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FDM Tutorial

You <u>MUST</u> complete this tutorial before using the FDM for the first time.

Overview

This is a **Dimension 1200es BST** rapid prototyping machine. This machine uses FDM (Fused Deposition Modeling) technology to build ABS plastic parts from solid models created in CAD programs such as SolidWorks. The FDM builds up solid models in successive layers, extruding a very small ribbon of molten ABS plastic. This is a fantastic tool for prototyping parts that are complex enough that they would normally need to be CNC milled, or have un-machinable geometry.

Because this machine and its controller are expensive and intricate, we require that students make an FDM License before they use the machine for their own projects. This tutorial will guide you through the steps needed to make an FDM License (and will give you tips to help you build any other FDM parts in the future). Once you have completed these steps, your name will be entered onto the FDM Approved Users List.

ABS is the model material used by the Dimension 1200es BST and produces parts that are both stable and durable. The Model material color that we use is Ivory, but it can be primed and painted however you'd like. The Breakaway Support material is a pale gray color. Realize that hand finishing will likely be required for many parts depending on their intended use. For many, however, a part straight from the machine is entirely suitable. Please see a TA for finishing suggestions.

Design Considerations and Limitations

Support Removal

This FDM uses *breakaway* support material to allow the machine to build undercut, hollow, or otherwise cantilevered geometry. After the build is complete, this material must be broken, chipped, or pried away from your model. This can be challenging with complex, fine geometry.

Minimum Feature Sizes

The software requires a minimum of 2 widths of extruded ABS ribbon to build a feature.

Z-axis resolution	Ribbon width	Double ribbon width (appx. min resolvable feature size)
0.010" (0.25mm)	0.024" (0.60mm)	0.048" (1.22mm)
0.013" (0.33mm)	0.028" (0.71mm)	0.056" (1.42mm)

Z-axis Resolution

Because this technology builds a series of flat layers in the X-Y plane (parallel to the floor) curvatures in the Z-axis are approximated. This machine can build in two different Z-axis resolutions: 0.010" and 0.013"—thinner layers will produce better curvature approximation, but take longer to build. In the images below, you can see how a thicker build layer (on the right) results in more curvature loss.
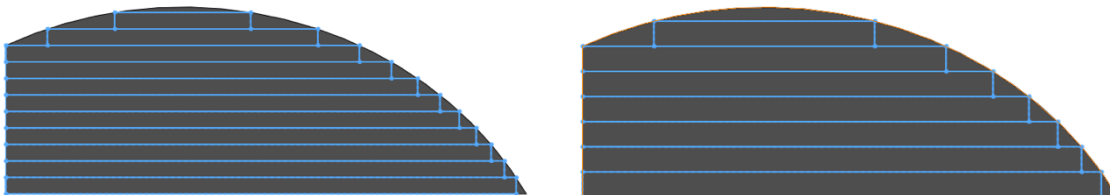

In the examples below, you can see how different build orientations result in drastically different curvature resolution. In the left image, the vertical curved sides of the shape will fully resolve and will be built quite true to the geometry. In the example on the right, the curved sides are lacking a lot of the refinement and detail of the original model.
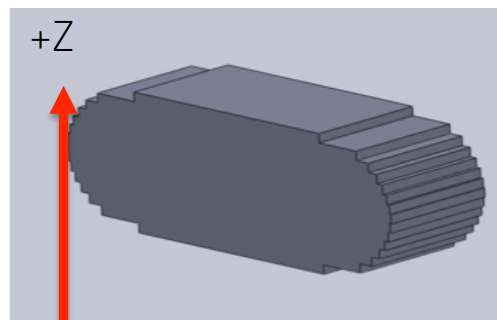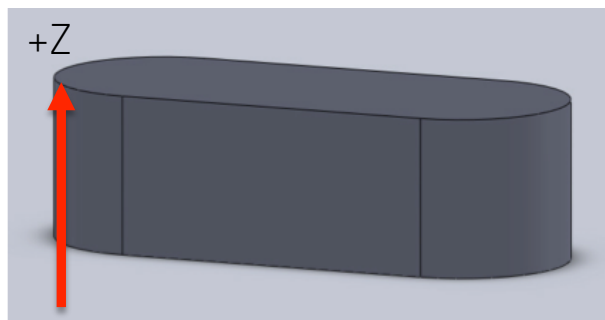
Simplify or Split parts for improved results

