University of Hawaii at Manoa (UHM) College of Engineering

Student Advisory Board (SAB) Proposal –3D Printer

August 20, 2013

1 ~~Student Advisory Board – 3D Printer Proposal~~

2 ~~University of Hawaii at Manoa, Electrical Engineering Department~~

3 Student Impact

500

4 Collaboration

EE Department + Undergraduate Students

5 Proposal Summary & Goals

The goal of this proposal is to give Electrical Engineering (EE) U~~u~~**ndergraduate students access to a 3D printer which can be used for school based and personal electrical engineering projects.** Lab Technicians trained in using the 3D printer will have the duties of operating the machine and reviewing mandatory proposals by EE students for them to use it. By having the EE students write proposals, they in turn gain valuable soft skills for the job market.

~~The proposal recommends the purchase of a printer.~~

6 Description

A 3D printer is a machine that has the capability to create or replicate a three-dimensional solid object through a scaled design (i.e. autoCAD, solidworks, similar interfaces). 3D printing technology is aimed- towards the capabilities of prototyping and manufacturing essential components for projects.

Although largely limited to industrial and heavy research applications before, 3D printers have been more easily accessible by consumers, smaller companies and universities in recent years. The primary advantage of having a 3Dd printer is the ability to rapidly prototype.

7 Outcomes

An accessible 3d printer for undergraduates will help broaden undergraduate project experience, as well as give them access to one of the emerging technologies in rapid prototyping. Undergraduate students will have access to a prototyping platform where they can submit designs for physical parts to be printed out. These designs can be either prototypes, or parts to be used in the semi-final design.

Although Electrical Engineering students do not normally focus on mechanical components, it is often a necessary part of Electrical Engineering undergraduate projects. For example, mounts may be required to secure electrical connections, or enclosures may need to be built to protect from weather. By giving electrical engineering students easy access to this new resource, it broadens the scope of where undergraduate student projects can reach. This, in the larger scale, provides students with a greater breadth of experience, since they now have another tool at their disposal.

8 Evaluation

The effectiveness of the 3D Printer can be gauged by looking at relevant undergraduate projects. Since the process of formal classroom projects (x96) is documented well, those projects can be used to gauge the effectiveness of the 3D printer. For personal projects, the effectiveness can be gauged by looking at the documentation which students will be required to submit when requesting the use of the 3D printer. In the long term, undergraduate student projects should show 3D printer use, and an increased variety of types of projects.

9 Issues~~Decision: TBD, awaiting quote from company?~~

10

10.1 Materials and material management

There are two primary materials used with 3D printers. This section will clarify the difference between both materials, and will also be referred to for storage and use management for raw material.

The two materials used by most machines are known as Acrylonitrile Butadiene Styrene (ABS) and a Polyactide (PLA). ABS is a petroleum based thermoplastic, and PLA is an organically derived substance, mainly from materials such as corn-starch, tapioca roots, and sugarcane.

Listed below is a summary of pros and cons for both materials.

- ABS
  - Pros
    - High durability
    - Flexible and high temperature resistance
  - Cons
    - Sharp corners will tend to warp and curve
    - Items such as gears will not be perfect or 100% to spec, material may also crack if temperature does not allow for proper adhesion between layers.
    - Improper heat will cause the print surface to be unsmooth or not perfectly flat to spec
- PLA
  - Pros
    - Environmentally friendly; printing does not produce plastic smell
    - In comparison to ABS, less warping when printed
    - Material is naturally transparent and more rigid
  - Cons
    - Lower melting temperature makes PLA very unsuitable for many applications; daily temperatures of heat can easily deform PLA printed components
    - Higher cost of material

10.2 Storage

A project lab room will be needed to keep this 3D printer. Materials are at best usability point when sealed from atmosphere (soaking moisture damages material over a period of time - so to speak).

- ABS
  - ABS will bubble if left in atmosphere and will cause deformations during the printing process. If the material is damaged due to moisture, drying in a food dehydrator is an easy fix.
  - ABS gives off a notable smell of hot plastic. Although most distributors use a contaminant free product, proper ventilation must be provided when printing.
  - ~~ABS gives off a notable smell of hot plastic. Although most distributors use a contaminant free product, proper ventilation must be provided when printing.~~
- PLS
  - PLS will also encounter similar problems like ABS if left out. A notable difference is that PLS material can change in crystallinity ratio if dried, which may cause external blemishes when printing.
  - PLA gives off a semi-sweet fragrance when being printed. Notably not ~~un~~toxic, the smell is due to the material being primarily plant based.
- Note: a food dehydrator will most likely be a necessary purchase when buying ingredients and refills. At about $50-$70 per cartridge of ingredients, quick fixes such as drying can possibly reduce and diminish the amount of waste in terms of cost and quantity of usable material.

