MANUFACTURING SERVICES OVERVIEW FOR STUDENT PROJECT WORK

RENSSELAER POLYTECHNIC INSTITUTE

SCHOOL OF ENGINEERING

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Introduction

This guide is addressed to all faculty/staff, teaching assistants, and students seeking manufacturing and fabrication assistance such as water jet cutting, laser cutting, rapid prototyping, and general machine shop services within the School of Engineering to support academic related projects. Research machining services are supported by MultiMedia Services Research & Development Machine Shop (http://mms.rpi.edu/shop.html) located in the basement of the Jonsson Rowland Science Center (J-ROWL).

This document introduces topics such as tolerances, costs, location, etc. related to the specialized manufacturing equipment in use within the School of Engineering. Preparing CAD/CAM files for use on the machines, submitting payment for machine usage, safety guidelines, and pickup instructions can be found in other documents. See the Related Documents section. The content may be revised in response to new information and observations on the use of the resources covered.

Safety Guidelines

All users of fabrication equipment are required to review the School of Engineering safety guidelines (available on LMS), and then pass the School of Engineering Safety Quiz (available on LMS) for the current semester. If a user is not enrolled in a current course that requires the completion of the safety quiz, please see the Shop Supervisor or Manager of Fabrication for assistance.

Related Documents

This document references several manufacturing forms. Some of these are required for fabrication. See Table 1. All forms can be found online at the following URL:

http://homepages.rpi.edu/~morrij5/CAM/

Table 1: Manufacturing Document Locations

Document Name	Location
Manufacturing Services Overview	WEB ONLY
CAD Modeling Translation	WEB ONLY
3DP Order Form	JEC 3rd FLOOR HUB & WEB
AWJ Order Form	JEC 3rd FLOOR HUB & WEB

Student Machine Shop (Located in JEC 1010)

The JEC Student Machine Shop is a primary resource for students seeking manufacturing assistance for construction of prototypes to support project work in a variety of engineering classes. The shop is staffed by Mr. John Szczesniak, Shop Supervisor and a group of undergraduate teaching assistants available to support students seeking the services of the shop. Students are welcome to use this resource during the weekdays anytime the shop is open. However, scheduled classes such as Engineering Process have first priority during class times. The shop does have open hours weeknights and on Saturday. Check the posted hours on the lab door for availability. Services in the shop are as follows.

General Machining

Machine tools and tooling for milling, drilling, sanding, sawing, and turning are available.

Laser Cutting

Laser cutting uses a laser to vaporize or chemically ablate materials. A laser is an intensely focused, coherent stream of light. Lasers can be used for joining, heat-treating, or fabrication. The laser cutting system in the student shop is used for engraving and cutting. The system can be used with acrylics, wood, fabrics, glass, leather, marble, stone, rubber stamps, paper products, coated metals, and certain plastics. Figure 1 displays the current Pinnacle M-Series laser cutting system available in the shop.

Figure 1: RPI Laser Cutting Machine showing sheet work piece (in white)

Table 2: Laser Machine Properties

Model	**Pinnacle M-40**
Laser Source	**40 Watt Sealed CO_2 Laser**
Max. Work Area	**25" × 18"**
Speed Control	**Adjustable 0.01 to 42 in./sec, Up to 16 color linked speed settings/job**
Power Control	**Adjustable, Up to 16 color linked power settings/job**
Z-Axis Control	**Automatic (Auto Focus)**
Resolution (DPI)	**1000, 600, 500, 300, 250, 200**
Avg. Turnaround Time	**Same Day**

Laser-Cutting Cost and Use Policies

The laser in the JEC Student Shop is available for use free of charge. Users must supply their own material for cutting. Most parts, especially plastic, are cut in less than 1 minute of operating time. The approximate cut time of a 2” diameter circle of 1/8” thick acrylic is 45 seconds. The maximum thickness of material that can be cut is 0.25”.

Materials typically cut on the laser include certain types of plastics (see the TA or Shop Supervisor), hard and soft woods, rubbers, and cardboards. Anodized aluminum sheets, plastics, woods, and cardboards can be engraved. Because the laser-cutting machine provides a level of cutting precision and versatility not easily attainable on band saws or table saws, please refrain from using the laser cutting resource to cut parts that could be as easily cut using a regular shop tool. The course faculty reserves the right to refuse parts from the laser machine in the interest of allocating the resource to uses that require the capability and precision of the cutting process. For example, simple linear or rectangular cuts requiring loose tolerances may be refused.

