Free Software in the 3D Printing Community

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3D Printing Overview

- Addative Manufacturing Process

- Most consumer products are FFF
  - "FDM" is a trademarked term
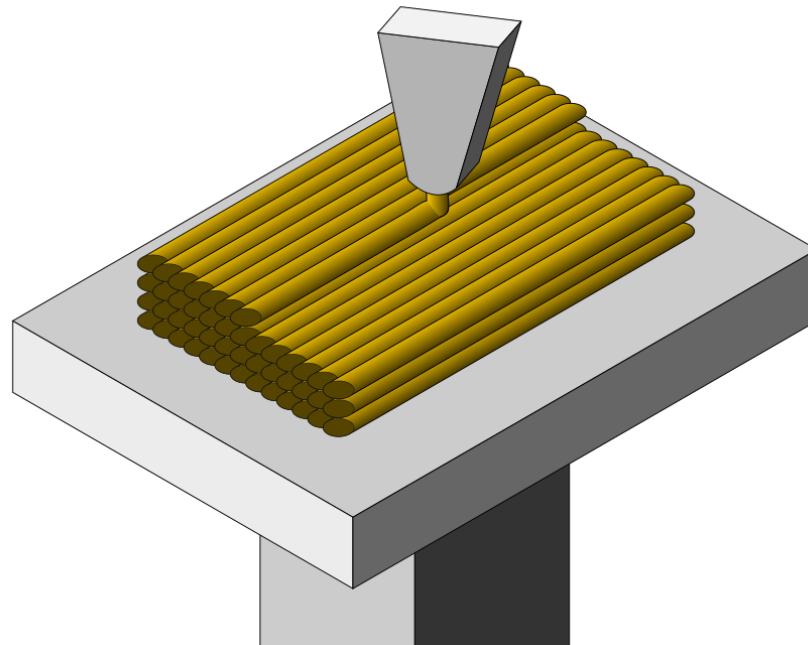 - Hot plastic is extruded to create shape

Image Source: Modified from "FDM Printing Modeling" (CC0), Wikimedia Commons

Some History

- Stratasys patented and trademarked "FDM"

- Patent expired 2009

- Explosive growth in field

- Printers became two orders of mangitude cheaper

- Hobbyist movement developed

Source: https://3dsourced.com/guides/history-of-3d-printing/

RepRap

- Hardware and firmware for 3D printers

- Released under GPL

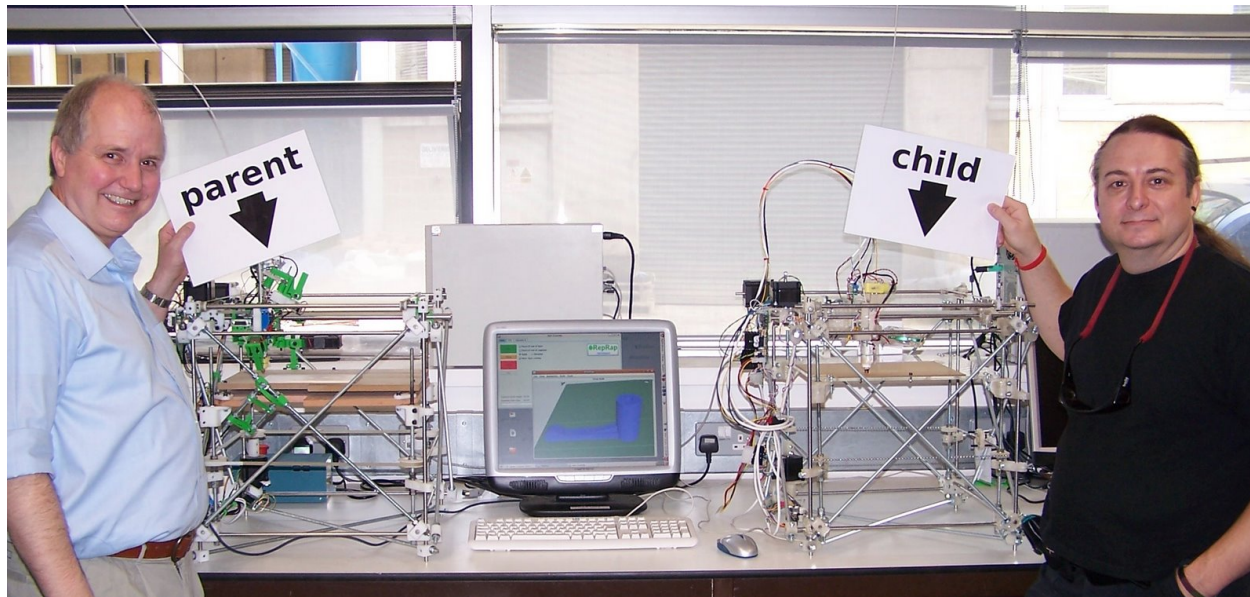- Credited with significant growth of hobbyist 3D printing

