# 3D Printing Design Guidelines
# Sierra College CACT

CACT
Centers for Applied Competitive Technologies

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## *Scope of this Document*

The purpose of this document is to present a list of capabilities and design guidelines for effective use of the Dimension 3D modeling printer services offered by the Sierra College Center for Applied Competitive Technologies (CACT). The CACT assists designers and entrepreneurs in making prototypes for one time or small number production builds. This document represents, in a number of tables and figures, typical results of objects designed and “printed” by the printers, but should not be taken as definitive results for any specific design as the number of relations between these guidelines are too large to document.

The intended purpose of the printers is for building prototypes. Any parts and assemblies built by these printers are presented to the designer “as is” and no expectations of the devices in the field should be made. Sierra College CACT offers these services as a prototyping service and DOES NOT WARRANTY parts put into any kind of service. It is contingent upon the designer that parts are designed properly, properly used, and that each part is checked for compliance in the particular application. It is not the responsibility of Sierra College CACT to verify any design beyond assessing its build ability on the printers from a software format position. It is also not the responsibility of Sierra College CACT to inspect or verify parts for any specific mechanical properties or performance.

Finally, this document should be considered a work in progress due to continual machine, software and technology upgrades as well as information gleaned from lessons learned and, therefore, the designer should check with the CACT for the latest revision of this document.

## *General Overview*

Sierra College has two models of Dimension 3D rapid prototype printers: the BST 768 and the SST 1200. More specific information on these devices can be found at http://www.dimensionprinting.com/. However, general information is provided here for reference.

The build process for these machines is based on the extrusion of a melted ribbon of ABS plastic through a process called Fused Deposition Modeling (FDM). The ribbon is extruded in successive layers in the Z axis to build the model up. "Support" material is extruded at the same time to hold the ABS ribbons in place as they cool. The important distinction here is that this process is an additive process and not a removal process, such as is typical for traditional machining.

As a result the process has both strengths and limitations. Some models will be very manufacturable using FDM but may prove very difficult using traditional machining (subtractive) processes. Although the model material is quite strong, typical performance of ABS with respect to material properties should not be used. The level of cross lattice bonding of the polymer ABS that is typically available in the material is not available in FDM and, therefore, standard documentation on the performance of ABS must be applied carefully.

The BST Machine has a total build plate of 8" x 8" x 12" inches. This size includes any needed support material, so actual parts may need to be smaller to provide proper support of the model as it is being made. The SST Machine has a total build plate of 10" x 10" x 12" inches.

The SST machine also requires room for support material so actual part size may be smaller depending on the need for support material around the outer edges during production. The amount of build material needed is dependent on the model design and orientation of the part during the building process. The Sierra College CACT will help you determine if your design will fit on the plate, or if it needs to be divided into several pieces and assembled afterwards.

The reference geometry for the printers defines the X-Y plane as the machine gantry axis (8 x 8 inches for the BST and 10 x 10 inches for the SST), and the Z-axis as the build up layer (12 inches for each machine). Models are oriented on the plate to minimize the use of plastic material. If a specific axis orientation is desired, please make note of that when requesting an evaluation of the prototype build.

The standard color of ABS material used in the SST and BST machines is white. Parts can be sanded and painted for specific color matching. Different colors are available but may incur additional fees: Black, White, Green, Yellow, Grey, Blue, Red.

## *File Format*

The only file format compatible with the pre-processing software of the Dimension Printers CatalystEX is STL. This format is generally available on most major CAD software packages. Conversion of different file formats to STL may be possible by Sierra College CACT but the responsibility of checking the output is on the part of the designer. Specific settings and instructions for each CAD package to generate the file are not presented here. However, general guidelines are as follows:

- The STL must be a single file for each part. This is usually a setting in the CAD system and is generally only needed for assemblies and not individual parts.
- Multiple parts can be made by the printer at the same time, including parts of a different design. However, each part must have a single and separate STL file.
- Assemblies with some captive moving parts must also be provided in a single STL file.

NOTE: Although the printers can build multiple parts at the same time, the overall processing space on the build plate must be kept in mind. Support material between each model will reduce the usable modeling space depending on part design.

## *SST Support Material*

The SST line of Dimension Printers uses a support material that is soluble in a water/lye batch solution. The support material is used to fix in place the ABS ribbons as they are extruded in each layer. This includes the part mounting to the build plate. The "water" soluble nature of this support material poses benefits and drawbacks, some of which are listed below. This section also contains design guidelines for feature sizes and spacings in both the Z and X-Y build directions.