CAD File Preparation for Laser

The laser system uses CorelDRAW as the CAD/CAM interface. CorelDRAW prefers the file to be in the AutoCAD™ Drawing (*.dwg) or Drafting Interchange Format (*.dxf). To create these formats from SoE supported CAD/CAM systems, the following steps should be followed:

1. Create an engineering drawing of the part you want cut.
2. Adjust the drawing to 1:1 scale
3. Remove all drawing formats including
   a. All annotations or notes
   b. All axes, centerlines, and dimensions
4. Prepare the drawing for one view only (usually the top view)
5. Remove all hidden lines. Any lines shown on the drawing will be cut.
6. Save file as DXF or DWG file.

For more information on exporting CAD, see the **CAD Modeling Translation** manual.

Submitting a Laser Cut Request

Contact the student shop supervisor or a qualified teaching assistant.

Plasma Cutting

Plasma cutting is a process that is used to cut used to cut sheet stock of metallic, conductive materials with a plasma torch, created by heating compressed gas into plasma via an electrical arc. The gas/plasma moves fast enough to carry the molten metal away from the cutting zone. The plasma-cutting machine is located in the room adjacent to the student machine shop. Figure 2 shows the current machine used in the School of Engineering.

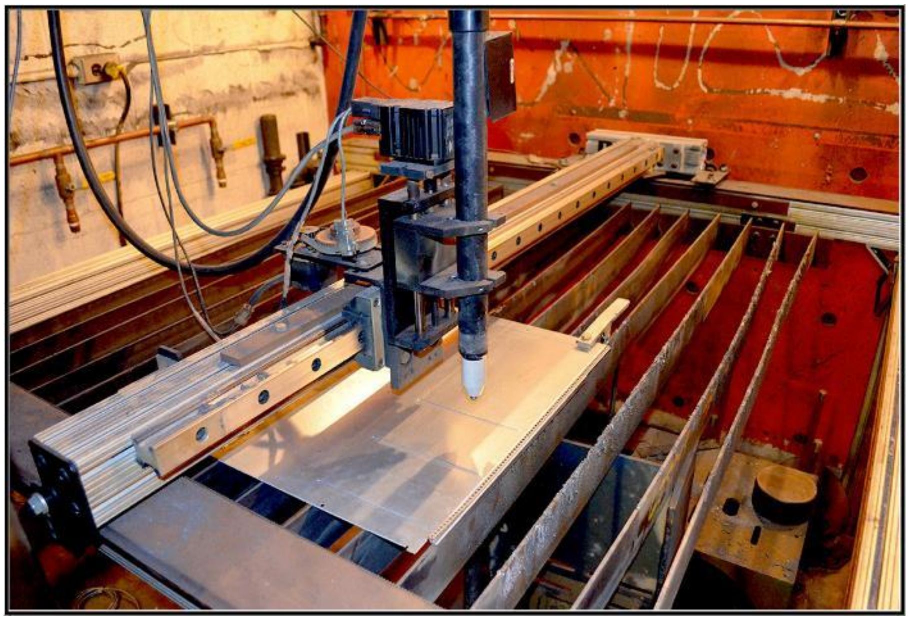

Figure 2: Plasma Cutter Machine with a sheet-metal work piece

Figure 3 shows an example shape of 0.06” thick steel after plasma cutter fabrication. Notice the edge roughness after machining that may need to be post-processed.

Figure 3: Plasma-cut shape (left) and close-up of edge effects after cut (right)

Plasma Cutting Cost and Use Policies

The plasma cutter in the JEC Student Shop is available for use free of charge, during Student Shop hours. The cutter can only be operated by the Student Shop Supervisor *or* a qualified teaching assistant. Users must supply their own material for cutting. The approximate cut time of a 2” diameter circle of 1/8” thick steel is 20 seconds. Material that is thinner than 0.04” tends to warp badly and material thicker than 0.25” tends to have very long cut times that may be out-of-tolerance. Stainless steel and other high chrome alloys may **not** be used due to the emission of hexavalent chromium (a known carcinogen).