Here is an example of a small part with several lumens through it. To build this part in one piece, these lumens would fill with difficult-to-remove Support material. Instead, the part has been split and small alignment tabs and holes have been added. These tabs and holes will allow the part to self-align for gluing.
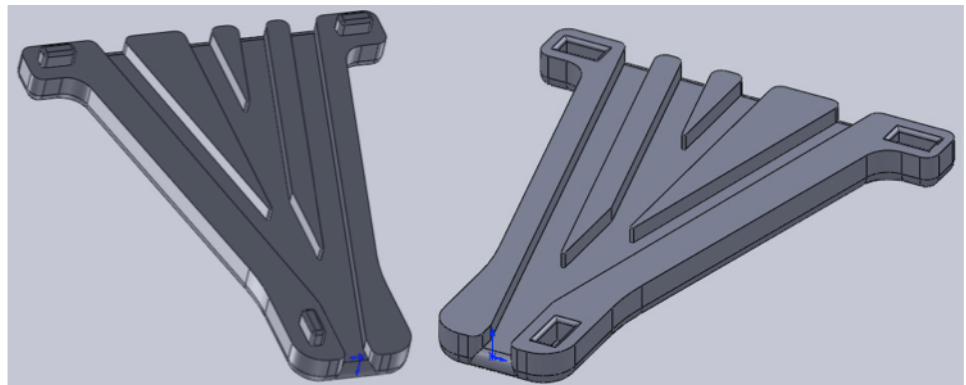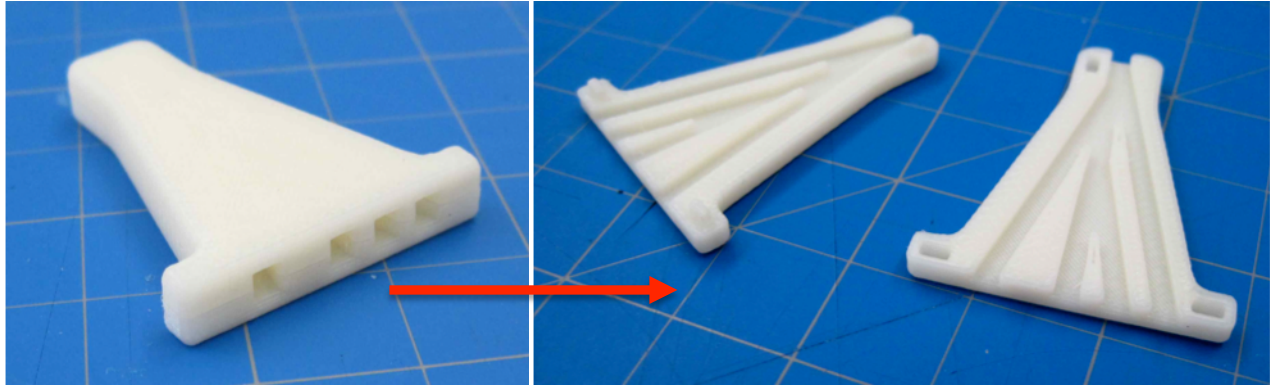
Making an STL file

Design your parts in CAD

You may create the parts that you would like to FDM in SolidWorks, which is available to all PRL users. The parts may alternatively be made in any other CAD program that can output STL files, including Pro/E, Catia, and SolidEdge, Inventor, etc.

Output an STL File from CAD

In SolidWorks, you can save either a .sldprt (part) or .sldasm (assembly) as an STL file. It is important to review the default settings of how SolidWorks will save your STL files. SolidWorks' default STL resolution is much coarser than the resolution available on the FDM – therefore, if you leave SolidWorks' default STL-output settings, the limiting factor in your part's resolution will not be the FDM, but the file. That would be a shame.

Increase STL File's Resolution in SolidWorks
The following will get SolidWorks to output a high-resolution, English-units STL file:
1. File ➔ Save As
2. Save as type ➔ Select STL
3. Click Options
4. In the Export Options window, verify that the output is set to Binary
5. Change the Unit dropdown to Inches (or Millimeters – but KNOW which unit system you're using—you'll need your units in the FDM software to match your STL units).
6. Move the Deviation slider to the right to maximize your STL file's resolution. Click OK to save your STL file.

Begin

Log in to FDM Computer
Log in to the computer using your SUNetID and password.

Locate your STL file(s)
Locate your STL file either on the Desktop, your AFS space, or an external storage device. *Previous FDM's used in the PRL required that your STL file be local on the Desktop. However, this machine stores your part in its own hard drive and is not affected by actions on the connected computer once the file has been received by the machine.*

If you are doing the FDM tutorial, use the PRL_FDM_TEST.STL file on the desktop.
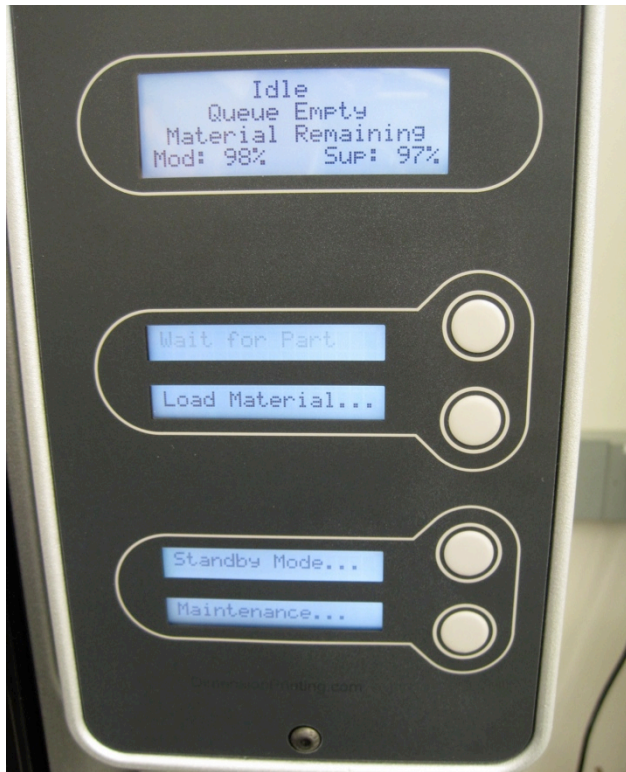
Turn on the FDM
Flip the switch in the lower right side of the machine if it is not already on.

As the machine turns on, you will see several initialization screens, and then it will sit on the following screen for a bit:

Once the machine has started up from OFF, it will sit in IDLE mode, with "Waiting for Part" flashing:

If the machine is at room temperature, it will take about 30 minutes before it has come to temperature and can begin building. There are no adjustments to be made—the required temperatures are hard set into this machine.
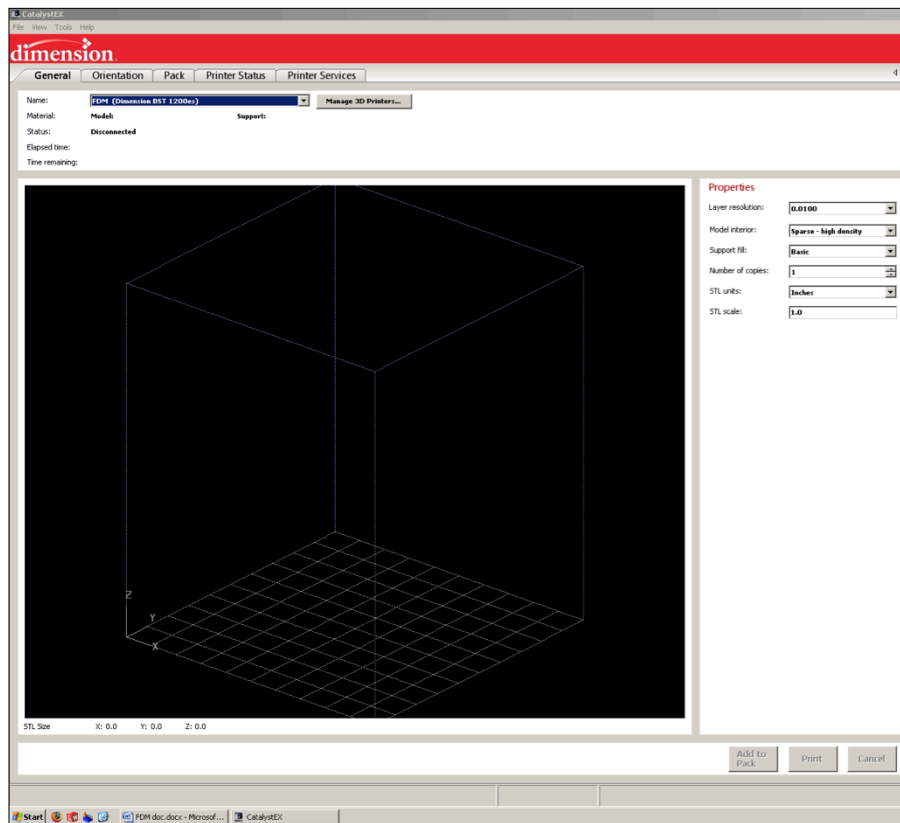
Preparing Your File(s) in the FDM Software - Catalyst

Start CatalystEX
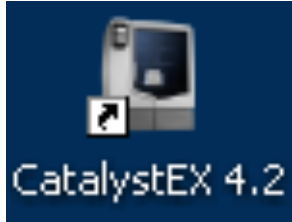
Catalyst is the program we will use to process STL files and send them to the FDM machine. It is only available on the computer next to the FDM machine.

Click the "**CatalystEX**" shortcut on the computer's desktop. When Catalyst opens, it will look like the image below:
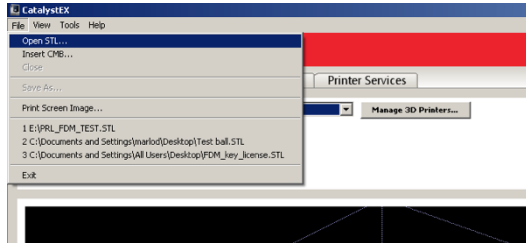

Your file will open in the lower left corner of the volume pictured here. This is NOT where your part will be built, but in only the default position. This image shows the 10"x10"x12" build volume.
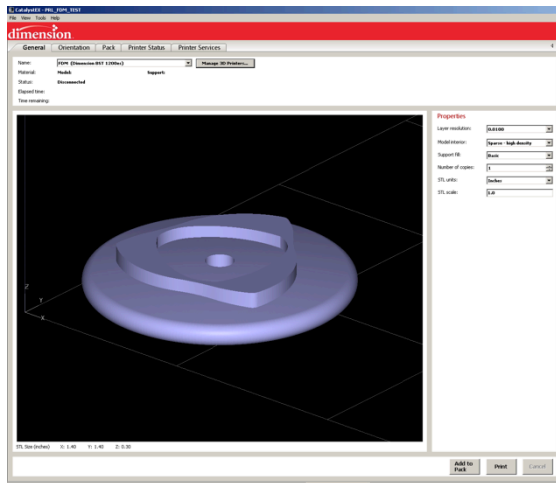
Open Your STL File

From the **File** menu, open your STL file.
If you are doing your FDM License part, open PRL_FDM_TEST.STL from the desktop.

Your part will appear in the FDM coordinate system as a shaded model.
Verify by zooming out that your part is approximately scaled correctly. The marking in the X-Y plane are on 1" increments.

Note: The tutorial part that you will open may have changed! That's ok!

The toolbar below the Dimension logo in the upper left corner of the Catalyst window has 5 tabs, though the first 3 are the most important:
-**General**: This is where the build properties are set.
-**Orientation**: This is where you can re-orient you model to the ideal orientation for building. An "ideal" orientation depends on part geometry and how the part will be used.
-**Pack**: This is where you will determine the build position of your model in the build envelope.
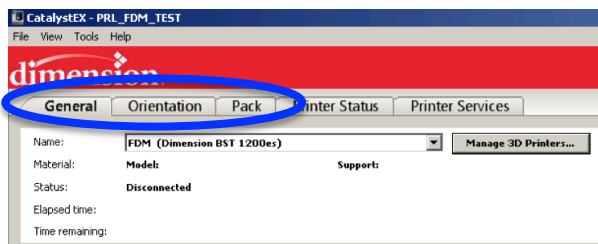
## Defining Build Properties – "General" tab

Layer Resolution:

You can choose between 0.010" and 0.013". As discussed earlier, 0.010" layer resolution will give you a more accurate approximation of your model, but will take longer to build. 0.013" resolution is a great build option for larger, simpler, or rougher models. 0.013" resolution will build much more quickly, and will use a bit more material.
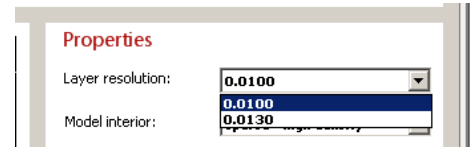
> TUTORIAL: Choose 0.010" resolution

Model Interior:

-**Solid**: We strongly advise that you do NOT build Solid parts. This build method is very slow, uses a lot of material (=very expensive), and can lead to stress in your part that can cause warping.
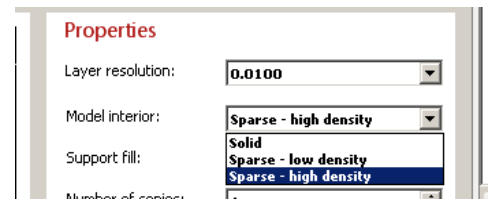
-**Sparse – low density**: Low density Sparse parts are built with an ~0.080" thick solid shell, and an ~30% fill interior of intersecting rows of material. This is the fastest and least expensive models to build. Low density Sparse parts will be structurally sound, but will not have the strength of a denser build.