BENEFITS

1. Models with internal features

   In comparison to the BST machine, the SST allows for internal structures and cavities that must be cleared of support material (e.g. a cork screw or a T-Slot through a block of ABS). BST support would be impractical because reaching inside the model to chip out the support would be very difficult.
2. Delicate Model Features

   The water soluble support material allows for slow and gentle removal. This virtually eliminates any mechanical stress on the features when extracting the model from the support material and build plate. As a result the fine feature sizes above the aspect ratio declared for the BST process can be obtained with the SST process.

DRAWBACKS

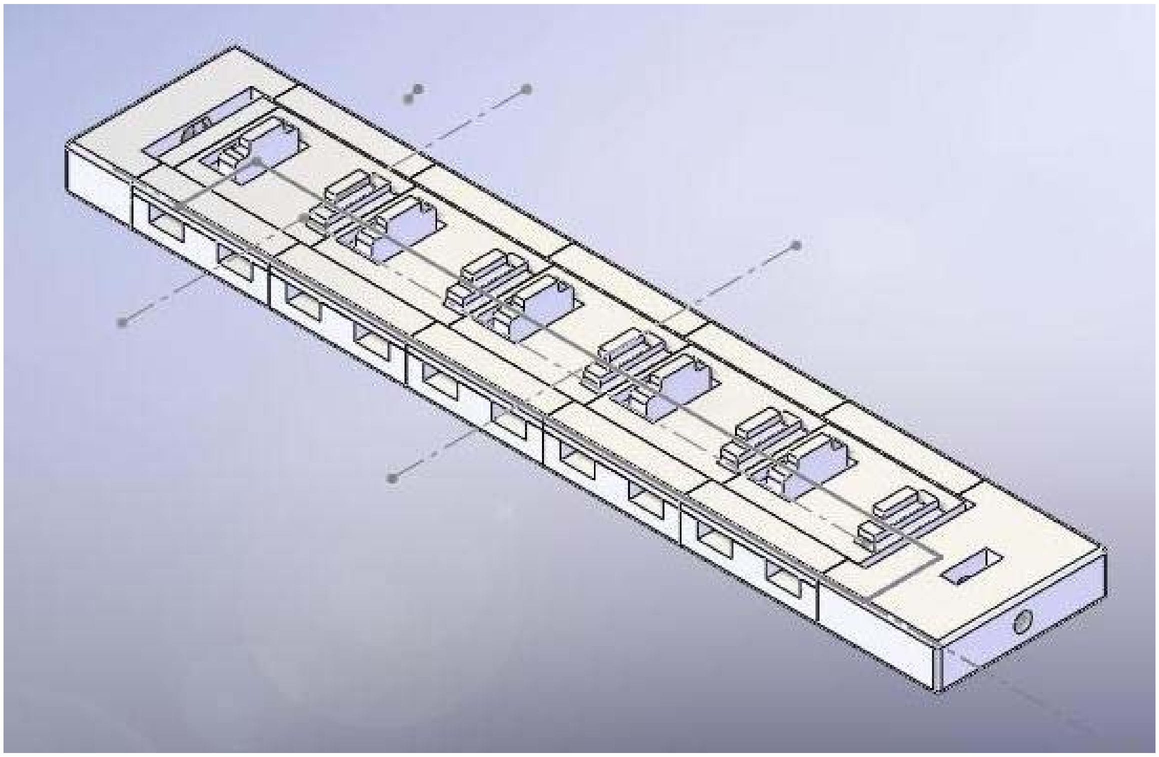
1. The SST process has a much slower support material removal process (usually greater than one day). In the case of the SST support material, manual removal is very difficult. The material adheres to the model ABS much more strongly and, therefore, is much more difficult to chip away.
2. Although the SST material is very rigid and difficult to chip away, it is brittle and forms sharp pieces when it is chipped away or becomes frayed on the edges of models. This may pose handling problems with prototype parts.

In order to get good results from the unique benefits of the SST process, the following guidelines in this section should be kept in mind. Because of the infinite variety of geometries and requirements of the models being prototyped, this guide is not to be considered as all inclusive, but as a good starting point for the designer. Specific points of the design that may be in question should be referred to Sierra College CACT (www.sierracollegetraining.com/contact) or Dimension at http://www.dimensionprinting.com/.

### *Venting Internal Cavities*

The SST dissolving process is a chemical reaction and requires a diffusion mechanism in the design of the product. If the support material cannot be accessed effectively by the solvent fluid, then it will not be removed effectively. However, if the internal cavity uses support material for weight reduction or reducing the amount of build material, the removal of support material may not be an issue. The support material is light weight and quite strong but, as mentioned above, is brittle and can pose a hazard to handling if it becomes damaged.