Table 3: Plasma Cutter Specifications

Model	**Torchmate**
Exit Stream Diameter	**0.06"**
X-Y Tolerance	**0.01” – 0.03”**
Work Area	**48" × 48"**
Min. Thickness	**0.04”**
Max. Thickness	**0.25”**
Avg. Turnaround Time	**Same Day**

Plasma Cutting CAD Preparation

The plasma-cutting machine requires 2-D CAD files in one of the following formats:

1. Drafting Interchange Format (.dxf)
2. AutoCAD™ Drawing (.dwg)
3. MasterCAM™ (.mcx)

For more information on exporting CAD, see the **CAD Modeling Translation** manual.

Submitting a Plasma Cutting Request

Contact the Student Shop Supervisor or a qualified teaching assistant.

Spot Welding

Spot welding is located in the room adjacent to the student machine shop. Figure 4 shows the current spot welding machine used in the School of Engineering.

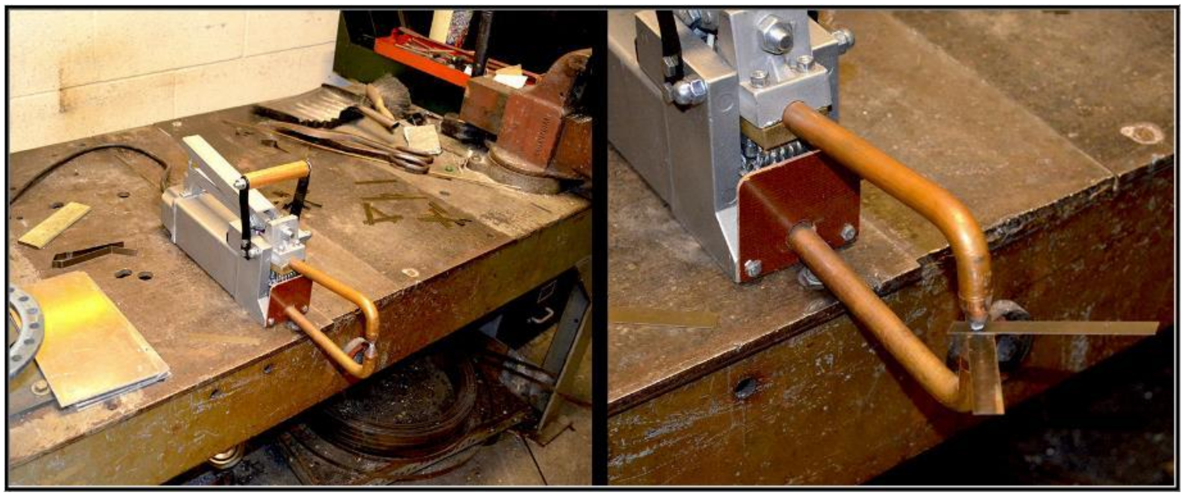

Figure 4: Spot Welding Machine (Left) and Close-Up prepared with two sheet-metal work-pieces (Right)

Spot Welder Cost and Use Policies

Use of the spot welding machine is free of charge. The spot welding machine has a working envelope of six-inches from the edge of the material to be welded. Carbon and stainless steel are permitted. Copper, brass, and aluminum are **not** permitted on this machine. The thickness of material should be less than 0.1" (preferably less than 0.08").

Soldering

The JEC student machine shop offers soldering capabilities for most iron, stainless steel, brass, and copper alloys depending the flux in stock. Soldering is located in the room adjacent to the student machine shop

Solder Cost and Use Policies

Soldering use is free of charge. Contact the Student Shop Supervisor or a qualified teaching assistant.

Welding

The JEC student machine shop offers MIG (metal-inert-gas) welding (shown in Figure 5) and ARC capabilities during shop hours.

