Project PAM

A Reference Design for Photoresin Additive Manufacturing for The Open Source Community

Saluki Engineering Company
Reference Number: S14-75-3DPR
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1 TRANSMITTAL LETTER: CWB

2014-12-03
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Mr. Blair,

On behalf of the Saluki Engineering Company, I would like to thank you for including us in the bid for a project to design a digital light processing printer. Attached is a design report for a DLP photoresin printer, Project PAM. Along with this report, we have included the computer host software code and build instructions of the prototype.

Project PAM proposes a reference Photoresin Additive Manufacturing (PAM) system which maximizes accessibility to the hobbyist. It is intended to be easily obtainable to consumers. This is achieved through extensive use of currently available or easily fabricated hardware and open-source software. The design allows this hardware to be very flexible, to scale to the size requirements of the maker. The reference design will be open-source hardware and software to the lowest practical level. Thorough documentation will provide the necessary means for the maker to go from an empty table to a functioning printer.

Our prototype is constructed to allow a build volume up to 192 mm x 216 mm x 216 mm with an X and Y pixel size of 100 µm and layer thicknesses down to 10 µm. In its current single-projector configuration it can provide a build volume of up to 216 mm x 121.5 mm with an X and Y pixel size of 112.5 µm. It can also close focus to provide a much smaller pixel size for smoother builds of smaller objects. This can be accompanied with a smaller build table and build vat to involve a smaller volume of resin.

The prototype comes with a 1920 x 1080 pixel ViewSonic projector which has been proven to provide very close focusing and will be perfect for later expansion to a large volume two projector system.

Please feel free to contact me at (815) 214 9661 or by email, burdickjp@siu.edu, if you have questions about this project.

Sincerely,

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ACKNOWLEDGEMENTS: CWB

We would like to express our thanks to Dr. Spyros Tragoudas and Dr. Rasit Koc along with the Electrical and Computer Department and the Mechanical Department for the support and financial contributions. The project would not have been possible without their financial backings.

We would also like to take the time to thank the backers of the crowed funding campaign. Very person's contribution was very much accommodating to the needs of our group. We would like to thank them for not only their financial report but their words of encouragement and belief in our project.

From the beginning of the project Dr. Lizette Chevalier has given priceless words of encouragement and advice that has been very critical to the success of the project.

At this time we would like to thank Lakendria Kenner of WSIU, Scott J. Grunewald of 3D Printing Industry, Eddie Krassenstein of 3D Print, and Austin Miller of Dailey Egyptian for the kind words in their articles. Their articles have help spread the work of Project PAM out to the global community.

We would like to take this opportunity to thank Dr. James Mathias for him allowing us to have use to his laboratory space giving Project PAM a place to call home.

We also would like to express a deep sense of gratitude to the team's Faculty Technical Advisors; Dr. James Mabry and Joe Lennox, for their constant support, valuable guidance, and professional advice throughout the various stages of the design project.

We are grateful for the assistance of Tim Attig of the SIUC Machine Shop. His vast machining skills and knowledge have been a great part of the project's success. Tim's time and technical advice was invaluable to the team.

Lastly, we would like to thank the professors and teachers of the class; Dr. Tod Policandriotes, Dr. Vidya Singh-Gupta, Dr. Frances Harackiewicz, and Dr. Alan J. Weston for their support, ideas, and suggestions.

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2 EXECUTIVE SUMMARY: CWB

Project PAM proposes a reference Photoresin Additive Manufacturing (PAM) system which maximizes accessibility to the hobbyist. It is intended to be flexible by allowing for configurations of hardware available or easily obtainable to the maker. This is achieved through extensive use of currently available or easily fabricated hardware and open-source software. The reference design uses open-source hardware and software to the lowest practical level. Thorough documentation provides the necessary means for the maker to go from an empty table to a functioning printer.

The major subsystems of Project PAM include: Mechanical Motion, Chassis, Printer Control Software, Hardware-Software Interface, Resin Management, Optics, Vat, and Coupler. Our teams is still striving to achieve the optimist solution to achieve the highest level of quality.