If the product requires the removal of the internal support material, a venting system should be incorporated into the design. The following visual demonstrates the application of venting.



*The 10 rectangular venting ports along the side were designed into this assembly to allow for venting of the support material from internal cavities.*

## *SST XY Axis Design Rules*

The following table depicts the effective feature sizes of the SST machine. Limitations are a result of the width of the ribbon extruded to build the model. For instance, model feature sizes that are smaller than the ribbon thickness will either be oversized to the ribbon width or will not be attempted by the machine. Below Φ represents the designed feature size of the model.

In contrast to embossed, cut structures do not suffer from the finite width of the extruded ribbon unless the spacing between cuts falls into the category of the embossing criteria. As a result, spacing within cuts can be managed to a finer resolution.

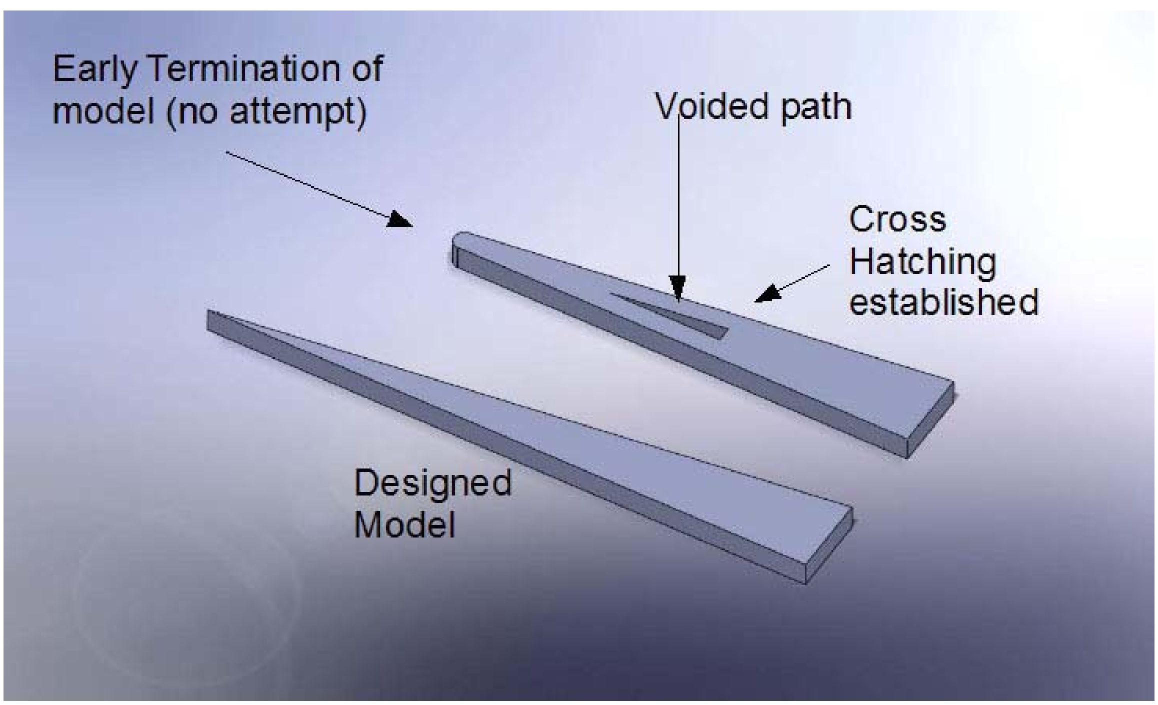
**EMBOSSED**

| Design Feature Size Width X,Y "Φ" | Printer Feature Size | Comment |
|---|---|---|
| Φ < .030 | - | No attempt made |
| .020 < Φ <.040 | .040 | |
| .040 < Φ < .055 | Φ | With voided path |
| Φ > .055 | Φ | Cross hatching established |

**CUT FEATURE**

| Design Feature Size Width X,Y "Φ" | | |
|---|---|---|
| Φ < .010 | - | No attempt made |
| .010 < Φ | Φ | |

The following figure shows the stages of printer limitations listed above. A wedge part was designed so that the gradual taper of the part would force the printer through all of the above regions. The lower model is the "as designed part" and the upper is a graphical representation of the part as it was made by the printer.