Image Source: "First Replication" (GFDL), blog.reprap.org

Hobbyists and Freedom

- With Free firmware available, maker movement took over

- Forum communities grew

- Emphasis on tinkering

- Not feasible for average user initially, but that changed with libre hardware

Libre Hardware in DIY

- Electrical, mechanical hardware made Free

- Appealed to DIY users

- KiCAD files, mechanical schematics made available

- Lowered barrier to entry and kits
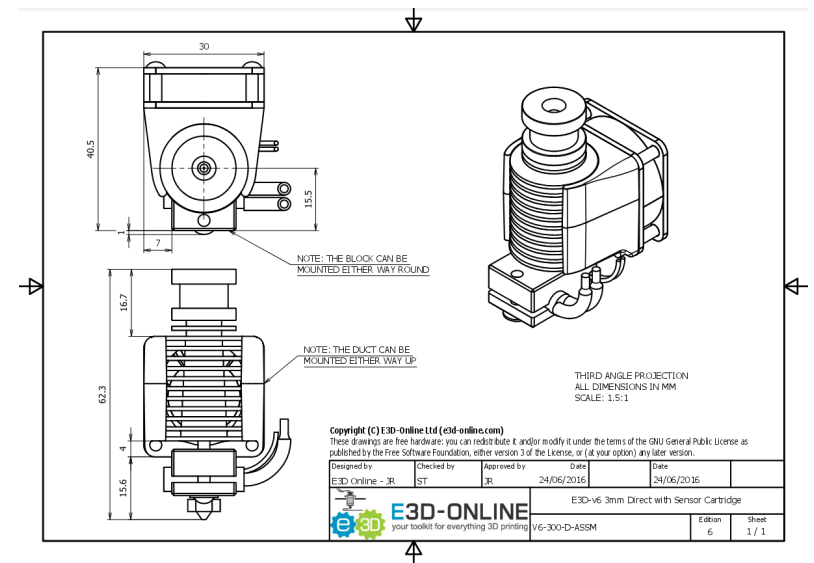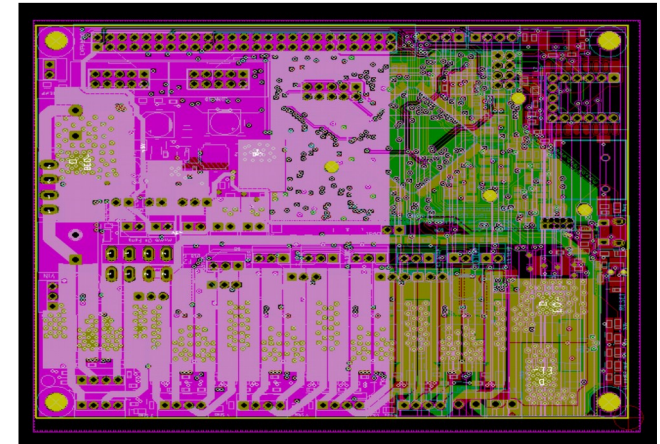
- Quality improvements

Image 1 Source: Screenshot of Duet 2 WiFi KiCAD Schematic
Image 2 Source: Mechanical schematic for E3D V6 Extruder

Expanse into "Pro-sumer" market

- DIY moved from kits to complete systems

- High quality and ease of use now a priority

- Aleph Objects, Prusa Research, and others

- Free software makes up significant portion of desktop market

Image Source: Prusa i3 MK2, image by Josef Prusa released under GFDL 1.3

Finding Free Software in 3D Printing

#	Printer Model	Manufacturer	Technology	Reviews	Rating
1	Taz 5	Lulzbot	FDM	157	4.89
2	M200	Zortrax	FDM	264	4.88
3	CR-10	Creality	FDM	241	4.85
4	Original Prusa i3 MK2S	Prusa Research	FDM	373	4.84
5	Original Prusa i3 MK2S	Prusa Research	FDM	565	4.84
6	Creator Pro	FlashForge	FDM	396	4.83
7	Original Prusa i3 MK3	Prusa Research	FDM	444	4.82
8	Ultimaker 2+	Ultimaker	FDM	218	4.80
9	Form 2	Formlabs	SLA	659	4.77
10	Ultimaker 2	Ultimaker	FDM	182	4.72

Data and original plot source: 3D Hubs 2018 Q4 Analysis

Finding Free Software in 3D Printing

#	Printer Model	Manufacturer	Technology	Parts printed
1	Form 2	Formlabs	SLA	14,142
2	Original Prusa i3 MK3	Prusa Research	FDM	13,961
3	Original Prusa i3 MK2	Prusa Research	FDM	12,674
4	Creator Pro	FlashForge	FDM	10,873
5	Ultimaker 3 Extended	Ultimaker	FDM	7,187
6	Ultimaker S5	Ultimaker	FDM	6,969
7	Original Prusa i3 MK2S	Prusa Research	FDM	6,546
8	M200	Zortrax	FDM	5,904
9	Tech FT-5	Folger	FDM	5,549
10	Ultimaker 2	Ultimaker	FDM	4,524

Data and original plot source: 3D Hubs 2018 Q4 Analysis

Community Values

- The ability to tinker

- Free Hardware also a priority

- Makerbot:

  - 40% market share when Free

  - Suffered when non-free

    - Loss of faith in product also a factor

  - Market share still in decline

Source: https://robertsoninnovation.com/makerbot-a-great-strategy-cant-save-a-bad-product/

Free Hardware

- Significant number of Free Software printers also use open designs

  - Aleph Objects, Prusa, Ultimaker, and others

- Open electrical boards and mechanical designs

- Increased repairability

- Increased ability to modify

Parallels between our communities

- Value the ability to share and modify

- Value openness in design

- Hack Value

- Conflict: Freedom as ideal vs. Obligation

- Communities highly compatable

Image Source: Q3D (GFDL), reprap.org

3D Printing and Free Culture

- Digital revolution allowed for files to be copied

- Free Culture benefited

- Software/Media can be freely shared

- Physical objects cannot

- 3D Printing offers similar revolution

- Already taking place in engineering

Libre Hardware importance to Freedom

- Hardware generally not rejected for being non-free

  - Viewed as unattainable

- Accessible manufacturing allows for open design

  - Manufacturing capability becoming public

- FSF stance:

  - "Distributing a nonfree functional object design is as wrong as distributing a nonfree program"

*Source: https://www.gnu.org/philosophy/free-hardware-designs.html*

Impact of 3D printing growth to Freedom

- Free software is majority market share for desktop printers

- 3D Printing growth is Free software growth

- Many users remain unaware of software freedom

- Common ground in values means this can be fixed

Increase in Accessibility

- 3D Printers becoming more user-friendly
  - Increased automation
- Supporting software is really easy
- Frequently found in >500$ range
- Common tool in makerspaces, libraries, universities
- Parts freely shared online

Customizable parts
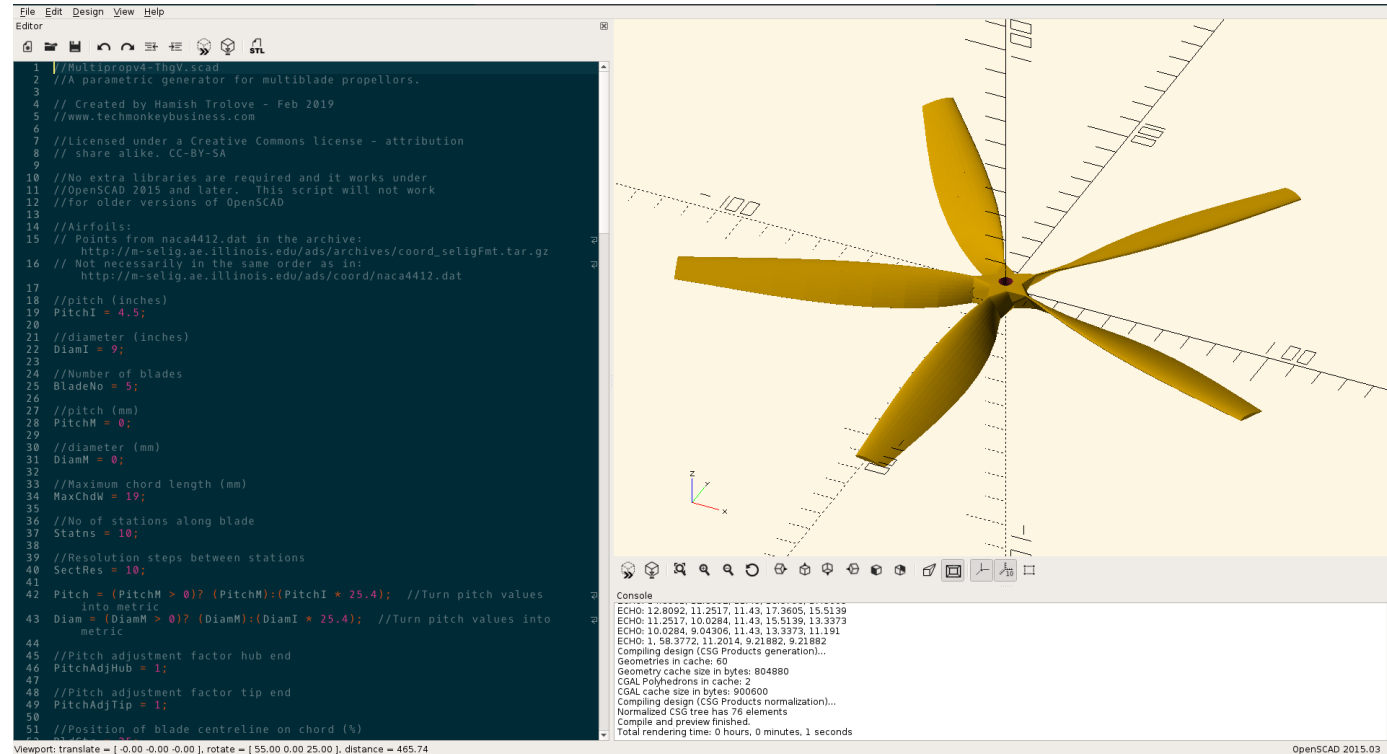
- Parts can be shared and customized for different needs

Images:
Left: Parametric Multi-Blade Propellor Generator by BouncyMonkey on Thingivese
Right: Source file open in OpenSCAD

Spread of 3D Printing Resources

- I went looking for 3D printers and found them everywhere I looked
  - Multiple spaces at Wentworth, MIT
  - Tufts, Boston Public Library, Brookline Library have devoted printers
- Libraries using desktop printers
- Universities using combination desktop, industrial printers

Industrial Freedom

#	Printer Model	Manufacturer	Technology	Parts printed
1	HP Jet Fusion 3D 4200	HP	MJF	6,406
2	P 396	EOS	SLS	4,714
3	Formiga P 110	EOS	SLS	2,526
4	Objet30 Prime	Stratasys	Material Jetting	1,100
5	J750	Stratasys	Material Jetting	858
6	Perfactory Vida	Envisiontec	SLA/DLP	645
7	Formiga P 100	EOS	SLS	600
8	Lite 600	UnionTech	SLA/DLP	582
9	Connex Objet350	Stratasys	Material Jetting	534
10	iSLA-650 Pro	Shining 3D	SLA/DLP	483

Data and original plot source: 3D Hubs 2018 Q4 Analysis

Reason for Freedom decline

- Industrial printers non-Free

- Universities willing to pay for industrial machines, hobbyists are not

  - Cost: Professional machines are 10k+

  - Needs: Ease of use

  - Advertisting: FOSS machines use word-of-mouth

  - Hobbyist experience: knowledge of what machines are worth the money

Free Software Movement losing traction in field?