11 ~~Final Analysis~~Solutions to Issues

11.1 Final Product Choices

- Printer choices
  - Objet30 Pro (See Appendix A)
  - Replicator 2 (See Appendix B)
- Material choice
  - ABS plastic
- Bath and cleaner
  - Quote from Objet will determine the cost for bath

- Rough estimate of ~$500
  - Cleaner
- Lye solution can be purchased from local retailers or from mainland vendors

11.2 Management

In order to prolong the life of the 3D printer, some regulations must be used. 1-2 Lab Technicians trained in using the 3D printer must be readily available. ~~Only those~~Those Lab Technicians will ~~be allowed to touch or use the~~be in charge of the 3D printer. If a student needs the use of a 3D printer, he or she will have to write a proposal to have access to it. The Lab Technician will review the proposal and it will be at the technician's discretion on whether or not he or she will make the component for the student.

- Supervisor
  - A supervisor will be required to review projects before printing. After an undergraduate fills out a necessary form, it is up to the discretion of the supervisor whether the printing is viable.
- When a student comes in to the supervisor, he/she will provide
- Their student id card
- Form for printing which documents
  - Name, grade, track
  - Purpose for use
  - If relative, the professor in charge of the project.
  - In terms of cleaning, the supervisor will direct a cleaning process with the bath and lye solution. Students who do not clean their boards will be penalized with a time restriction of use.
- For example, if a student does not properly clean and dispose, they will have a ~~one-week~~one-week ban from use of the machine. If the habit continues, the student can be banned for up to a month.
- Machinist
  - A person, or a group of people will have to be responsible for the printer. This includes fixing the printer, replacing parts, etc.

12 Projected Problems

- Management
  - The person(s) delegated to running the machine will require a lot of dedicated free time to supervising the printing. If possible, the management could switch shifts during the dedicated time, but the amount of time needed for some printing jobs may be extensive.

- Product Replacement
  - Some materials may have to be continually shipped from the mainland, so if materials run out before a dedicated delivery time, students may be pushed back in terms of deadlines and schedules.
- Safety
  - When working with the lye solution, there is a possibility that students or faculty make contact with their skin. If that is the case, the bath machine must be near a sink or faucet where they can quickly cleanse him/herself.
    - There should be a dedicated station that allows for emergency cleansing.

13 Evaluation

The effectiveness of the 3D Printer can be gauged by looking at relevant undergraduate projects. Since the process of formal classroom projects (x96) is documented well, those projects can be used to gauge the effectiveness of the 3D printer. For personal projects, the effectiveness can be gauged by looking at the documentation which students will be required to submit when requesting the use of the 3D printer. In the long term, undergraduate student projects should show 3D printer use, and an increased variety of types of projects.

~~Reasons to get printer:~~

- Reasons to get 3D printer:
  - Undergraduate experimentation and learning
  - Enhance student experience with latest technology and methods
  - Rapid prototyping (cost effective in terms of time)
  - Elevate skill-set beyond standard EE

~~Uses:~~

- Uses for 3D printer:
  - Small Project Parts
  - Enclosures
  - Custom mounts, screws
  - Educational advantages
  - Experimentation

14 Budget

- Yearly Costs
  - Not accounting for the cost for Management, the rough estimate of cost (at optimal usage of machine) is:
    - ~$170 per month for a year of ABS plastic:
    - $2,200 per year
    - ~$60 per month for a year of lye solution:
    - ~$750 per year
    - **Total yearly cost**
    - ~$3,000
    - **Note:** These estimated costs are based off research, and speculated if the machine is being used as most as possible.
    -
    -
- 3D Printer
- ~~3D Printer~~
  - Introductory Market (ex. Replicator 2):
    - The printers in this market are simpler, but are still capable of making prints. They may be less precise than the more advanced market, and use a smaller range of materials. If buying in this range point, it might be useful (and within budgetary concerns) to buy two printers to have redundancy as well as for ease of troubleshooting.
    - Printer: ~$1500 - $3000 price point
    - Plastic: ~$30 per roll
    - PLA- https://www.protoparadigm.com/products/