Several of the design activities and decisions show how Project PAM is more desirable than the competition. One example of this is Project PAM's build volume size. The maximum build volume is almost double that of any other DLP printer. This is achieved by supporting the use of two 1920 x 1080 pixel projectors. As consumer resins increase with quality this feature will allow the PAM system to grow. Though the maximum build volume would use up to 9 L of resin, Project PAM's flexible design can accommodate smaller vats and build tables. The maker can use a vat and build table sized appropriately for their build. This will minimize resin waste, saving the maker money.

This printer is expected to have the capability of producing high quality prints. The initial goals of Project PAM included: keep the cost of the project under $700 excluding the price of the projectors, support the use of two projectors, have a maximum build size of approximately 8 L, layer thickness as thin as 100 µm, and have a printing resolution error within 100 µm.

The prototype is sized to support a build volume of 192 mm x 216 mm x 216 mm which is a volume of 8.9 L. This would be achieved through the use of two 1920 x 1080 pixel projectors used in tandem, providing a pixel size of 100 µm. The prototype is currently configured with a single 1920 x 1080 pixel projector. With 2mm pitch lead screws and stepper motors providing 200 steps per revolution layer heights can be as thin as 10 µm without microstepping.

This report consists of: a project description that will introduce the report and project, a cost analysis allowing the open-source community to see the end cost, expected build time schedule, detailed subsystems descriptions along with recommendations, and an appendix.

3 PROJECT DESCRIPTION:

3.1 INTRODUCTION: CWS

Today when one uses the term "3D printing" they referring to the manufacturing process that allows a digital model to be manufactured through an additive process. 3D printing is unique from other machining processes because it implements what's known as additive manufacturing rather than the more common techniques of drilling or cutting to remove

material. 3D Printers are able to accomplish this by slicing the virtual models into several two dimensional layers and then printing those layer one by one to build up the object. This is advantageous because it is much less wasteful than traditional techniques. A 3D printer is also capable of building nearly any object which allows manufacturers to change products without having to buy any new equipment.

The first 3D printer was built in 1984 by Chuck Hall [1] but the process has not been widely available until the early 2010's. Printers are most commonly used for cheap and rapid prototyping but the process has shown potential in a number of fields, including architecture, automotive design, and even the biomedical field to print human tissue and organs. Because of this potential the industry is estimated to be worth more than $2.2 billion today [2].

There are several techniques used to accomplish this layer-by-layer building operation, the most common of the additive manufacturing processes today is extrusion deposition. With this extrusion deposition each 2D layer is built by extruding a bead of material which will harden almost instantly upon leaving the extruder nozzle. The nozzle head moves across a surface depositing the material in the shape of the given layer and then moves on to build the next layer of the object. As each layer is added the print object gains volume. This method is simple and inexpensive but is less accurate than other techniques and also error prone since any defect can lead to a jam or clog in the extruder.

However, another method that is slowly gaining popularity is using light and photocurable resins to build these layers. The resin is exposed to some form of UV light which hardens the resin. This hardened section of resin is one layer of the object. The print area then moves down and the process is repeated to build the next layer. This is known as photopolymerization and the most common form of photopolymerization is using a DLP projector to project images onto the resin. DLP printing has several advantages over the previously mentioned extrusion deposition method, the first of which is speed. Instead of moving an extrusion nozzle slowly across a surface to build the individual layers, DLP printers project an image of the entire layer and cure it all at once. Another advantage is that since there is no physical contact between the projector and the building material there is not possibility for jamming. However, DLP printing’s greatest strength lies in its ability to produce extremely precise and detailed print objects since its resolution is only limited by the resolution of the projector used.