- These spaces are >4 years old

- Most recent FSF Essay on topic was 2015

- Only 1 manufacturer FSF Certified

- SLA Printing becoming more accessible

  - One Open Source SLA printer

- Demand for design tools not adequately met

Sources:
https://www.fsf.org/news/lulzbot-taz-6-3d-printer-now-fsf-certified-to-respect-your-freedom
https://www.prusaprinters.org/introducing-original-prusa-sl1-open-source-sla-3d-printer-by-josef-prusa/

Makerbot retaining makerspace presence

- Popular as first library/makerspace purchase
  - Donations to libraries
- Tries to be the Apple of 3D Printing
- Consumer arm of Stratasys
  - Publicly traded, so we know Makerbot isn't doing well

Source: http://blog.makerbot.com/2010/08/09/back-to-school-makerbot-teacher-giveaway/

Makerbot History

- Originally major player in Free software, open design
- Venture capital firm joined board
- Founding member Zachary Smith forced out for being pro-open design
- Acquired by Stratasys, closed source
- Community felt betrayed, loss of trust in product
- Now in decline
- Still popular in libraries because of friendly package

Source: https://hackaday.com/2016/04/28/the-makerbot-obituary/

Libraries as Injection Vectors

- Local Libraries are often how people encounter 3D printing

- It can be a way to expose people to Free software

- Donate a Taz or Prusa instead

    – Makerbot Replicator+: 2,800$

    – Aleph Objects Taz 6: 2,500$

    – Prusa Research i3 MK3s: 800$

Why Prioritize 3D Printing?

- Accessible manufacturing

- Growing market

  – Doubling in size every 3 years

- Offers opportunities for free software not found elsewhere

Source: 3D Hubs 2019 Q1 Analysis of 3D Printing Trends

3D printing as potential freedom driver

- Makes manufacturing accessable

- Potential driver of mechanical Freedom

- Electrical access to DIY

    - Boards designed available in KiCAD

    - Potential driver of Electrical freedom

- Offers opportunity in Free software development

    - Firmware and user-facing code

3D Printing is a Free Software Opportunity

- Significant amount of Free software, despite lack of Freedom as a goal

- Hobbyist and library needs easily met by Free Software

- 3D Printing community values very similar to Free Software values

- 3D Printing directly promotes Free Culture values

Software is invisible

- Free software is abstract, 3D printing is tactile

- Free software struggles with "Real"

- People take software freedom for granted

- Lack of technical literacy makes stressing importance of freedom difficult

Opinion is ready to shift

- See Facebook
  - Facebook was given enormous access to data
  - They abused it
  - Awareness of danger spread
- Mainstream outlets for this shift are proprietary
  - Instagram
- Shows interest in ethical technologies

Source: https://www.nytimes.com/2018/03/29/opinion/facebook-privacy-zuckerberg-society.html

Captuing interest

- Engaging, easy projects possible
- Easy to integrate into schools
    - Middle and high school programs
    - University programs
- Appeals to educators and students
- 3D Printers are mesmerizing

Open Hand Project

- Open designs for prosthetics

- Medically certified

- 3D printed

- Demonstrates benefits of Free technology

- Great press

Image source: Open Bionics press kit

Freedom in the toolchain

- Options on all operating systems

- Slicing largely free

- Part design (CAD) is largely proprietary
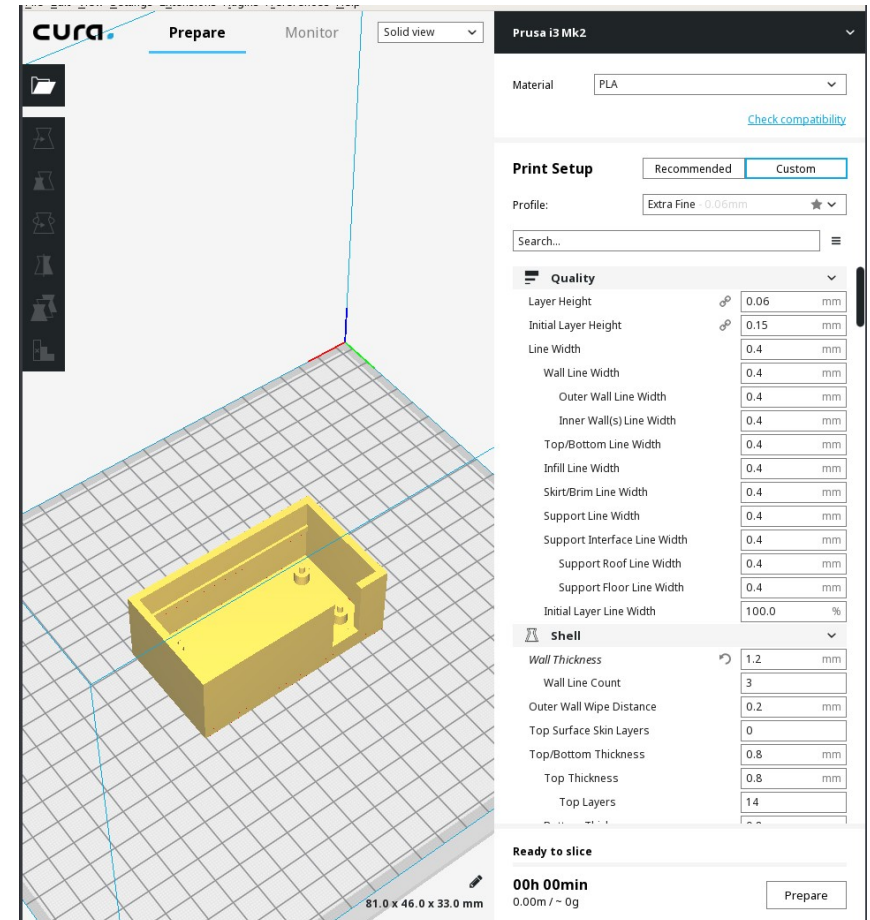
Importance of CAD