~~**Introductory market:**~~

  - Advanced Market (Objet30 Pro):
    - The purpose of the more expensive/advanced 3D printer is for components that have gone through the trial process with the more basic printer. These components are meant to be final products that are to be used with the final installment of a product or project. Starting price for these types of 3D printers can be roughly at $19900.
    - In terms of total quote, the Objet has yet to respond to us with a rough quote, but it can be expected to be (* per month):
- ~$21,000 Objet30 Pro
- ~$130-$170* monthly material refill
- ~$500 bath cleaner

- ~$60-$70* lye solution

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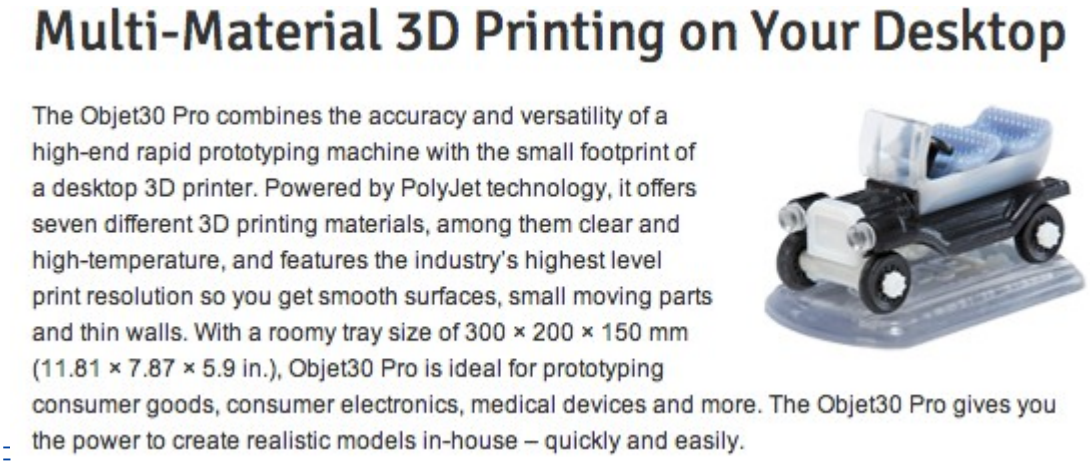
- **Advanced Market 3D Printermarket:**



Starting price at roughly $19900

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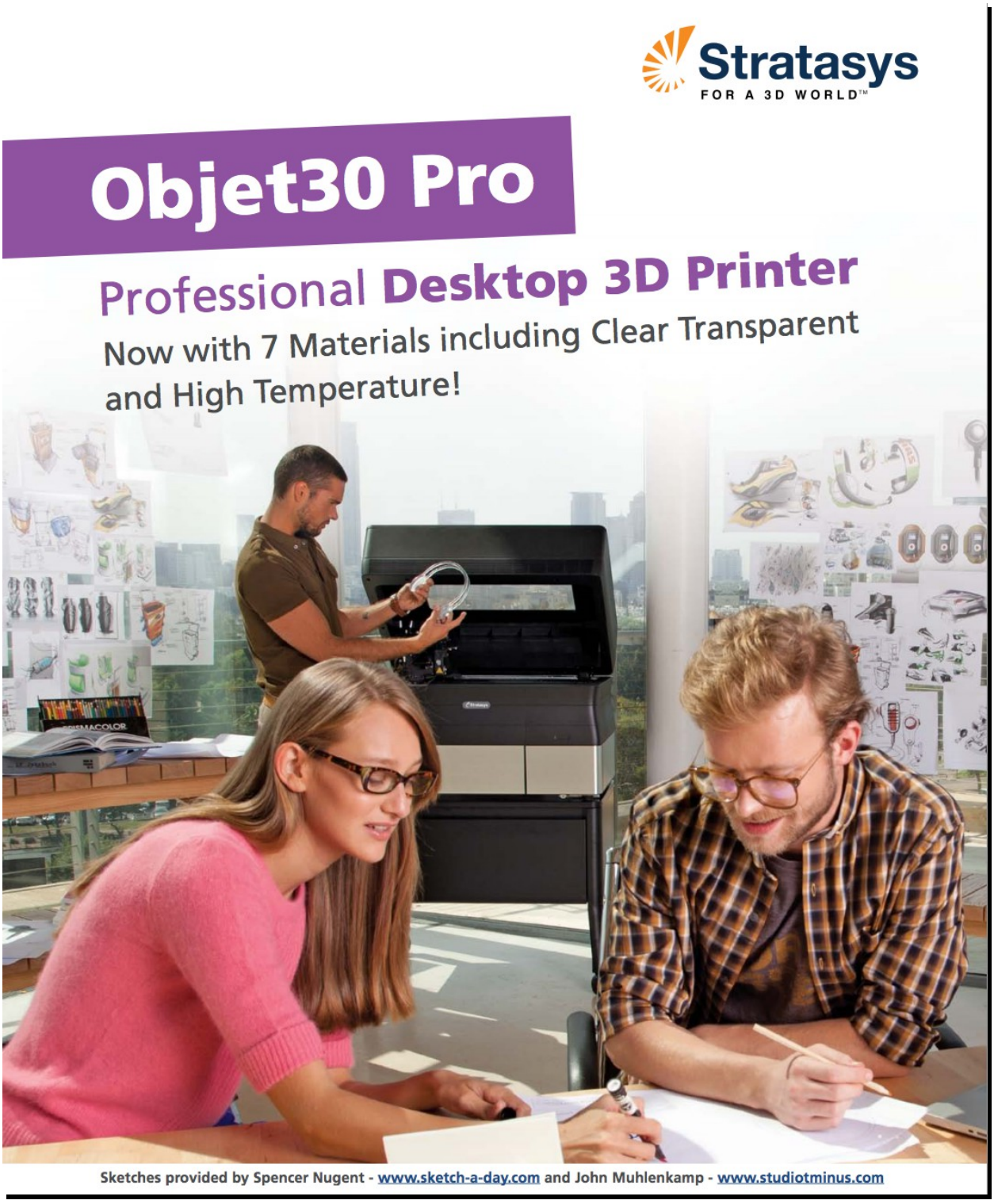
Appendix A: Objet30 Pro Spec-Sheet~~Notes~~