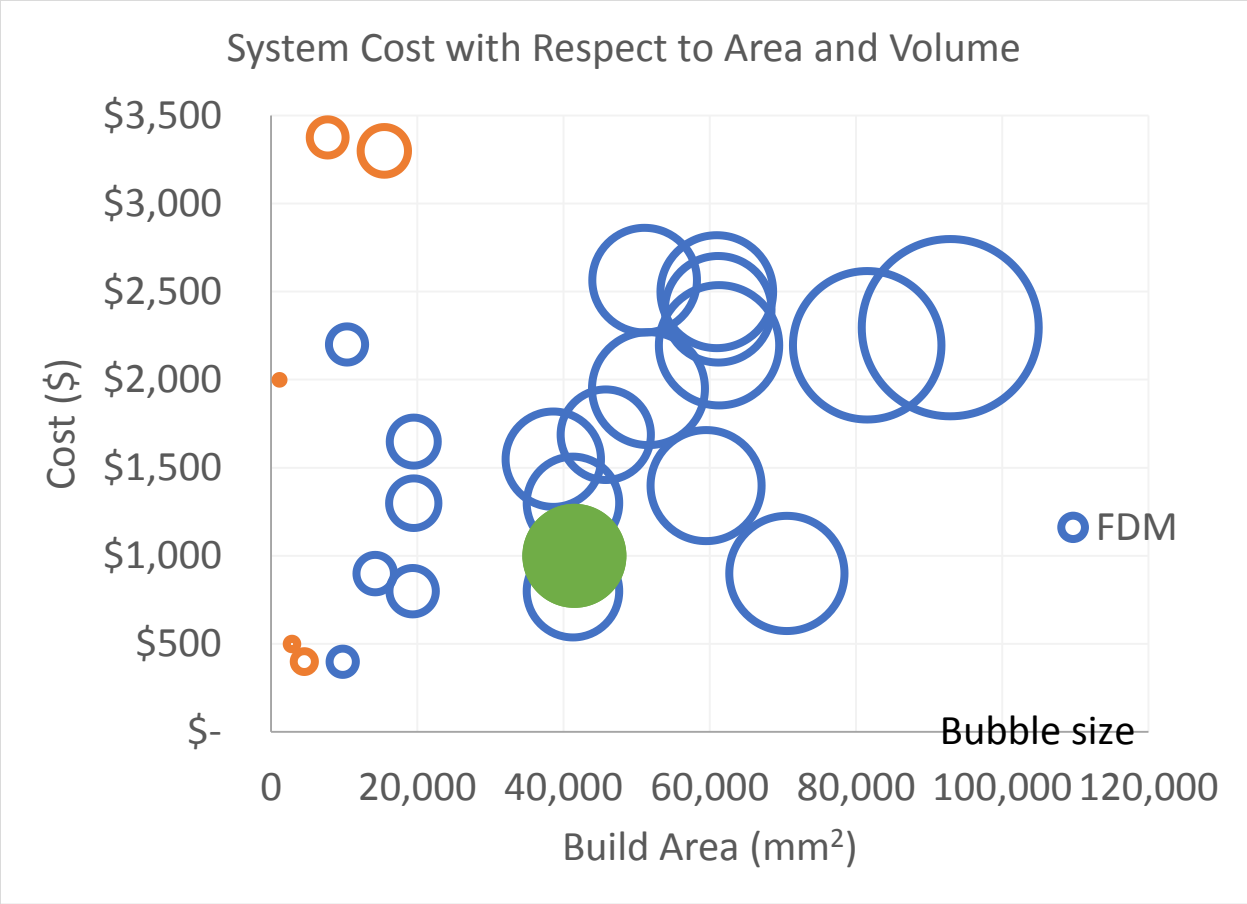

Figure 1. Market gap

3.2 OVERALL PRINTER DIAGRAM:

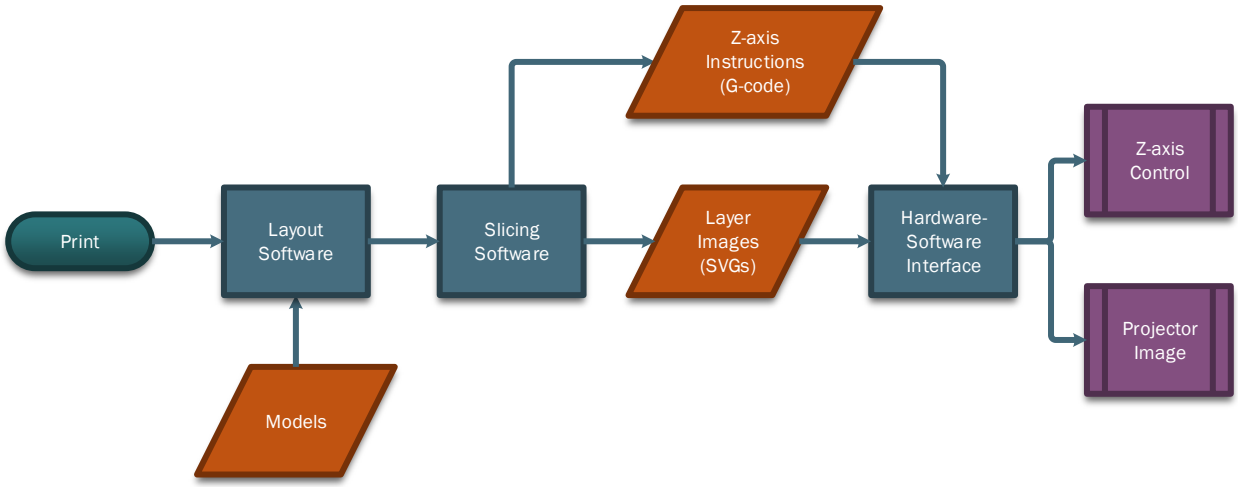

Figure 2. Flow diagram for Project PAM printer control software

4 COSTS: DMO

4.1 CROWDSOURCING CAMPAIGN: DMO

The idea of crowdsourcing Project PAM was brought up during the spring; however, it was decided to be too much of a commitment for the team members at that time. As the semester continued and the estimated cost of building the prototype became apparent crowdsourcing was again looked at. The decision was made at the beginning of the fall to move forward with a crowdsourcing campaign.

The first step of this process was to pick a crowdsourcing platform. Originally Kickstarter was chosen; however, after during the process of trying to create the campaign it was determined Kickstarter did not meet the needs of the project. Because of this Indiegogo was chosen as the crowdsourcing platform for Project PAM.

One of GitHub's features called GitHub Pages, which hosts simple static HTML websites for free and provides Creative Commons licensed templates to use, was used to develop a website for Project PAM [3]. GitHub supports both project pages (website for repo) and organization pages. For Project PAM an organization page along with two project pages (Hardware and Software Repos) were created using the Architect theme as a starting point. The print outs of the website are included in the appendix at 9.6.

4.1.1 INDIEGOGO