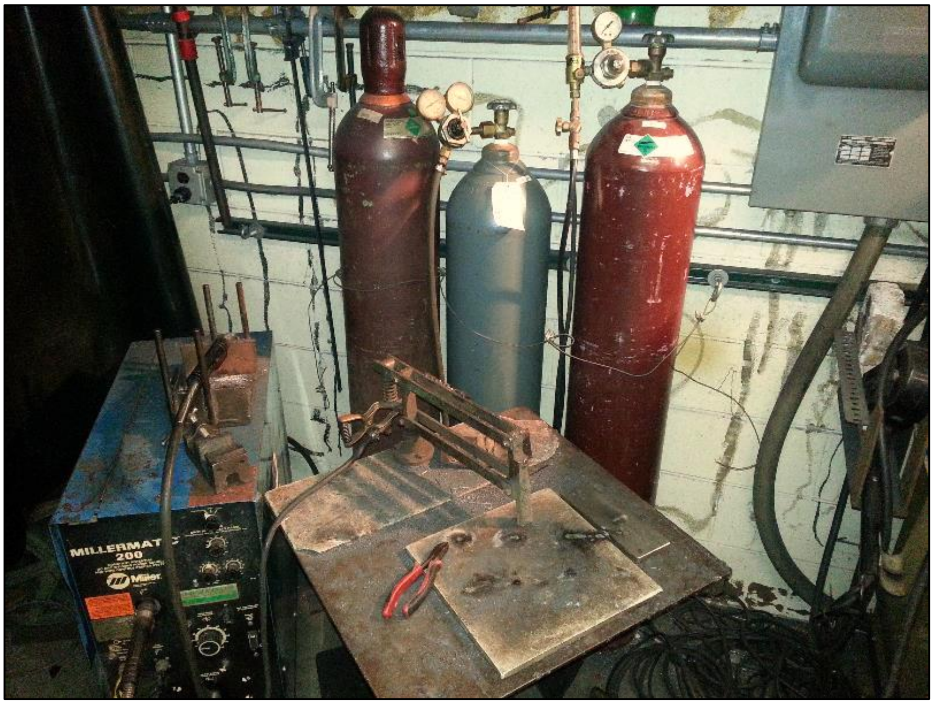

Figure 5: MIG Welding Setup in JEC Student Shop

Welding Cost and Use Policies

Use of the welding equipment is free of charge. Users will need to supply their own materials to be welded. Materials are restricted to carbon steels only. Stainless steels are **not** permitted. Based upon the experience of the requester, a qualified teaching assistant will need to be present. Contact the Student Shop Supervisor or a qualified teaching assistant.

Aluminum welding is available in the R &D Machine Shop located in the basement of the Science Center, room BW-13. There is typically a charge associated with this service. The telephone number for the shop is 518-276-6241 and the hours of operation are 9 am - 4 pm M-F.

Other Services

For any additional question related to services in the JEC Student Shop, please contact:

John Szczesniak, Student Shop Supervisor
JEC 1010
szczej@rpi.edu
(518) 276-6551

Or

Sam Chiappone, Manager of Fabrication and Prototyping, SoE
JEC 3100A
chiaps@rpi.edu
(518) 276-8295

Abrasive Water Jet Cutting

Water-jet cutting uses a high-pressure stream of water to cut through material. Abrasive water-jet (AWJ) cutting adds small abrasive particles to the stream of water to speed up the process. Both processes force the water (typically 20,000 to 55,000 psi.) through a tiny hole in a jewel orifice (usually 0.010" – 0.015" diameter of a ruby, sapphire, or diamond material). The abrasive is then added to the stream and goes through a mixing tube to produce a stream of wet abrasive moving upwards of Mach 3 (2,200 mph). The abrasive allows the process to cut metals and other hard materials.