The Ultimate in Professional **Desktop 3D Printing**

High End Performance with a Small Footprint

The ***Objet30 Pro*** is a 3D printer that combines the accuracy and versatility of a high-end rapid prototyping machine with the small footprint of a regular desktop printer. The ***Objet30 Pro*** provides a number of unique capabilities in one machine: the industry's highest level print resolution and 7 different 3D printing materials.
In fact, the ***Objet30 Pro*** is the world's only desktop 3D printer capable of printing in clear transparent material, high-temperature resistant material and polypropylene-like material.

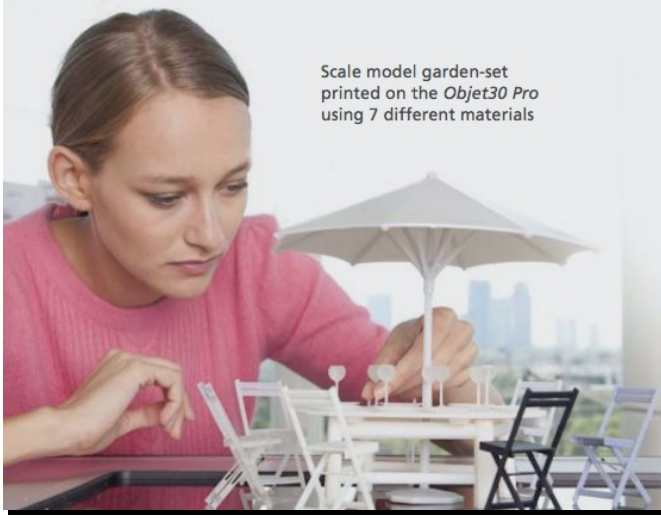
Combine these with Stratasys' obsession with reliability and ease of use and you get a world-class 3D printer for every prototyping capability that you could need, in-house.

Built with your Applications Needs in Mind

Featuring a compact build tray size of 300 X 200 X 150 mm, the ***Objet30 Pro*** is ideal for the rapid prototyping needs of companies producing Consumer Goods, Consumer Electronics, Medical Devices as well as Rapid Prototyping Service Bureaus and Design Consultancies.

Ensure the Successful Delivery of Product Concept to Creation

Packing a punch well beyond its size, the ***Objet30 Pro*** is the ultimate prototyping solution for designers, engineers and product managers. By providing the industry's highest levels of prototyping accuracy and material versatility, the ***Objet30 Pro*** ensures dramatic cuts to product development times and promises the successful delivery of concept to final product creation.