The first part of the Indiegogo campaign was to take the information from the website and modify to follow the Indiegogo Playbook, a guide to running a successful crowdsourcing campaign [4]. Indiegogo recommends creating a short video to introduce the project and be a commercial for the product [4]. The decision was made to use an online tool called Prezi, a kind of PowerPoint tool for presenting ideas on a virtual canvas [5]. With the help of a student in the Mass Communications program voice over was recorded for the Prezi.

The second step for the Indiegogo campaign was to set the funding goal for the campaign. Unlike other crowdsourcing platforms Indiegogo has an option to allow the campaign to keep all funds raised instead of requiring the campaign to reach the goal to receive the funds. Indiegogo calls this option flexible funding and charges a higher rate if the goal is not reached. Because of this and the ability to receive funds that were donated through PayPal immediately it was decided to use Indiegogo flexible funding option [6]. The main portion of the project that was hoped to be funded through the crowdsourcing campaign was the two 1080p projectors, which at the time coasted a total of $1,400. Because of Indiegogo's and credit card companies' percentage they take of the raised funds and it was decided to set the goal at $2,500. This goal would have made possible for the purchase of the two projectors along with the purchase of additional resin and additional prototyping costs.

The final step was to decide on the perks for funders to claim. It was decided for Project PAM to have 4 perks at differing price points. The perks that were used for Project PAM are described in Table 1 along with the number of funders who claimed them.