- Everything in the modern world is designed in CAD

- Non-free hardware blocks additional level of Freedom

- Non-free design software blocks that

- Accessible design is essential to freedom
  - Electrical options?
  - Mechanical?

Blender Background

- Developed as an in-house animation tool

- Later released under GPLv2

- Used in professional environments

  – Pre-visual effects in *Captain America: Winter Soldier*

  – Some credit sequences in *Wonder Woman*

  – Some promotional artwork for *Super Smash Brothers*

Sources:
https://www.fxguide.com/featured/captain-america-the-winter-soldier-reaching-new-heights/
http://www.artofthetitle.com/title/wonder-woman/
https://cgcookie.com/articles/max-puliero

Blender as engineering modeler

- Professional quality CAD tool

- Does shapes and meshes

- Capable of physics simulation

- Not really a parametric design tool

Parametric Design

- Performing design by parameters
- Create shapes of specific lengths, widths, etc.
- Critical for real-world parts
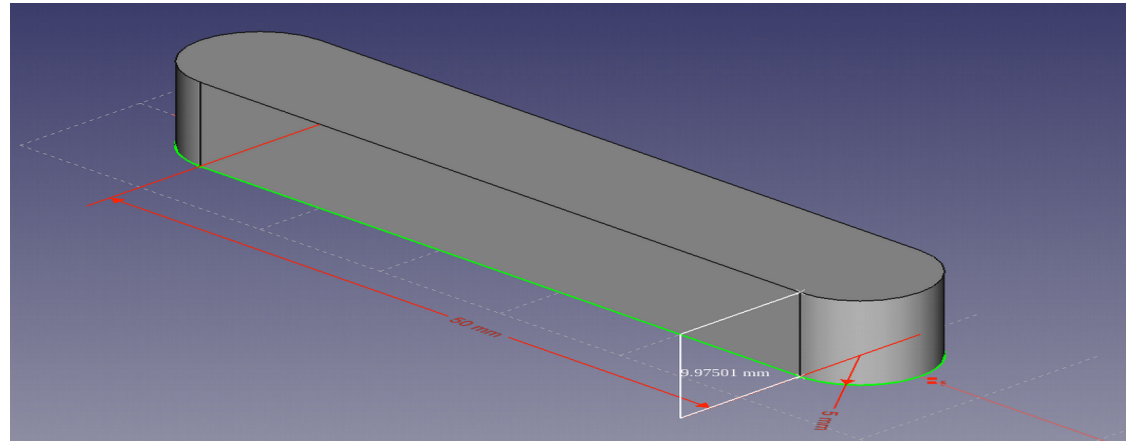- Largely proprietary industry, but free software exists