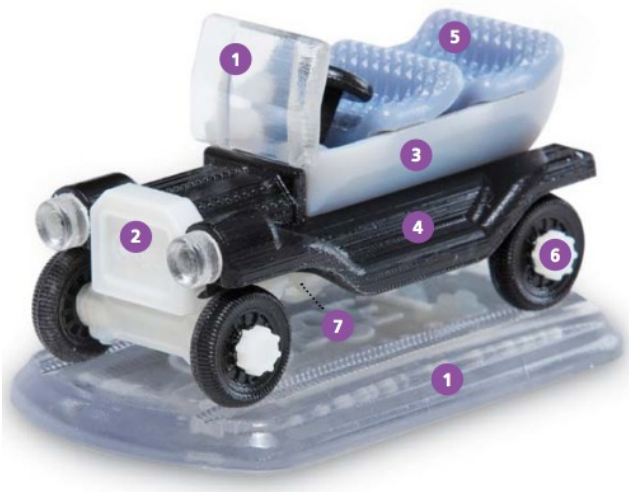


Scale model garden-set printed on the *Objet30 Pro* using 7 different materials

Objet30 Pro at a Glance:

- The ultimate prototyping solution for ***designers, engineers*** and ***product managers***
- Ideal for ***consumer goods, consumer electronics, medical devices*** and ***design consultancies***
- Combines the ***accuracy*** and ***versatility*** of a high-end RP machine ***with a small footprint***
- ***7 different materials;*** the world's only desktop 3D printer with ***clear transparent, high temperature*** and ***rigid opaque polypropylene-like materials.***
- ***Reliable*** and ***easy to use***

The Industry's Widest Desktop Versatility with 7 Materials



1. Windscreen, Headlamps & Base – in **Objet Transparent Material** (Objet VeroClear) for fit and form testing of transparent parts & PMMA simulation
2. Engine & Radiator – in **Objet High Temperature Material** for advanced functional testing, hot air & water flow, static applications & exhibition modeling
3. Bodywork – in **Objet Rigid Gray Material** (Objet VeroGray) ideal for fine detail emphasis and superior dimensional stability
4. Chassis & Wheels – in **Objet Rigid Black Material** (Objet VeroBlack)
5. Seats – in **Objet Rigid Blue Material** (Objet VeroBlue) ideal for fine detail emphasis & photography
6. Hubcaps – in **Objet Rigid White Material** (Objet VeroWhitePlus) for multi-purpose applications
7. Axels & Crankshaft – in **Objet Polypropylene-like Material** (Objet DurusWhite) for Polypropylene like snap fits applications

Technical Specifications - *Objet30 Pro*

Layer Thickness (Z-axis)
Horizontal build layers of
28 microns (0.0011 inch)
Horizontal build layers of
16 microns for VeroClear material
(0.0006 inch)

Tray Size (X×Y×Z)
300 × 200 × 150 mm
(11.81 × 7.87 × 5.9 inches)

Net Build Size (X×Y×Z glossy)
294 x 192 x 148.6 mm
(11.57 x 7.55 x 5.85 inches)

Build Resolution
X-axis: 600 dpi
Y-axis: 600 dpi
Z-axis: 900 dpi

Accuracy (glossy) @ Operating Environment
0.1 mm (0.0039 inch) typical
Accuracy may vary depending on part geometry, size, orientation, material and post processing method

Model Materials
- VeroClear Transparent
- RGD525 High Temperature
- VeroWhitePlus Opaque
- VeroBlue Opaque
- VeroBlack Opaque
- VeroGray Opaque
- DurusWhite Polypropylene-like

Support Material
- FullCure®705
- Non-toxic gel-like photopolymer
- Easily removed by WaterJet

Materials Cartridges
Sealed 4 x 1 kg (2.2 lbs) cartridges

Power Requirements
Single phase:
100 to 200VAC; 50/60Hz; 7A
200 to 240VAC; 50/60Hz; 3.5A

Product Dimensions (W×D×H)
82.5 × 62 × 59 cm
(32.28 × 24.4 × 23.22 inches)

Product Weight
93 kg (205 lbs)

Frontend Software
Objet Studio™ features:
- Automatic build orientation
- Automatic real time support structure generation
- Slice on the fly

OS Workstation Compatibility
Windows XP, Windows 7 32/64-bit

Network Connectivity
Ethernet TCP/IP 10/100 base T

Input File Format
STL and SLC Files

Operating Environment
Temperature:
18°C to 25°C (64°F to 77°F)
Humidity:
30 to 70% RH (non-condensing)