Table 1. Indiegogo perks

Perk	Price	Description	Number Claimed
Thank You	$5	For contributing $5.00 or more you will receive a personalized thank you email from the team and you will be immortalized as a funder on our website.	0
Key Chains	$25	For a contribution of $25.00 or more you will receive one Open Source Hardware Association logo key chain AND one Open Source Initiative logo key chain. Our intent is to 3D print these key chains with the Project PAM prototype. (Additional cost of $10 for international shipping.)	7
Bound Documentation of Design	$250	For a contribution of $250.00 or more you will receive all documentation associated with the design professionally bound and well presented. Also includes $25 perk. (Additional cost of $50 for international shipping.)	1
Full Kit and Documentation	$1500	For a contribution of $1,500.00 or more you will receive a full unassembled build kit for the printer. (The kit does not include projectors.) Also includes $25 perk and $250 perk. (Additional cost of $300 for international shipping.)	0

The campaign was launched on September 30, 2014 and was originally planned to be 14 days and end on October 14, 2014. However, after a week and a half the decision was made to use Indiegogo's one time campaign extension to extend it to a full 30 days and to end on October 28, 2014. The performance of the campaign is shown in Figure 3. The majority of the funds raised was raised in the final day of the campaign, it went from $300 to over $700 during that day.

Overall $741 was raised, in 11 contributions, of the $2,500 goal or the project was 29.64 % funded. This does not include funds raised outside of Indiegogo. If the funds raised outside of the Indiegogo are included the total was around $960, which was enough to purchase a single refurbished 1080p projector and additional items needed for prototyping. Additionally the Indiegogo page had 1,253 visits and 146 referrals.

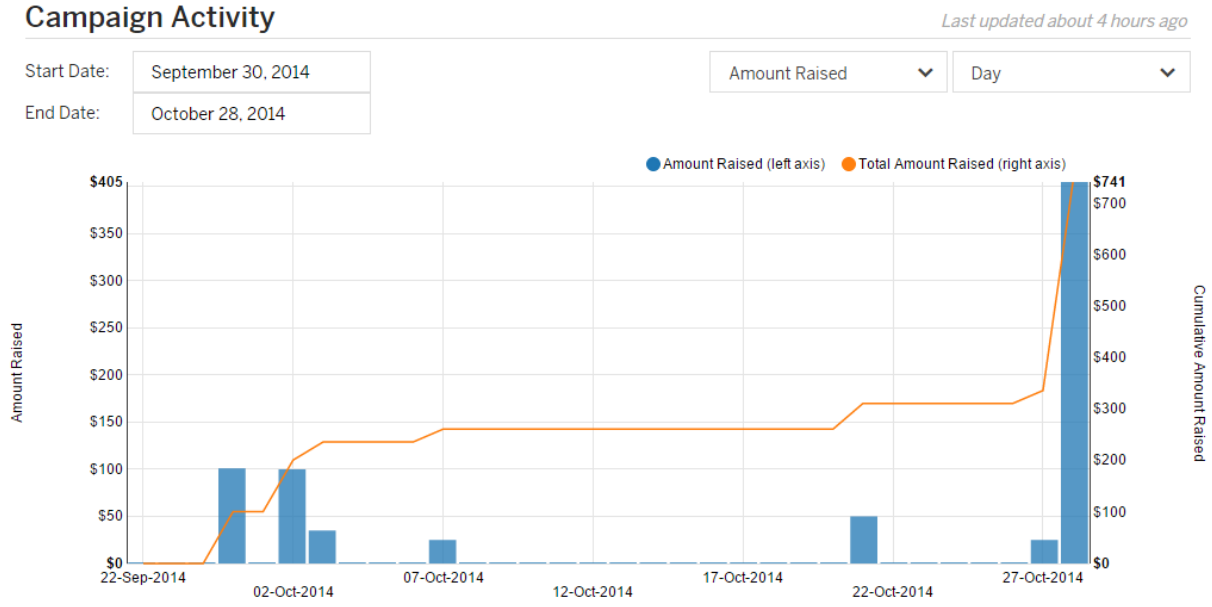

Figure 3. Crowdsourcing campaign activity

4.1.2 SOCIAL MEDIA

In addition to the GitHub organization for Project PAM, a Gmail account for email, and the GitHub Pages, social media accounts/pages were created to supplement the crowdsourcing campaign. These accounts/pages included Twitter (@ProjectPAM), Facebook, Google+, and YouTube. Twitter had 59 tweets and 17 followers, Facebook had 40 likes, and the YouTube videos had 1062 views. Additionally, Google Analytics were set up for the GitHub Page and the reports of traffic for September to December are included at 9.6.4.