*Image: An extruded part in FreeCAD.*

FreeCAD

- Free parametric design tool

- Awesome project that fills a big need
  - Therefore very important project

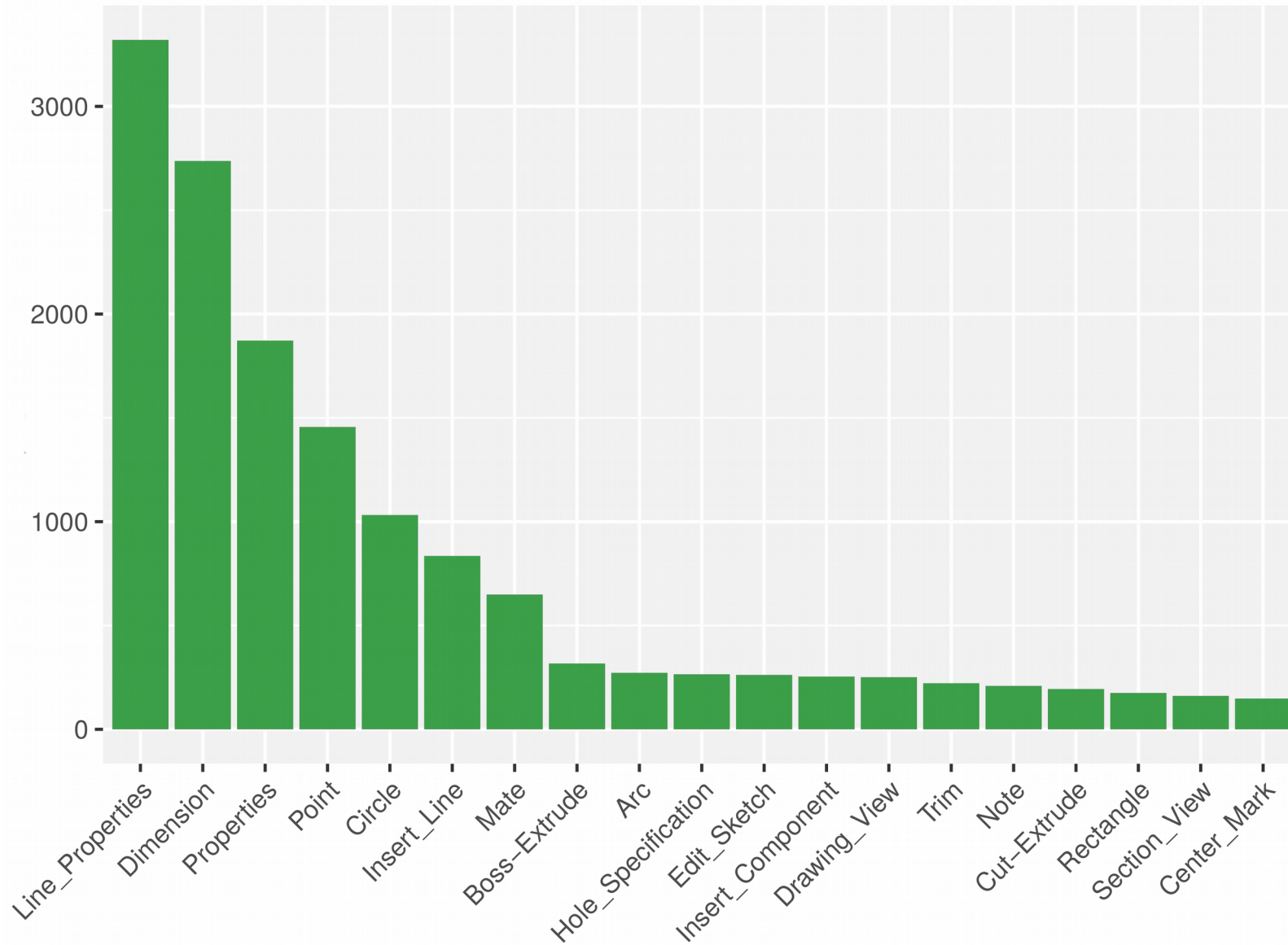- Is it a replacement for Solidworks, Inventor, etc?