Special Facility Requirements
None

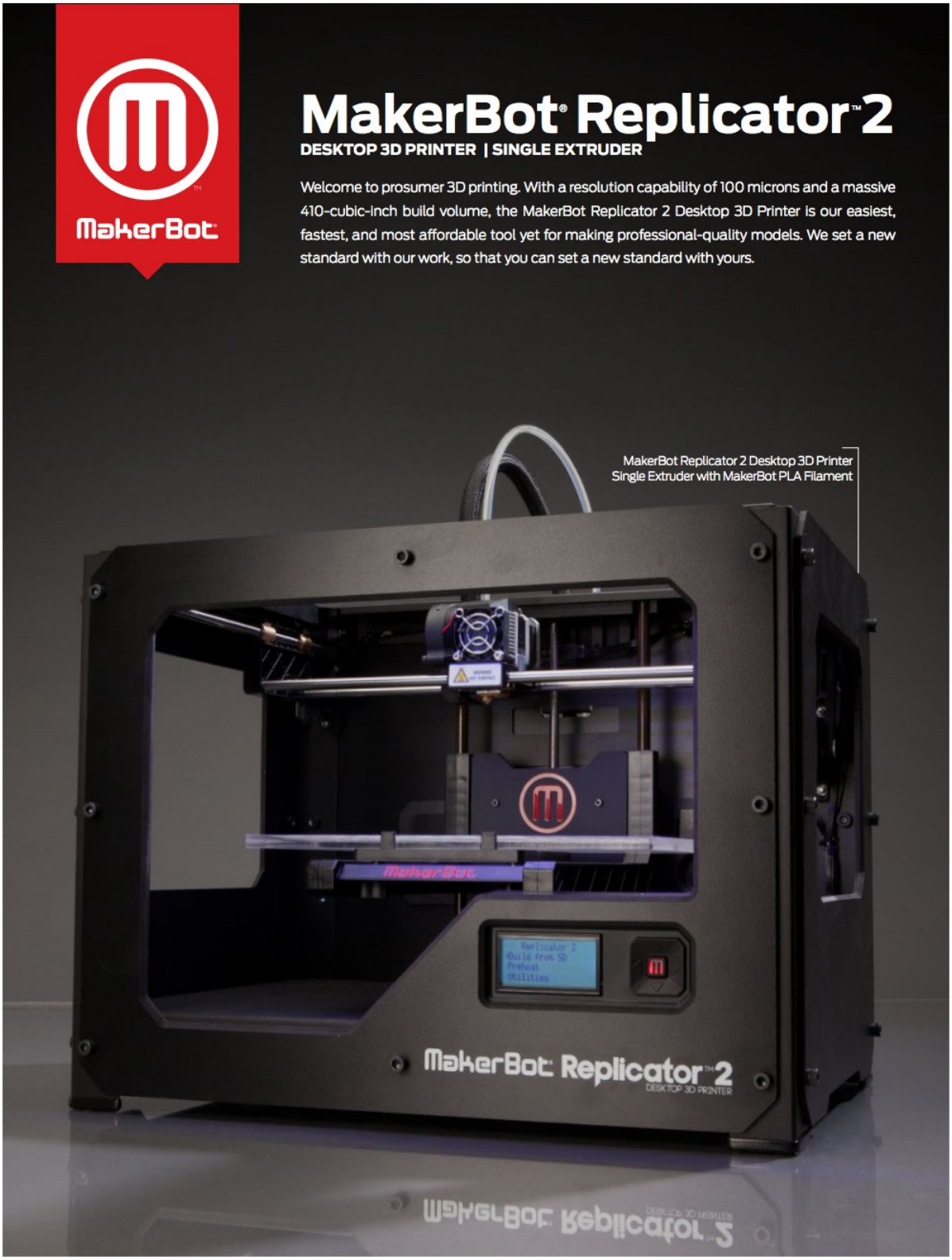
Jetting Heads
2 printing heads
SHR (Single Head Replacement)