4.1.3 MEDIA COVERAGE

The Project PAM crowdsourcing campaign was featured in 4 major news outlets. Those include 3DPrint.com, 3DPrintingIndustry.com, WSIU, and Make Magazine. Full page print outs are included at 9.10.

Table 2. Articles Project PAM was featured in

Media Outlet	Article Titles
3DPrint.com	Project PAM – College Students Look to Create an Entirely Open Source DLP 3D Printer [7]
3DPrintingIndustry.com	Help The Open Sourced DLP 3D Printer called Project Pam on Indiegogo? [8]
WSIU	SIU Engineering Students Use Crowdfunding for 3D Printer [9]
Make Magazine	Cool Crowdfunding: October 26, 2014 [10]

4.2 PROTOTYPE COSTS: DMO

The costs of Project PAM are split into two tables: one for the cost of the subsystems and the total cost of the printer including the projector. A complete bill of materials is included at 9.2.

Table 3. Cost of subsystems

Subsystem	Price
Motion control	$113.61
Chassis	$315.99
Hardware software interface	$25.97
Motors/motor control	$82.83
MakerJuice G+ resin	$45.00
Total	$602.17

Table 4. Total system cost

Subsystem	Price
Printer	$602.17
Projector	$690.00
Total	$1292.17

5 SCHEDULES:

5.1 PROPOSED AND REWORKED SCHEDULE: DMO

With the addition of an additional team member at the start of the second semester, the schedule was able to be reworked to free up team members. The proposed and reworked (additions in orange) are included in the appendix at 9.1.1.

5.2 AS WORKED SCHEDULE: DMO

Project PAM experienced procurement problems that set the schedule back 3 weeks. The setback was not a total waste because it allowed for the construction of a linear motion test rig to be used for testing as soon as the parts arrived.

The other big change to the schedule was the addition of the crowdsourcing campaign. This set software back a whole month because the team member doing software was put in charge of developing the campaign.

The as worked schedule can be found at 9.1.2.

6 SUBSYSTEM DESCRIPTIONS:

6.1 CHASSIS: JPB

6.1.1 PROCESS OF DESIGN

An early goal of the hardware design was to have a product which was very rigid and allowed adjustability for all pieces which need to be aligned. Several options were considered for the construction of the chassis, from an incorporated enclosure and chassis design to open source linear motion systems.

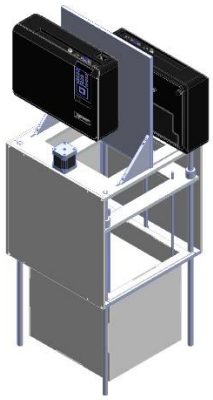

Figure 4. An isometric view of the current chassis design

It was decided that conventional round linear bearing shafts could be used as the vertical component of the chassis, as shown in Figure 4. This removes the necessity for a separate vertical chassis structure. This simplified the chassis design to just two horizontal structural plates to hold the motion-driving components, projector, and vat, and the linear bearing shafts. The chassis plates attach to the linear bearing shafts by clamping. The height of the system could then be easily changed, and the system could be easily squared by adjusting the plates and shafts.

A design was considered which used three linear bearing shafts as legs instead of four, as this would make the alignment process easier and was thought to reduce material. It was found that material costs would not be reduced, as a configuration using three or four legs would involve ordering the same length of shaft because of minimal material requirements with most industrial suppliers. The tripod design would also necessitate larger chassis plates and more material waste.

The initial design proposal involved chassis dimensions of 300 x 320 mm to accommodate stepper motors mounted on the bottom chassis plate. This would require the order of a 12 x 18 inch plate and involve wasting a lot of material. In order to fit the design within a 12 x 12 inch plate the stepper motors were moved to the top plate. This also allowed the weight of the carriage to be carried by thrust bearings in the bottom plate rather than the stepper motors and couplers.

