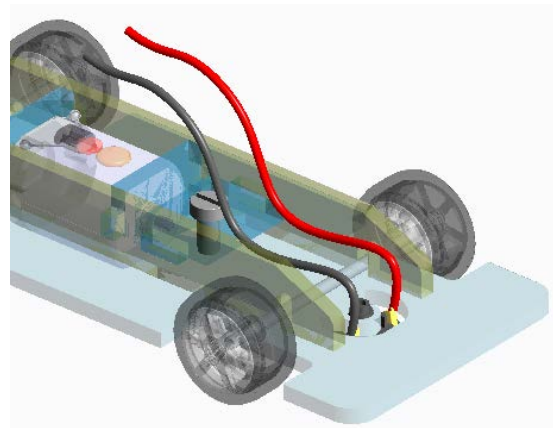
19. Place two small washers over the slot guide boss.

20. Insert the slot guide fixing screw, making sure the slot guide can rotate freely.

Note: Do not over tighten the screw!
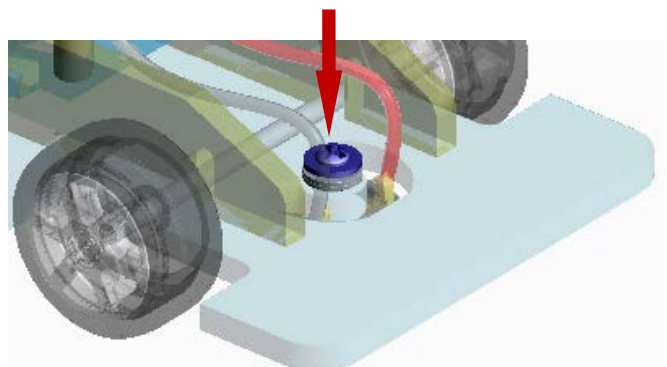
21. Solder the loose ends of the wires to the motor connections.

The finished chassis should look something like this image.

22. If the car travels around the track in the wrong direction, swap over the brass contacts in the slot guide.

Session 7: Setup

Blueprinting

This is technical term used to describe making sure a product is exactly as the designer intended. Manufacturing variatio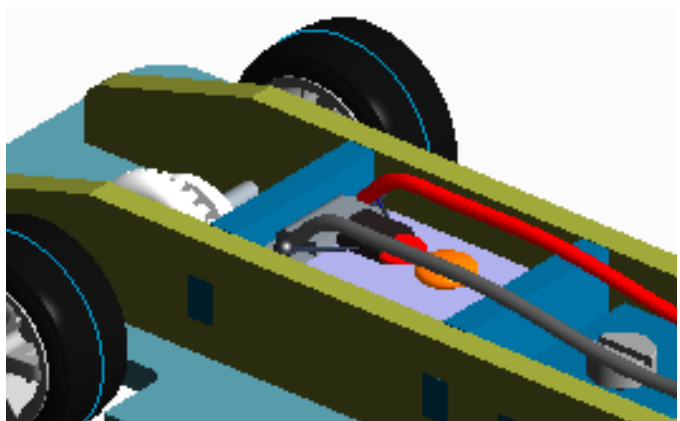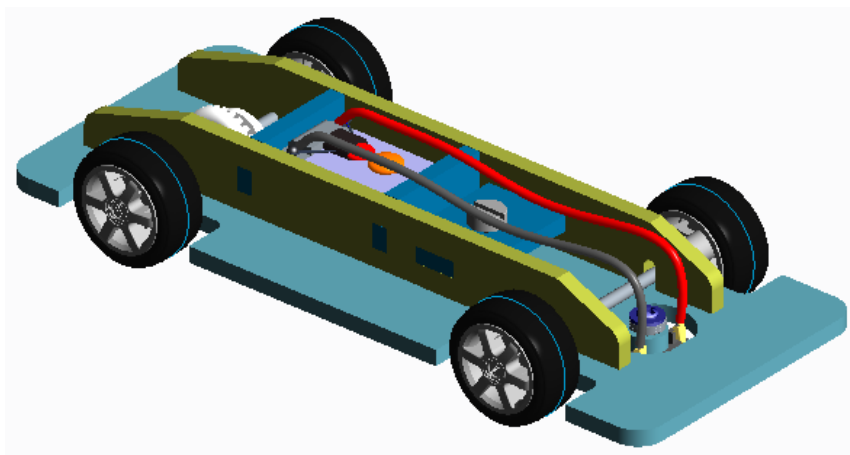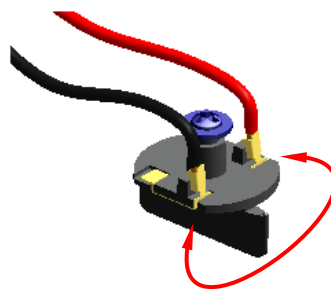ns and differences in the way components go together when assembled means there may be slight inaccuracies and misalignment.

Take something as simple as an axle passing through a hole. Manufacturing tolerances on the 2mm axle might be plus zero and minus 0.1mm making the largest axle 2mm diameter and the smallest; 1.9mm diameter.

Due to variations in laser power and acrylic thickness, tolerances for the 2mm hole in the acrylic chassis side frames could be plus 0.5mm and minus zero.

What relevance does this have to car performance? If we put the largest diameter axle in the smallest diameter hole there will be no clearance or room for lubricant. The slightest amount of grit in the hole will make the axle jam. Combining components at the other extremes of the tolerances we would have an axle of 1.9mm diameter in a hole of 2.5mm. Clearly the axle would appear very loose and may even move enough to let the gears come out of mesh.

So an important part of blueprinting is measuring everything very accurately and selecting components that mesh exactly as intended in the original design.

True tires

Tires and wheel hubs are injection molded which is great for producing thousands of components very cheaply.

However, variations in temperature, alignment of mold halves and wear mean the components may be slightly different shapes and sizes. Different rates of cooling in the molten material means there might be distortion and molding lines often show where the mold halves meet.

This means the tires are unlikely to run concentric on the axle causing the tire to lose contact with the track. Truing the tires will give you a significant improvement in acceleration and speed.

Place the car on the track with the drive wheels on a piece of fine glass paper. Keeping the slot guide and connections in the track, lift the rear of the car and operate the speed controller. With the wheels spinning gently lower the rear of the car until the rear tires are spinning against the glass

Lubrication

The first thing that comes into most people's mind when lubrication is mentioned is oil. There are many different types of oil, a topic worth researching. Also consider alternatives including: copper slip, silicone spray and even talcum powder!