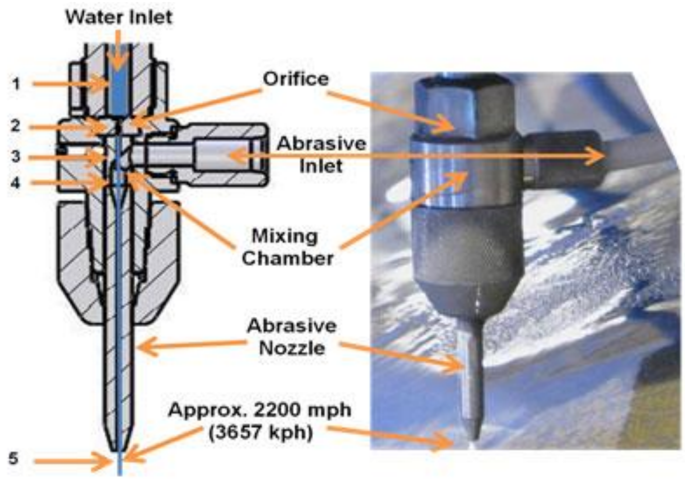

Figure 6: Abrasive Water-Jet Components

Water passes through the jewel at an approximate diameter of 0.010". Once the abrasive is added and the stream leaves the mixing tube, it is 0.040". This stream expands slightly as it flows through air, much like water coming out of a fire hose. If setup correctly, the material being cut helps to restrict the stream from fanning out, the cut will be relatively straight. Typically, the stream produces a tapered cut (shown in red in Figure 7) that expands approximately 0.01" per unit inch of depth of cut (1.0° – 1.2° taper).

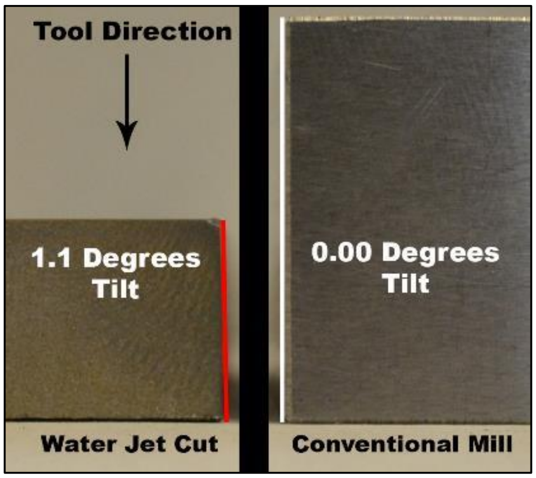

Figure 7: Taper Edge Comparison

The abrasive water jet is described as a ‘floppy tool’. This is because it is not rigid and cannot maintain its shape as it cuts through the material. Rather than staying vertical as it passes through the work-piece, it slowly eats through the material and only hits the upper surface at full speed. As the nozzle moves forward, the water stream slows down and curves away from the direction of travel. The jet lags between where it enters the work-piece and where it exits, shown in Figure 8.

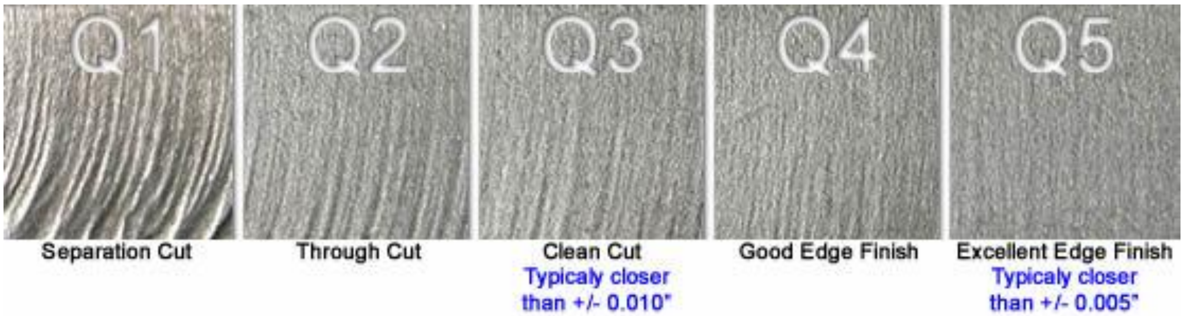

Figure 8: Abrasive Water-Jet Edge Finish Scale

Abrasive Water-Jet can cut many materials including aluminum, copper, steels, and plastics. Because there is no heat produced during cutting, there is no warping or heat-affected zone. This eliminates the need for heat-treating and stress reducing in post-processing. AWJ is safer, more environmentally friendly, and cheaper than laser-cutting systems. Thicker parts are possible with AWJ (2"- 3" vs. <1" for laser cutting).

Acrylic and other ‘brittle’ materials can be problematic when using the water-jet machine due to cracking, spalling, chipping, etc. Laser cutting may be better suited for these materials. Laminated materials may de-laminate unless certain precautions are taken in job-setup. See the shop supervisor for assistance.