Regulatory Compliance
CE/FCC/RoHS

Other Features
Quiet office operation

*All specifications are subject to change without notice

Appendix B: Replicator 2 Desktop 3D Printer Specs & Features



MAKERBOT® REPLICATOR™ CUSTOMER LIST

3D Imaging
Activision
Alaska Manufacturing Extension Partnership
Amherst County Public Schools
Bainbridge Island School District
Bartlett School of Architecture
Biola University
Bloomington Public Library
Boston College
Boston University
Bowling Green State University
Brooklyn College
Brown University
BUR Bikes
CBS Network West Coast
Chang Bioscience, Inc
City University of Hong Kong
Coinstar
Columbus School for Girls
Corcoran Gallery of Art/College of Art & Design
Cornell University
Deloitte Innovation
Duke University
Edelman
Electronic Arts
Finnish Institute of Occupational Health
GE Power Conversion
Georgia Institute of Technology
Gonzaga University
Google
Gulfstream Aerospace Corporation
Hardin Marine
Harkins Custom Knives
Intel Corporation
JELD-WEN
Kennedy-Matsumoto Design
Kent State University
Kitchen Concepts LLC
Libero Jewelers
Mars Space Flight Facility
MIT
NASA
NASA Glenn Research Center
NASA Marshall Space Flight Center
NASA Goddard Space Flight Center
National Federation of the Blind
Neurosciences Research Foundation
New York Hall of Science
Northrop Grumman
The New York Times Company
Proctor & Gamble
Pixil Inc.
PPG Industries
Purdue University
Qualcomm Inc.
Rochester Institute of Technology
San Francisco Art Institute
Sandia National Labs
Seattle Academy of Arts and Science
SIU - School of Architecture
Sony Electronics
Southwest Energy
Stanford University
Texas A&M University
The Eli Whitney Museum
The New York Public Library
The University of Chicago
UC Berkeley
US Army
US Cutter
United Nations International School
Valley Fine Foods
Woodbury University School of Architecture
Yale University

SPECIFICATIONS

PRINTING

Print Technology:	Fused Filament Fabrication
Build Volume:	11.2 L x 6.0 W x 6.1 H in [28.5 x 15.3 x 15.5 cm]
Layer Resolution Settings:	High 100 microns [0.0039 in] Medium 270 microns [0.0106 in] Low 340 microns [0.0133 in]
Positioning Precision:	XY: 11 microns [0.0004 in]; Z: 2.5 microns [0.0001 in]
Filament Diameter:	1.75 mm [0.069 in]
Nozzle Diameter:	0.4 mm [0.015 in]

SOFTWARE

Software Bundle:	MakerBot MakerWare™ Bundle 1.0
File Types:	.stl, .obj, .thing
Supports:	Windows (XP/7), Linux (Ubuntu 10.04+), Mac OS X (10.7/10.8)

PHYSICAL DIMENSIONS

Without Spool:	19.1 x 12.8 x 14.7 in [49 x 32 x 38 cm]
With Spool:	19.1 x 16.5 x 14.7 in [49 x 42 x 38 cm]
Shipping Box:	23 x 21.5 x 17 in [59 x 55 x 43 cm]
Weight:	25.4 lbs [11.5 kg]
Shipping Weight:	32.0 lbs [14.5 kg]

TEMPERATURE

Ambient Operating Temperature:	15° – 32° C [60° – 90° F]
Storage Temperature:	0° – 32° C [32° – 90° F]

ELECTRICAL

AC Input:	100 – 240 V, ~2 amps, 50 – 60 Hz
Power Requirements:	24 V DC @ 6.25 amps
Connectivity:	USB, SD card [included]

MECHANICAL

Chassis:	Powder-coated steel
Body:	PVC Panels
Build Platform:	Acrylic
XYZ Bearings:	Wear-resistant, oil-infused bronze
Stepper Motors:	1.8° step angle with 1/16 micro-stepping

COMPLETE FEATURE LIST MakerBot® Replicator™ 2 Desktop 3D Printer

A

World-class additive manufacturing at 100-micron layer resolution. High resolution is now a standard feature.

- Discover what it's like to make true-to-life, high-resolution models and things.
- Make surfaces so smooth they don't need sanding or post-production.
- Hold real-life objects that feel good to the touch.
- Create professional-quality, realistic products.

B

Think bigger than ever, make bigger than ever: 410 cubic inches of creative potential.

- Maximize! Build pieces up to 11.2 L x 6.1 W x 6 H in(12.75 in diagonal).
- 37% more volume than the original MakerBot Replicator: 410 in^3/6,717 cm^3 (vs. 310 in^3/4905 cm^3).
- Make complex assemblies in fewer runs.
- Make whole projects, not just single things.
- Multitask and save time for the next project on your list.

C

Designed and optimized for MakerBot PLA Filament [renewable bioplastic].

- Rely on builds that stick to the platform; practically no peeling, curling, or sliding.
- Build big with dimensional stability.
- Expand your creative palette with a whole new range of matte, translucent, shimmery, metallic, and sparkly colors.
- Super strong, great for moving parts and complex assemblies.
- Ready to print in less than two minutes.
- Minimal shrinkage factor means smooth builds with no cracks.
- 32% energy savings versus building with ABS Filament.
- Make things that feel great to the touch.
- Design accurately; get what you expect.
- Environmentally friendly.