I took my friends logs

- Solidworks keeps debug logs
- Logs from ~600 sessions sampled
- Parsed for operations information
  - ~65000 individual operations
  - 175 unique operations
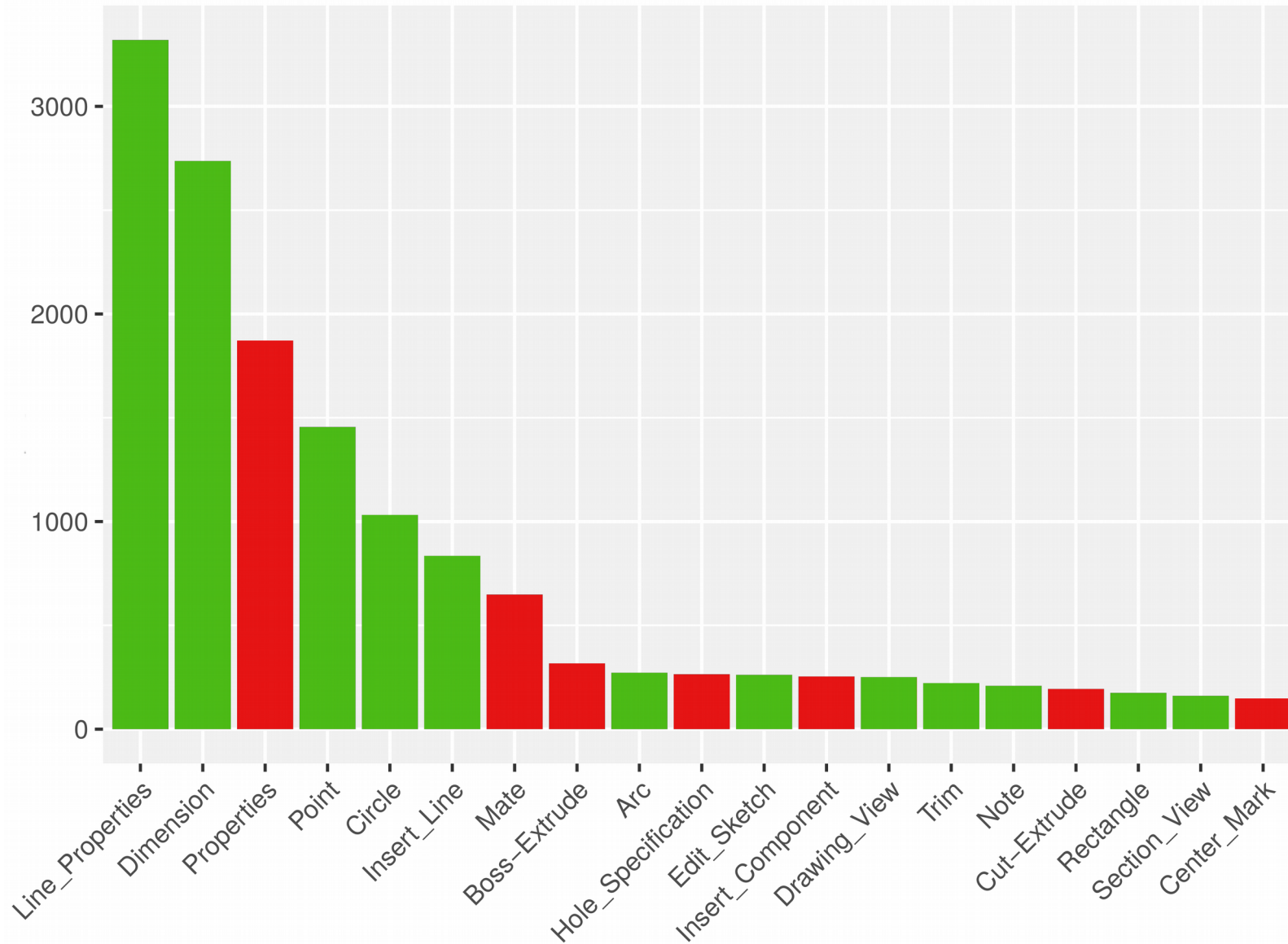- Data set of usage frequency plotted
- Available upon request
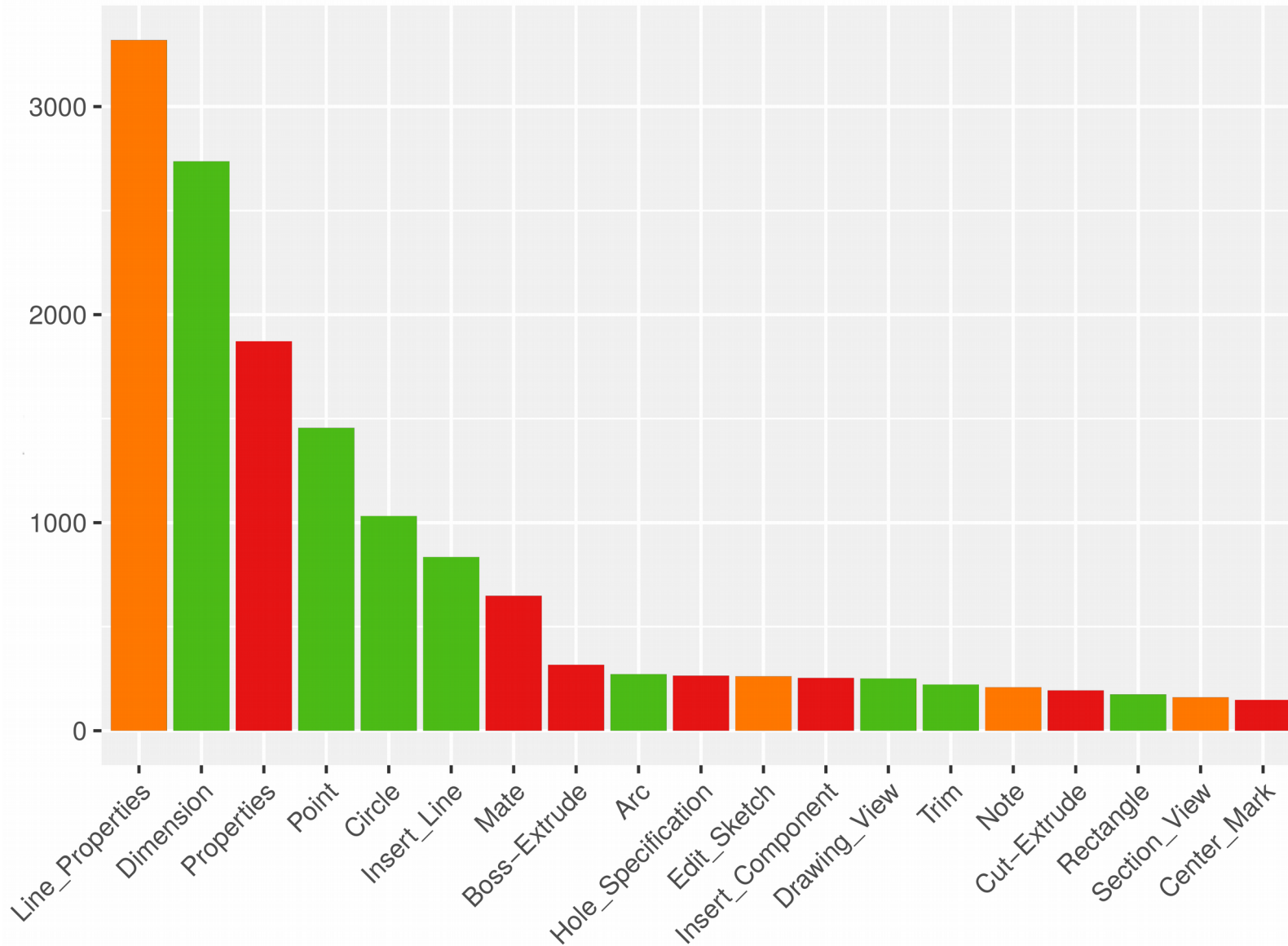
Top 20 Solidworks Operations
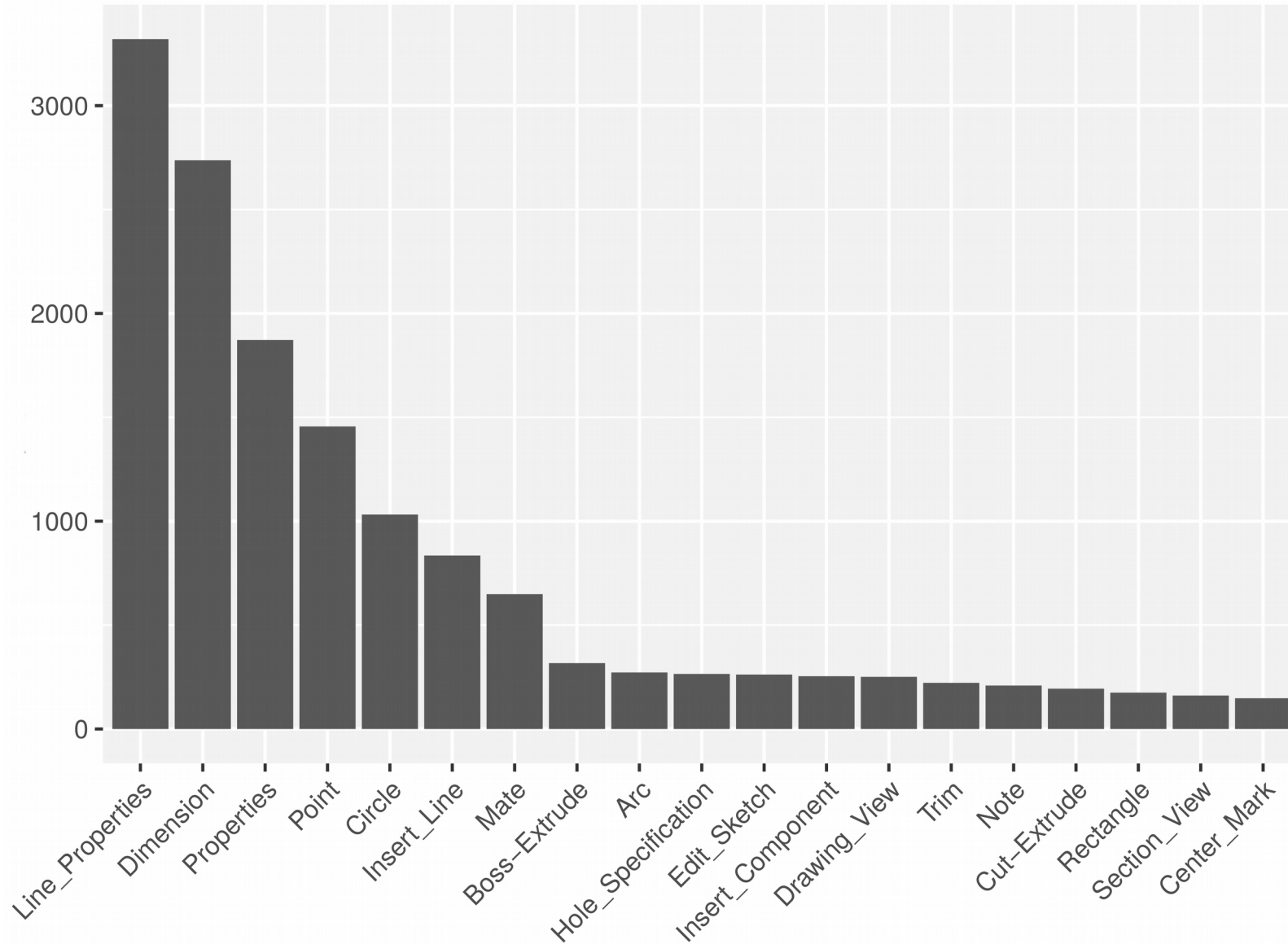
Can FreeCAD do it?