AWJ Machine Properties

Figure 9 (Left) displays the current AWJ machine in use at the School of Engineering. Figure 9 (Right) displays a typical setup. Note the simple weights used as 'clamps' on the border of the aluminum sheet-metal work-piece. There should be no less than one-inch (1") of excess material added to the outer perimeter of the work-piece to allow clamping to the machine Figure 9 (Right).

Figure 9: RPI AWJ Machine Front (Left) and Overhead showing sheet-metal work-piece (Right)

Table 4: AWJ Machine Properties

Model	**Flow Mach 2**
Orifice Stone	**Ruby**
Stream Exit Diameter	**0.04"**
X-Y Tolerance	**±0.01"**
Abrasive Material	**Garnet**
Max. Work Area	**60" × 64"**
Max. Cut Size	**48" × 48"**
Avg. Turnaround Time	**4 – 5 Business Days**
Location	**CII High Bay Area**

AWJ Cost and Use Policies

The estimated cost of water jet cutting is **$27.00 per hour of machine operating time**. Operating time is determined by the complexity of the geometry, material, thickness, and length of cut. There is no cost for job setup. The approximate cut time of a 2" diameter circle of 1/8" thick ABS plastic is 20 seconds.

AWJ is usually reserved for cutting on uniform thickness sheet material. Because the machine provides a level of cutting precision and versatility not easily attainable on band saws or table saws, please refrain from using the water jet resource to cut parts that could be as easily cut using a regular shop tool. The course faculty reserves the right to refuse parts from the water jet machine in the interest of allocating the resource to uses that require the capability and precision of the cutting process. For example, simple linear or rectangular cuts requiring loose tolerances may be refused.

AWJ is only available on weekdays between 8 AM and 5 PM. Scheduling and operation is handled by a teaching assistant. See the **AWJ Order Form** for contact information.

AWJ CAD File Preparation

To create a CAD drawing for the water jet machine, the following steps should be followed:

1. Create an engineering drawing of the part you want cut.
2. Adjust the drawing to 1:1 scale.
3. Remove all drawing formats including
    a. All annotations or notes
    b. All axis
    c. All centerlines
    d. All dimensions
4. Prepare the drawing for one view only (probably the top view).
5. Remove all hidden lines. Any lines shown on the drawing will be cut.
6. Save file as DXF file.

For more information on exporting CAD, see the **CAD Modeling Translation** manual.

Submitting an AWJ Request

1. Purchase/obtain the material for the part or parts. If there are several parts, batch the parts into one submission, one email. The operator will explore combining the pieces onto one piece on the machine.
2. Include PDF files of the complete engineering drawings with the request, to allow verification of dimensions and scaling.
3. Follow the procedure outlined on the **AWJ Order Form.**

3-D Printing

3-D Printing (3DP) (formerly "Rapid Prototyping" or (RP)) refers to technologies that automatically create solid physical models from CAD data. These models allow designers to display prototypes of their designs quickly and easily. 3DP is generally considered an "additive" machining process. Through this method, parts are built layer-by-layer using wax, plastic, paper, or other materials. Compared to traditional machining methods, this method can construct complex geometries quicker.

Depending on the process used, rapid prototyping has a wide variety of applications. Aside from being used as a visual representation, 3DP methods can be used to create injection mold inserts, investment casting patterns, hard tool production, and for low volume manufacturing.

RPI's 3-D printing equipment currently includes a Z-Corp Z310 Plus 3-D printing system and two Stratasys Inc. machines: Dimension Elite and uPrint. All three of these systems are in the Manufacturing & Innovation Learning Laboratory (MILL), located in the high-bay area of the CII.

3-D Printing Off Campus

If you plan to use stereolithography 3-D printing available at Benet Laboratories in Watervliet, NY, this is **NOT** the correct document. Contact the Manager of Fabrication & Prototyping.

Z-Corp Z310 Plus Machine Properties

The Z-Corp Z310 Plus machine creates models by printing a binder (a water-based glue) onto individual thin layers of powder. After one layer is printed, the binder hardens and the next layer of powder is added. The process resembles an inkjet printer in operation. Figure 10 displays the current Z-Corp printer.