-**Sparse – high density**: High density Sparse parts are also built with an ~0.080" thick solid shell, but with an ~70% fill interior of intersecting rows of material. These models are a good compromise of build speed, material usage, and strength.
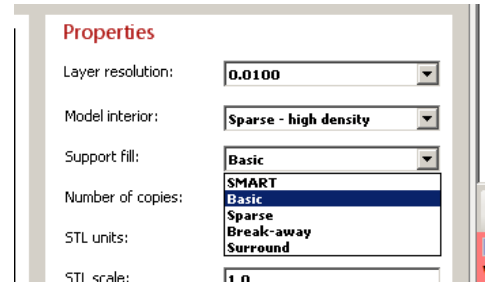
> TUTORIAL: Choose Sparse – low density

Support Fill:
-**SMART**, **Basic**, **Sparse, and Surround**: These are all meant for different types of FDM machine and will not work with the Dimension 1200es BST. **DO NOT SELECT THESE!**

-**Break-Away**: Support with perforations for easy removal.

ALWAYS Choose Break-away!

Number of Copies: This allows you to generate multiple copies of your model. Generally this will be left at 1.

TUTORIAL: Choose 1

STL units: Leave on Inches.

STL scale: Generally this will be kept at 1.0

Defining Build Orientation

Click on the second tab at the top of the window, "**Orientation**".

Here you can adjust which face or features are facing up in the **positive Z direction**. Refer to the "Overview" section above for some additional background on ideal orientation.

Use the X, Y, and Z axes buttons to rotate the model AROUND that axis by the degrees listed in the dropdown box.

You can add custom degree increment by overwriting the drop box. You can also select a **FLAT** face on your model to use to orient to Top, Bottom, or Front. (STL files generate a series of flat triangles to approximate your geometry – and if you select a CURVED surface here, it will find A flat triangle and tip your part up into a jaunty angle.)

You may find it easier to adjust your model's coordinate system in SolidWorks if you have a complex geometry that you are struggling to align in the Catalyst window.
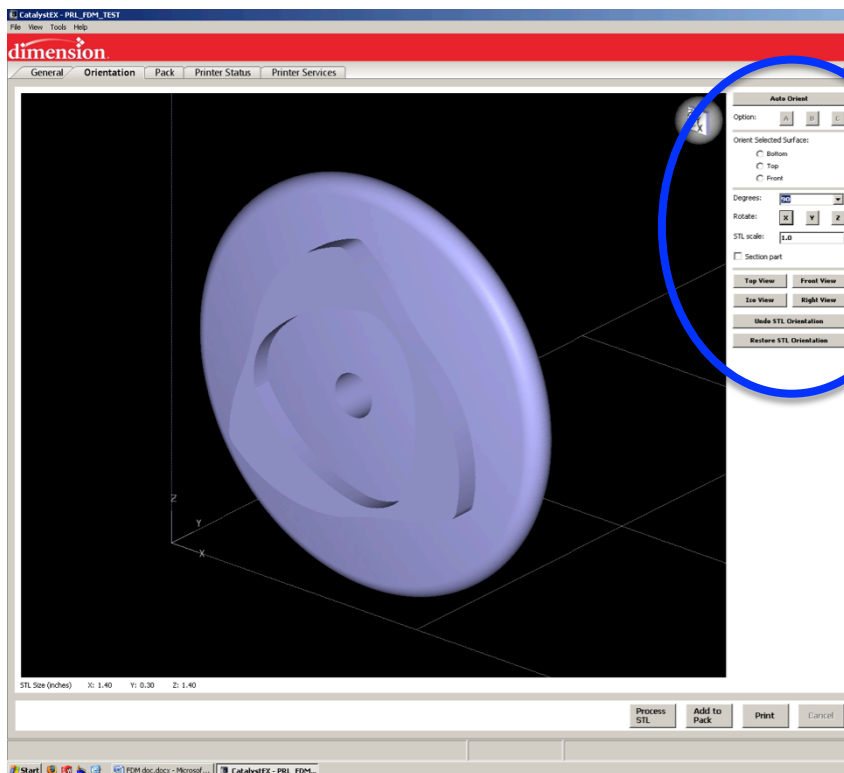
Once you have achieved your desired part orientation, Click "**Process STL**" in the bottom right corner of the window:
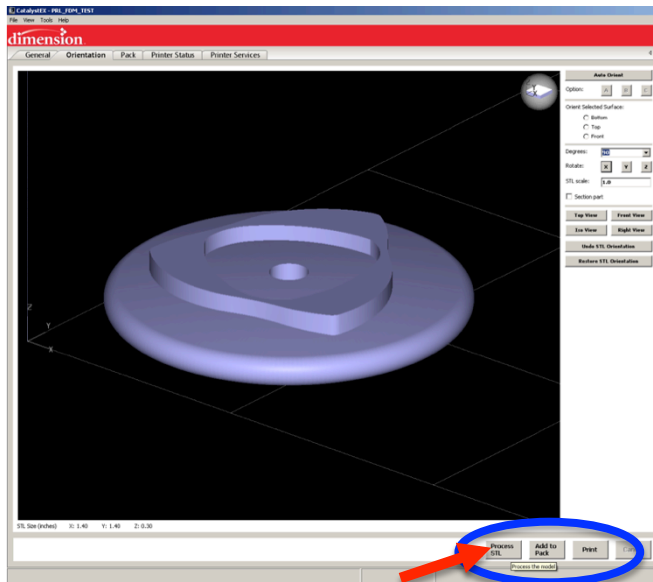

The STL processing can take a few minutes if you have a large model.
At this point your part will be saved as a CMB file type in the same directory as your original STL.