The throw and focusing distance of the project allowed it to be clamped directly to the top chassis plate. Testing could then be accomplished without needing to permanently mount the projector.

6.1.2 PROCESS OF ASSEMBLING

The four bearing shafts are placed in the bottom chassis plate. The protrusion of the shafts from the plate is established using calipers. One of the shafts is tightened fully, while the others are left snug. The assembly is then placed on a surface plate and the chassis plate is leveled using a height gage. The carriage is placed on the bearing shafts and the top plate is placed. After the correct distance between the two plates is determined, the top chassis plate is leveled using the height gage and the carriage can be leveled according to the assembly directions in section 6.2.2.

6.1.3 EQUIPMENT NEEDED

Manufacturing of the prototype was completed using machine tools, but manufacturing for the maker can be achieved by water jetting, EDM, or CNC machining. This is easy and inexpensive to contract with machine shops, or made in bulk. Finish machining can be done using hand tools.

6.1.4 RECOMMENDATIONS

An enclosure can be assembled from nearly any sheet material. Gaffers tape is good for sealing. When doing quick testing a leaf bag can be used as an expedient enclosure.

6.2 MECHANICAL MOTION: JPB

6.2.1 PROCESS OF DESIGN

The single axis of motion is achieved by the use of a carriage plate riding on four linear bearings riding on the chassis shafts. The build table hangs from this carriage into the vat.

The initial motion control design involved a single lead screw. It was determined that the rigidity required to implement the design with a single lead screw would require a prohibitive amount of complication. Using two lead screws would allow for smoother operation without an excessive cost increase. Both lead screws ride on ball-bearing thrust bearings held in the bottom chassis plate.

Backlash has been a rather prolific problem with 3d printers of all varieties. Many interesting and complicated methods of handling backlash have been suggested in the community [11]. It was decided to make the lead screw nut out of acetal and attempt a novel method of implementing threads which involved heating the lead screw and allowing the acetal to flow

form around it [12]. The cooled lead screw nut would then fit more snugly than cut threads. This proved excessively difficult with the acetal used. It was decided to abandon this method in favor of a more traditionally manufactured lead screw nut, but retain delrin as the material of choice. A section of lead screw was used to construct a tap and a section of acetal was drilled to the smallest inside diameter specified for the thread profile in the hopes that a tight fit could be achieved. After tapping this proved to provide a sufficiently tight enough fit to prevent backlash. When implemented on the chassis it has shown to not produce so much friction as to cause mistepping of the stepper motors.

The stepper motors are connected to the lead screws by flexible couplers, which allow axial misalignment while maintaining torque transmission. While off-the-shelf components are readily available and inexpensive, a design for these couplers is included in the project.

6.2.2 PROCESS OF ASSEMBLING

The linear bearings are assembled on the carriage plate which is then installed between the chassis plates during chassis assembly. The lower chassis plate is then leveled. The thrust bearings are then installed in the lower chassis plate. The lead screw nuts are fitted to the lead screws, which are fitted up into the carriage plate and dropped into the thrust bearings. The positioning of the upper chassis plate is determined to ensure the lead screw couplers engage the stepper motors and lead screws thoroughly. The lead screws are then removed, the upper chassis plate is then leveled, and then the lead screws are reinstalled. The lead screw nuts are fastened to the carriage plate by M20 jam nuts threaded to the outside of the lead screw nuts. The couplers are attached to the lead screws and the stepper motors are installed, but left unattached to the couplers. The carriage is leveled by adjusting the lead screws and then the couplers are tightened to the stepper motors. The lead screws should not be turned by hand, as this would put the carriage out of level.

The build table should be suspended from the carriage and leveled. The level of the build table should be checked by filling the vat with salt water and adjusting the build table to ensure that the liquid is level over the build table.

6.2.3 EQUIPMENT NEEDED

Proper leveling should be done on a surface plate with a height gage, but can be achieved on any sufficiently flat surface with a good ruler, calipers, or trammel points.

6.2.4 RECOMMENDATIONS

Suspending smaller build tables by three rods instead of four should allow faster leveling. If there is a bend or warp to the table the fourth rod can be introduced to minimize this. Level and flatness of the build table is much more obvious when suspended over a level of liquid than when just using a height gage.