Figure 10: Z-Corp Z310 Plus Top view

Models created using the Z-Corp machine can be post-processed many different ways. At this time, wax penetration and cyano-acrylate penetration are available at RPI. Cyano-acrylate (similar to super glue) provides extra strength and toughness to models. However, this process adds additional time and cost to prototype production. For scale models where forces and stresses on the part are low, the Z-Corp model without post-processing should be adequate.

Table 5: Z-Corp Z310 Plus 3DP Specifications

Maximum part dimensions	10"W × 8"L × 8"H
Print speed with Starch	One vertical inch per hour
Material	Starch or plaster based powder
X-Y Accuracy with Starch	± 0.025"
X-Y Accuracy with Plaster	± 0.012"
Z-Layer height with Starch	0.007"
Z-Layer height with Plaster	0.003"
Avg. Turnaround Time	4 – 5 Business Days
Location	Manufacturing Innovation Learning Lab (MILL) CII High Bay Area

Recommendations for models built with the Z-Corp Z310 Plus:

1. *Avoid thin walls.* Although walls with dimensions of 1/32" (0.031") have been constructed, they often are considerably damaged (distorted, cracked, or broken) during handling and post-processing. Wall thickness should generally be at a minimum of 1/8" (0.125) and thicker if are used as supporting structures.

2. *Avoid small features.* Tiny features, including protrusions, holes, and writing should be avoided. Small hole and rod sizes of 1/8" (.125") usually work well, and to a minimum 1/16" (0.0625") sometimes turn out. These results are contingent on the size of the features. A 1/8" hole going through a 1/4" of material is most likely going to work, but a 1/8" hole or rod that is an inch long is going to be difficult to produce.

3. *Avoid areas that wax or powder will settle into.* Right angles will often end up with a radius due to post-processing and wax infiltration.

4. *Avoid unsupported features.* Until the models have fully cured and been post-processed, they are going to distort when being handled. If a model contains an unsupported overhanging feature, this feature is going to be distorted from the weight of the liquid wax.

5. *Internal features.* Although 3DP allows for the creation of internal part features, it is often difficult to remove powder fully from the insides during post-processing.

6. *Model cost is based fully on part volume.* Volumes can be easily calculated in CAD while the part is being designed, and where possible certain sections can be shelled out to decrease the part volume. Always be aware of wall thickness and overhanging features when attempting to decrease the part volume.

Stratasys Dimension Elite Machine Properties

The Stratasys fused-deposition-modeler (FDM) builds three-dimensional parts by extruding a bead of ABS plastic through a computer-controlled extrusion head. To ensure build quality and precision, a removable solid support material is applied where necessary. The strength of the finished part is approximately 75% the strength of an injection molded ABS part. Figure 11 depicts the current Stratasys Dimension Elite with door open and part inside.

Figure 11: Stratasys Dimension Machine with printed part

Table 6: Stratasys Dimension 3DP Specifications

Maximum part dimensions	8"W × 8"L × 12"H
Print speed	One cubic inch per hour
Material	ABS plastic
X-Y Accuracy	± 0.015"
Z-Layer height	0.010" – 0.013"
Avg. Turnaround Time	4 – 5 Business Days
Location	Manufacturing Innovation Learning Lab (MILL) CII High Bay Area

Stratasys uPrint Machine Properties

The material used and most of the machine properties of the uPrint and the Dimension are identical, **with the exception of the support material type** (see Figure 16 for an example). The uPrint filler/support material is water soluble, making it ideal for designs where support material would be difficult to extract. Figure 12 depicts the current Stratasys uPrint in the CII High Bay.

Figure 12: uPrint

Table 7: Stratasys uPrint 3DP Specifications

Maximum part dimensions	8"W × 6"L × 6"H
Print speed	One cubic inch per hour
Material	ABS plastic
X-Y Accuracy	± 0.015"
Z-Layer height	0.010"
Avg. Turnaround Time	4 – 5 Business Days
Location	Manufacturing Innovation Learning Lab (MILL) CII High Bay Area

3DP Cost and Use Policies

The cost of 3D printing on the **Z-Corp** machine is **$5.00 per cubic inch** of material. Figure 13 shows a typical part created on the Z-Corp machine. This part in Figure 13 has a build time of approximately five minutes. Post-processing parts, an example shown in Figure 14, adds more time.