Once it has completed processing, your model will look something like the image below. The red lines indicate **Model** material, and the lavender lines indicate areas where **Support** material will be extruded. Once you've processed your STL, you can go back and change your build properties or your part orientation and re-process and re-save the CMB to incorporate the changes.
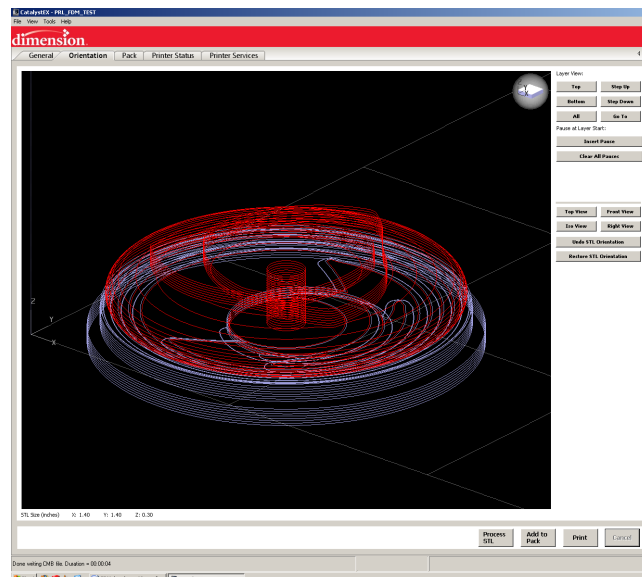
Using the "**Layer View**" buttons along the right side of the window, you can slice through each of your build layers to evaluate how the various build parameters will affect your part model. The Model material is shown in green, and the Support material is shown in cyan:
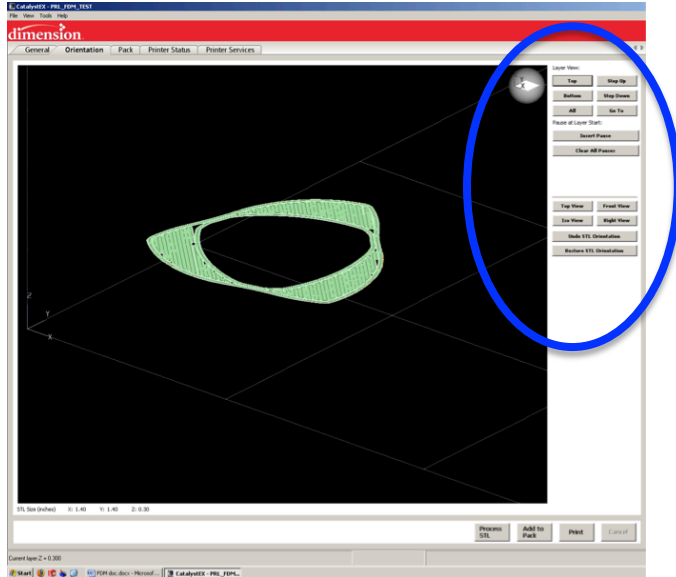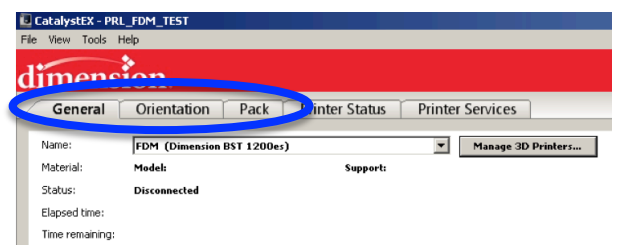

Press the Step Up or Step Down buttons (or "Page Up/Down" on the keyboard) to step through each build layer. You will notice how your geometry, particularly on 3D curves, is simplified or blunted by the software.
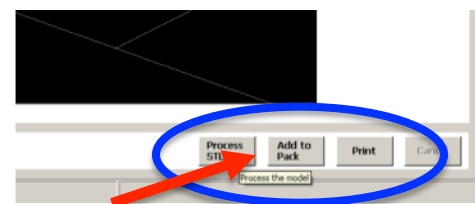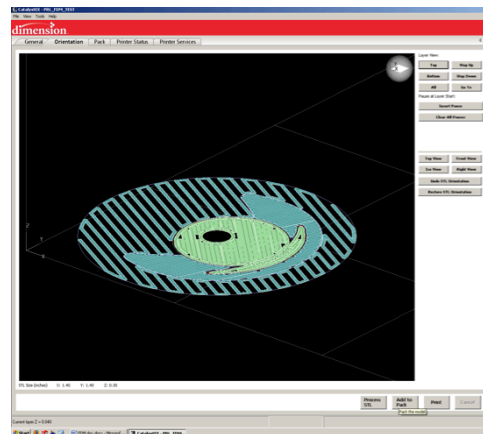
Once your STL is processed and you are satisfied with the build parameters, click "**Add to Pack**".
Click on the 3rd tab at the top of the window:
Pack

Managing the Pack

Here is the "Pack" or the build envelope.
The lines on the white square model base in Catalyst correspond to the grooves in the black plastic model bases. Take a look at the build platform that you will be using, and move your model around to most efficiently use the build platform space. The bottom edge of the screen corresponds to the front handle of the black build platform.