### *SST Z Axis Feature*

The Z axis also has feature interpretation. As the ribbons are deposited on the model, the build will proceed in incremental steps. The following table represents the fine feature stepping that will be developed in the Z axis. This will become most obvious in cases where curves or vertical slopes appear in the model. A staircase topology will be evident in such models due to the finite thickness of the modeling material. Although this is only a very small effect due to the thin nature of the Z axis layers, it should be kept in mind by the designer.

| **Designed Feature Size<br>Embossed Z axis** | **Printer Feature Size** | **Comment** |
|---|---|---|
| $\Phi < .010$ | - | No attempt made |
| $.010 < \Phi$ | Stair Steps at .013 | |

## *SST Text Characters*

Due to the complex shape and structure of text, it falls into both Feature Size (width of text lines) and Feature Spacing (spacing between lines and letters) requirements. In addition, text is often viewed or defined differently than typical structures in mechanical devices. Therefore, specific design guidelines are set here for text. If a specific text or logo is important, a test ingot can be designed and checked for satisfactory readability. Listed below are a set of fonts and their necessary point size for good reproduction on the part.

| FONT | NORMAL | BOLD | ITALIC |
|---|---|---|---|
| Ariel Embossed | 20pt | 16pt | 16pt |
| Ariel Cut | 16pt | 16pt | 16pt |

## *BST Support Material*

The BST line of Dimension printers uses a support material that is broken away when the model is complete. Like the SST printer, the support material is used to fix in place the ABS ribbons as they are extruded in each layer. This includes the part mounting to the build plate. This section contains design guidelines for feature sizes and spacing in both the Z and X-Y build directions.

In order to get good results from the BST process, the following guidelines in this section should be kept in mind. Because of the infinite variety of geometries and requirements of the models being prototyped, this guide is not to be considered as all inclusive, but as a good starting point for the designer. Specific points of the design that may be in question should be referred to Sierra College CACT (www.sierracollegetraining.com/contact) or Dimension at http://www.dimensionprinting.com/.

### *Venting Internal Cavities*

The BST process uses a breakaway support material. Venting is limited to the model's design ability to enter internal crevices with tools to break out the material, and the feature sizes in the model with respect to their ability to withstand mechanical stress. For fine features or internal cavities that cannot be effectively reached, the SST machine should be considered.

## *BST XY Axis Design Rules*

The following table depicts the effective feature sizes of the BST machine. It should be noted that the printer builds models by extruding thin ribbons of ABS plastic on an XYZ gantry-based build plate. Model feature sizes that are smaller than the ribbon thickness will either be over sized to the ribbon thickness or will not be attempted by the machine. Below Φ represents the expected output of the model based on the designed feature size. The cut features do not suffer from this same issue unless the spacing between cuts falls into the categories outlined as embossed features.

**EMBOSSED**

| Design Feature Size Width X,Y "Φ" | Printer Feature Size | Comment |
|---|---|---|
| Φ < .020 | - | No attempt made |
| .020 < Φ <.040 | .040 | Effective ribbon size |
| .040 < Φ < .055 | Φ | With voided path |
| Φ > .055 | Φ | Cross hatching established |

**CUT FEATURE**

| Design Feature Size Width X,Y "Φ" | | |
|---|---|---|
| Φ < .010 | - | No attempt made |
| .010 < Φ | Φ | |

## *BST Z Axis Feature*

The Z axis also has feature interpretation as ribbons are deposited on the model will proceed in incremental steps. The following table represents the fine feature stepping that will occur in the Z axis. This will become most obvious where curves or vertical slopes appear in the model. A staircase topology will be evident in such models due to the finite thickness of the modeling material. Although this is only a very small effect due to the thin nature of the Z axis layers, it should be kept in mind.

| **Designed Feature Size Embossed Z axis** | **Printer Feature Size** | **Comment** |
|---|---|---|
| $\Phi < .010$ | - | No attempt made |
| $.010 < \Phi$ | Stair Steps at .013 | |

## *BST Text Characters*

Due to the complex shape and structure of text, both Feature Size (width of text lines) and Feature Spacing (spacing between lines and letters) requirements must be considered. In addition, text is often viewed or defined differently than typical structures in mechanical devices. Therefore, specific design guidelines are recommended for text. For specific text performance, the designer may want to consider making a test ingot with the text or graphic desired for readability. Listed below are a set of fonts and their necessary point size for good reproduction on the part.

| **FONT** | **NORMAL** | **BOLD** | **ITALIC** |
|---|---|---|---|
| Ariel Embossed | 18pt | 14pt | 14pt |
| Ariel Cut | 14pt | 14pt | 14pt |