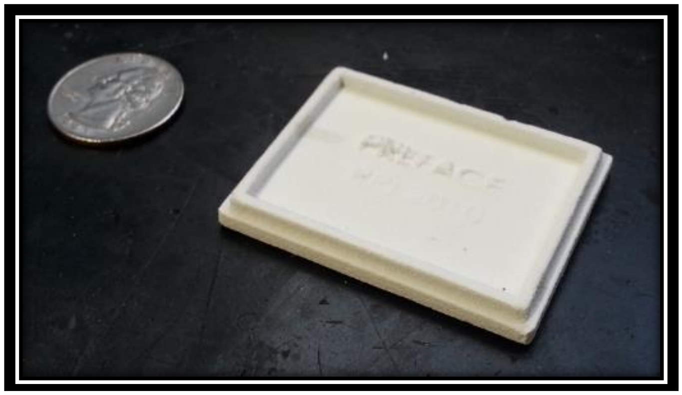

Figure 13: Z-Corp plaster printed part without post-processing

Figure 14: Z-Corp plaster printed part with post-processing (Wax Coated)

The cost of 3D printing on the **Dimension** and **uPrint** machine is **$10.00 per cubic inch** of material. Figure 15 shows a typical part created on the Dimension and uPrint. This part in Figure 15 has a build time of approximately 38 minutes. Layer orientation relative to the geometry will affect build times. See the teaching assistant for more information.

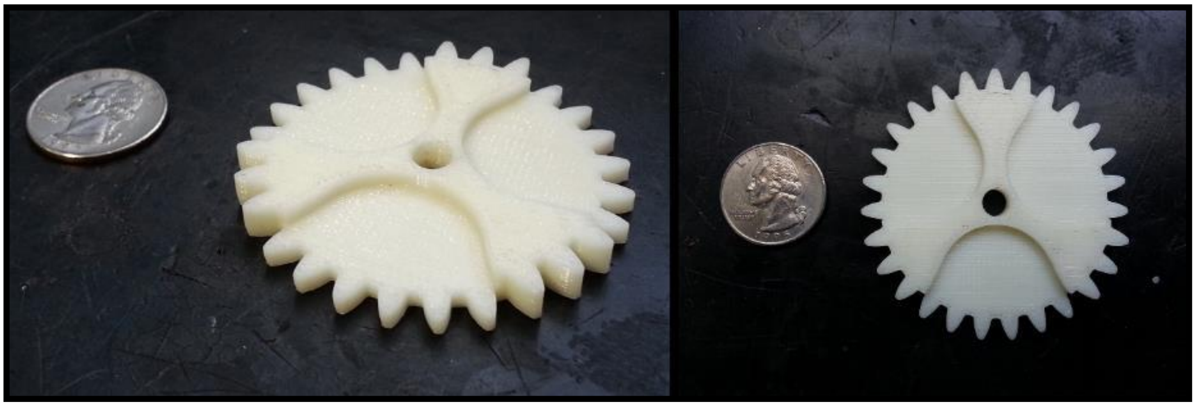

Figure 15: Stratasys ABS Printed Part Iso View (Left) and Top View (Right)

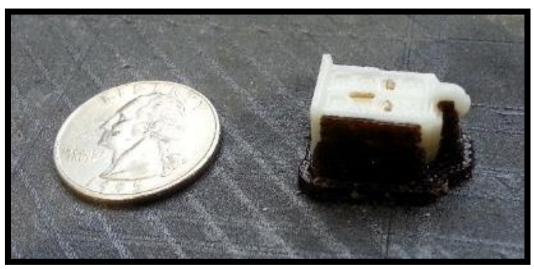

Figure 16: uPrint SE printed part (white) with support material (in black)

Because 3D printing provides a level of part shape versatility not easily attainable using traditional material removal operations, please refrain from using the 3DP resource to make parts that could be as easily cut or made using a regular shop tools. The course faculty reserves the right to refuse parts from the 3DP machines in the interest of allocating the resource to uses that require the capability of the process.

3D printing is only available on weekdays between 8 AM and 5 PM. The number of hours on the machine staffed for use is limited.

3DP CAD File Preparation

A stereolithography file (*.stl) is required. For more information on exporting to STL, see the **CAD Modeling Translation** manual.

Submitting a 3DP Request

Follow the procedure outlined on the **3DP Order Form**.