The build platforms are a reusable consumable. Ask a TA if you are unsure if the platform you plan to use is in good shape—you want some of the fine texture of the platform to still be present.

Try to avoid the 4 circles indicated in this screen (these circles are not physically present on the black build platform) **unless you are unable to locate your part elsewhere**. These locations are used by the machine to self-calibrate the z-height of the build platform, and when a model has been built in these areas, material residue left in those areas on the surface can prevent the machine from properly calibrating and the model base `cannot` be re-used. We do not want to be wasteful, so be thoughtful here!
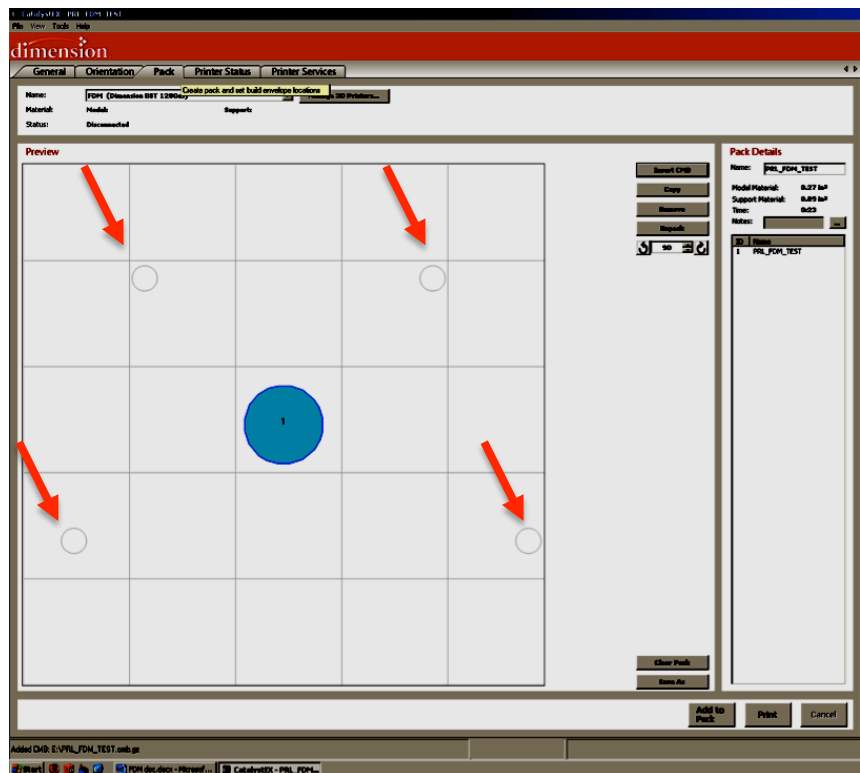

Click on the part and drag to relocate it.

At this point you can add additional parts to the Pack. If you see black cross-hatched lines over your parts, then they are too close together and need to be repositioned.

Go to **File → Insert CMB**, and any other STL files that you have processed into CMB files can be inserted into the Pack.

Notice under "Pack Details" that the Model and Support material volumes are listed (circled in **BLUE** below), as well as an estimated build time. Most likely, you will be surprised at how long the build time is! At this point you can still go back and reconfigure your build parameters to build your part more coarsely/sparsely.
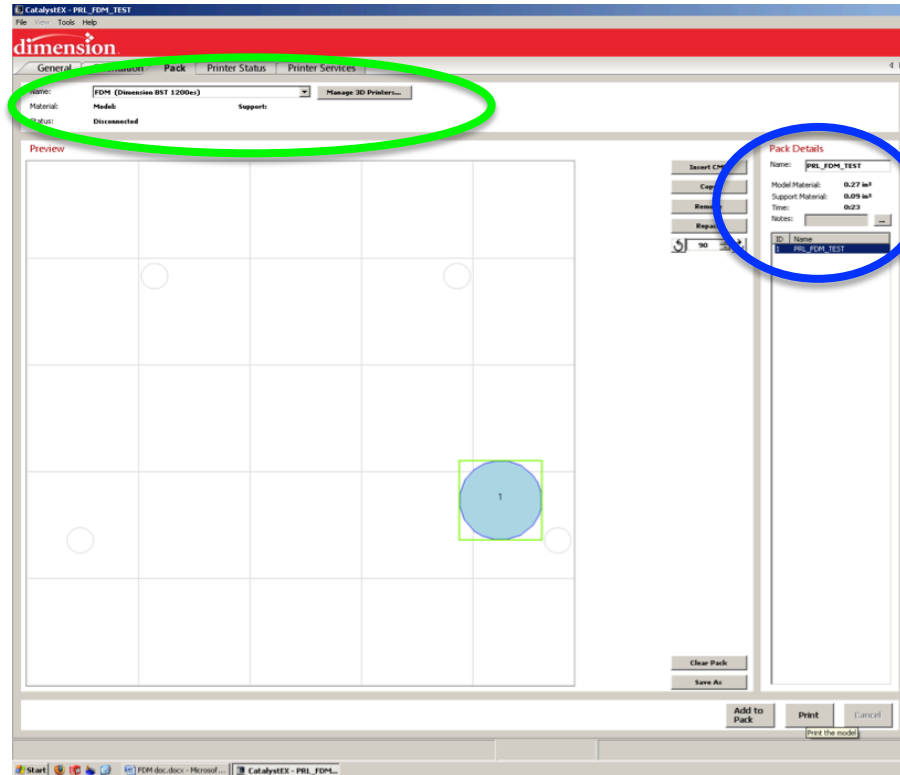
Important: Verify that the Model and Support material volumes (indicated by the **GREEN** oval above) are GREATER than the Model and Support volumes required by your Pack. If there is not enough material remaining, the material CAN be replaced in the middle of your build, but it is best to let the TA know.