Does FreeCAD have an equivalent operation?

Does FreeCAD make it easy?

Assemblies

- Multiple seperately designed parts interacting with each other

- Allows for testing of sizing, spacing, etc

- Essential for complex designs

- Currently non-native to FreeCAD

- Number one complaint from engineers

Learning from this data

- FreeCAD is a great tool!
  - Aims to solve almost every CAD need
  - It can be better with a better UI
  - It has the technology
- Assemblies are an overlooked need
- Workbenches could be streamlined
  - All the functionality is there but gets split up
  - Experienced users un-split it

Demand for Gratis, entry-level CAD

- Tools like TinkerCAD, OnShape have done well in market
  - OnShape founded by Solidworks execs
- Professional level tools not suitable for average user
- Getting CAD tools to average user necessary for greater accessibility
- Expands freedom to wider audience
- Extends into the maker movement

Connecting to Maker movement

- Maker movement potential entry point to spread Free software ethics

- Maker movement has larger reach

- Previously no entry point to maker movement

- 3D Printing potential method to bridge gap

Lack of Freedom in education

- Getting next generation of engineers and thinkers is critical

  – Is this an aging movement?

- Not a priority in most tech courses

  – IEEE/ACM recommends 3 hours for CE

  – Not much better for CS

- Many students are unaware of need for Free software

Source: https://www.acm.org/education/curricula-recommendations (CE2016, CS2013)

Getting Students

- If it won't happen in class, it needs to happen extra-curricularly

- Easy CAD tools and 3D printing potential fix

- Spread free, easy CAD tools to spark interest

  – 3D Printing already popular on college campuses

- Students more receptive to new philosophies

In Conclusion

- 3D printing actively benefits from Free software and vice-versa

- Free software modeling tools need to be a higher priority

- We have not actively taken advantage of 3D printing as a Free software opportunity

- 3D Printing offers actionable approaches for greater software freedom

Thank you

Questions?

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