D

Our easiest to use, most affordable desktop 3D printer yet. We've simplified everything for quick startup and ease of use.

- No assembly required.
- Wear-resistant, oil-infused bronze bearings mean less maintenance.
- Nothing to wash, dissolve, scrub, or tape.
- 3-point leveling system adjusts more precisely than previous model, and stays level longer.
- Grab your designs more easily with a pop-out platform.
- Uses 32% less power than the original MakerBot Replicator.
- Updated extruder requires less maintenance.

E

Professionally engineered and expertly built for speed. Design it, then hold it. Faster than ever.

- With advancements over original Replicator, achieve better prototypes and product designs, with more iterations in less time.
- Multitask and meet deadlines.
- Industrial-strength, powder-coated steel frame, made to handle high printing speeds.
- Quickly print projects with optimized software and hardware.
- Improved acceleration control firmware.
- Engineered with exacting tolerance to please any caliper-toting engineer.

F

MakerBot MakerWare is designed for the ultimate Replicator 2 experience. A fast machine needs even faster software.

- Prepare models for printing up to 20 times faster with the new MakerBot slicing engine.
- Drag and drop multiple models right onto the virtual build space, and then make them all at once.
- Now supports .stl and .obj files from all leading design software.
- New .thing file format saves multipart projects in one file.
- Friendly interface has intuitive icons and controls.
- Compatible across Mac/Linux/Windows.

G

Brand new look and feel. Our fourth-generation machine is made for the desktop...and the workbench.

- Designed to look great on a desk or table in your home, office, lab, or classroom.
- Black powder-coated steel frame for incredible strength and durability.
- Resistant to changes in temperature and humidity.
- Sleek and customizable.
- Designed for quiet desktop operation.
- Assembled with pride in our Brooklyn factory.

H

Responsive, expert customer support. We're ready to help if you need it.

- Online support available 6 days a week: support@makerbot.com [Mon–Sat, 9 AM–6 PM ET].
- Each of our support team members has thousands of hours of experience. Get expert help and advice when you need it.
- Feel the difference of a support team that cares as much as you do about your projects.
- Reference videos, tutorials, and thorough documentation 24/7.

[Appendix C: Notes]

NOTES

Other higher printer choices:
Other higher printer choices: Objet Connex, Envisiontec Perfactory or 3D Systems Projet

ABS vs PLA (http://www.protoparadigm.com/blog/2013/01/the-difference-between-abs-and-pla-for-3d-printing/)
ABS is petroleum based, PLA is organically derived. ABS worse for envin. PLA is better for env (partially decomposable). ABS requires active heating and cooling (warps heavily), while PLA does not necessarily. ABS requires ventilation.

ABS more stronger.. " It's strength, flexibility, machinability, and higher temperature resistance make it often a preferred plastic for engineers, and professional applications. The hot plastic smell deter some as does the plastics petroleum based origin. The additional requirement of a heated print bed means there are some printers simply incapable of printing ABS with any reliability."

Leaning towards.. PLA based solution-- less complicated. Initial investment can lead to a greater investment later on, once a proper knowledge base has been established. Should buy 2x printers at the $2000 price range for redundancy..

Issues:
Cost, department must fund
Maintenance.. someone has to maintain this thing
Access -- undergraduate access policies

** NOTES ** Not for final version

Printer Tiers:

- "Hobbyist"
-
    - Since 3D printers have been increasingly available for general use by the public, there are a large amount of commercial 3D printers on the market. These printers are relatively inexpensive, and may not come completely built. These 3D printers often extrude either PLA or ABS plastic to generate their models. Often these printers are below the $5k range.

- "Industrial"
-
  - More expensive industrial or research grade 3D printers have more features, but can be much more pricy. These 3D printers may offer multiple color (at once) support, as well as support for many other different types of materials. Due to cooling and heating issues, these printers also can be sealed to prevent warping.

Note: ** In order to make a more informed recommendation the 3D printer committee must explore the commercial ***

REIS Lab has the Replicator 2
Printers:

Replicator Line:

Replicator 2x
http://store.makerbot.com/replicator2x.html
ABS

Replicator 2
http://store.makerbot.com/replicator2.html
PLA Plastic

Type A machines series 1
http://www.typeamachines.com/collections/3d-printers
PLA, good recommendations around