Ask the TA on duty for an FDM confirmation card.

Fill out your FDM confirmation card with the build volume and time information found in the "Pack" window and show it to the TA. The card will look something like this:

Starting the Build

*NEVER touch any parts of the machine that are not buttons, the build platform and latches, and the purge bucket at the back of the machine.

*You **MUST** make enough consecutive reservations (**ACTUAL** reservations, not waitlist) to cover the build time of your part.

Pay For Your Part
Pay the TA on duty for the total model and support material your part will use, BEFORE it starts running. The FDM Confirmation Card will list the appropriate material price per in^3. If you are doing the FDM license part, you do not have to pay for the material you use.

Sending your Pack to the FDM
All that's left is to build your model.

If the machine is in Idle mode, "Wait for Part" will be flashing. Press the button next to "Wait for Part".

You will be asked if a Model Base is installed. If so, Select "Yes". If not, select "No" and you will be prompted to insert a model base. Verify that the two **BLUE** tabs are in the vertical position to retain the black build base.
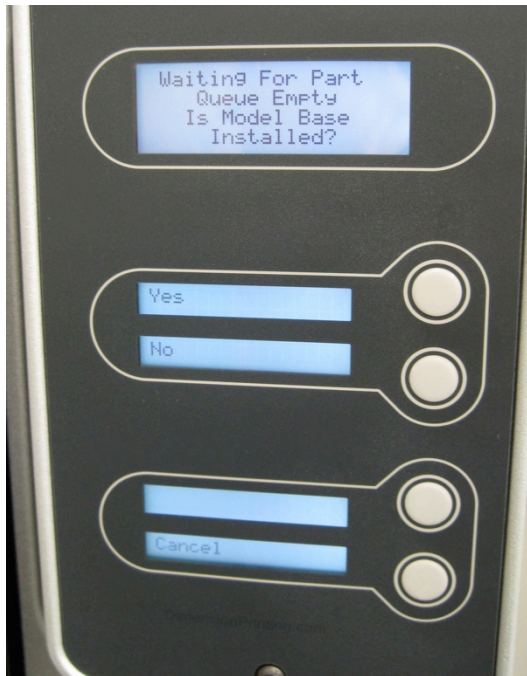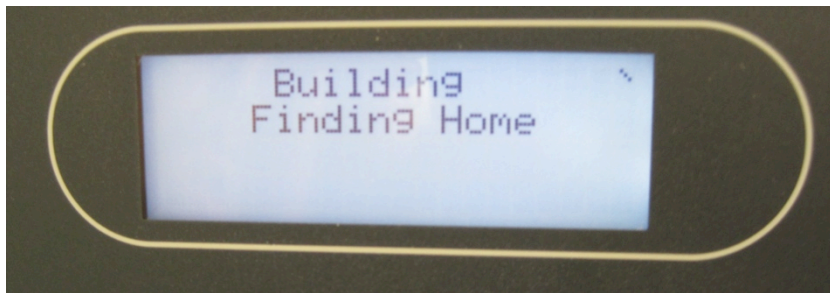
Once you've told the machine that a build base is in place, the machine mode will be "**Waiting for Part**".
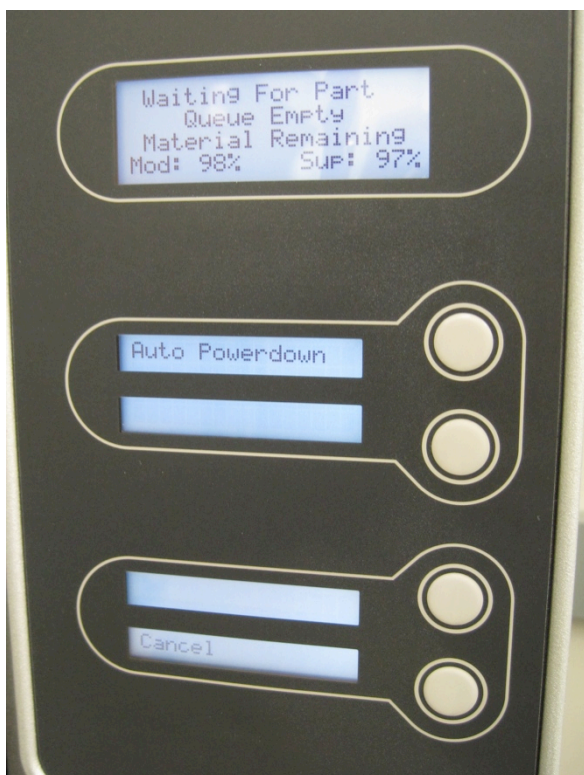

Go back to the computer: in the lower right corner of the Catalyst window, press "**Print**".

After your part has been sent, the machine will go through an initialization sequence.


Once the part has been sent, the machine will begin warming up. The M and S temperatures indicate the temps at the Model and Support tips. In Idle mode, these will be at about 100C, and will need to heat up to about 300C. The E, or Envelope (space inside the machine) will be at about 70C in Idle mode (or cooler, if you have just turned on the machine), and will heat up to about 75C before beginning to build.
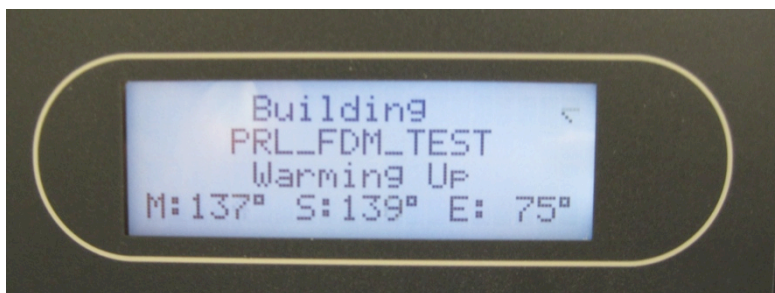
Once the machine is warmed up, your part will immediately begin building.
Watch it for a couple of minutes to make sure that the build starts without issues.
Post your FDM confirmation card on the front of the machine with the clipboard.

Once the part is running, you can Pause the build, turn off the machine lights, Show Material or Time Remaining, and set up **Auto Powerdown**.
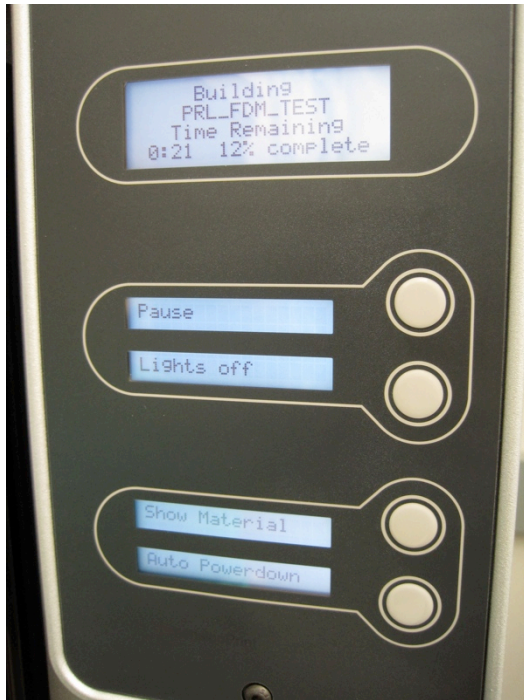
Most parts that will be built on this machine will require many hours of build time**. Auto Powerdown** should be used to prevent overheating and excessive wear on the machine. Once your part has begun building successfully, press the button next to "**Auto Powerdown**", and when prompted, turn **OFF** the machine in the lower right corner. The machine will continue running until it has completed your build and completed its cool down cycle.

If you want to get OUT of Auto Power down mode, simply turn the switch back on.

Removing the Part

Return to the shop close to when your part is due to finish. You will know it is finished when the main LCD reads "Completed".

Please try to come back to Room 36 when you expect your part to be done. If you are not here when your build is complete, it will be removed from the platform on your behalf. We try not to leave completed parts on the build platform.

You will see "Remove Part and Replace Model Base" flashing when you come to pick up your part.


The door will have unlocked itself, and you can open the door and remove the black build base. If the machine is still on, the surfaces inside the machine will be **HOT**! Even if you used Auto Power down and the machine is cold, you should not touch ***anything*** inside the machine except for the blue tabs holding the model base in place and the black build base.

Put on gloves and pull the black build platform out of the FDM by rotating the two blue locks holding it in place and sliding it straight out of the machine.

Remove your part from the black model base by first twisting or bending the platform (this is easier when the platform is warm) or using a putty knife to scrape your part off the base. The stick blade is reserved for TA use ONLY! If you are having trouble removing your part, ask a TA for help.

To use the putty knife, place the build platform into the plywood platform-holder on a stable table surface. Hold the putty knife with BOTH hands at a low angle to avoid gouging the build plate or your part. **However tempted you may be, do NOT put your hand in the line of the putty knife's travel!** This is a guaranteed injury, and we like to avoid those.
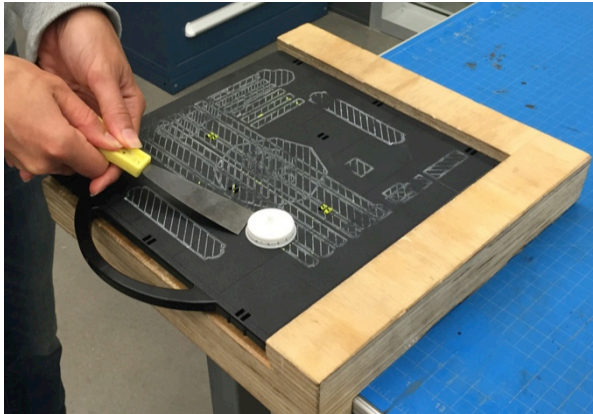
You can remove all other support material from your part with various hand tools.
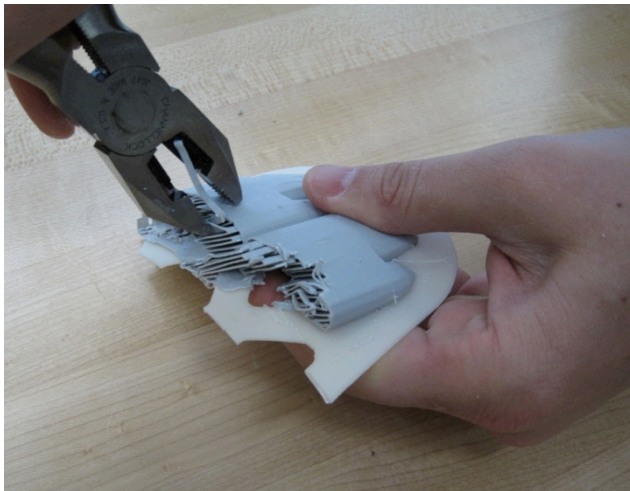
Clean Up and Shut Down

-If no one is going to be using the machine immediately, turn off the machine by toggling the switch in the bottom right corner of the machine to OFF.

-Carefully remove the tall black purge bucket in the back right corner on the inside of the machine by lifting it up and out from the back wall. Remember, if the machine has recently been running, all of the machine surfaces will be hot.

-Clean up the surrounding area, put away all tools, and sweep the floor.

-Show the completed license to the TA on duty who will enter your name onto the FDM approved users list.

-Ask the TA on duty to check out the machine and give you a 5-minute shop job!

Once you have completed your license part, you are free to use the machine for your own projects. If you find errors or problems with this manual, please report them to a TA.