6.3 TECHNICAL DRAWINGS: NBT

While adhering to ISO standards, part files were dimensioned in drawing files. In short, ISO, is an international standard-setting body composed of representatives from various national standards organizations.

The ISO standard for dimensioning parts is GD&T (Geometric Dimensioning and Tolerance). In short, this system is useful when communicating engineering tolerances. This form of dimensioning follows a symbolic language that allows engineering drawings within a computer three-dimensionally. In other words, one can virtually fabricate solid models that explicitly describes nominal geometry and its allowable variation.

It is important to clarify that GD&T is not synonymous for Basic Dimensioning. In short, basic dimensioning represent an ideal case and consequently lacks the necessary tolerances to appropriately design parts. Thankfully, GD&T overcomes this fabrication hurdle and provide the machinist both the necessary dimensions tolerances to produce high quality parts. In technical drawings, a basic dimension is a theoretically exact dimension, given from a datum to a feature of interest. Basic dimensions only communicate a designs critical dimensions and consequently lack tolerance. To facilitate manufacturability, a feature control frame is often used to assign a dimensional tolerance to the feature that is referenced in by the basic dimension. It is important to note that a set of chained basic dimensions do not create tolerance stack up. Furthermore, proper tolerance must be inferred by Datum's referenced in the feature control frame, and not by dimension arrows or start points. In summary, a numerical value used to describe the theoretically exact size, profile, orientation or location of either a feather or datum target is the basis from which permissible variations are established by tolerances on other dimensions, in notes, or in feature control frames. In conclusion, basic dimension are denoted by enclosing the number of the dimension in a rectangle.

The 3D printer is comprised of many parts which must be appropriately dimensioned. To produce a high quality design one should GD&T the hardware component; i.e. the ribbed vat, carriage, lead screw(s), coupler, and etcetera.

SolidWorks was the program used to create parts, technical drawings, assemblies, & preform simulations on subsystem assemblies; i.e. the ribbed vat as shown in

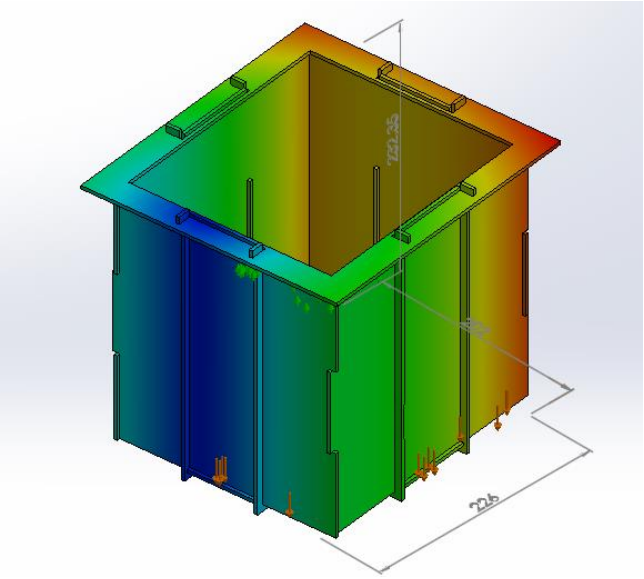

Figure 5. Ribbed vat undergoing an FEA simulation (displacement diagram)

The point of the placing the Ribbed Vat under an FEA Simulation was to determine the theoretical motion of the assembled subsystem when holding the resin in a static environment. The goal of this simulation was to reduce all areas of motion to values less than zero. Due to bonding issues experienced in SolidWorks the simulation above is incorrect. At the end of the FEA Simulation, SolidWorks was able to generate a Report in Microsoft words which summarized all of its findings in the FEA analysis.

In total there were three subassemblies prior to the final printer assembly; the chassis, build table, & ribbed vat. Furthermore, the final assembly included the projector. The purpose of the three subassemblies was to simplify the overall/final assembly, and to assist the end user. Exploded assemblies were created to help the client gain a visual understanding of all the components comprised within the 3D Printer assembly. These visuals assisted in the instructions for piecing the subassemblies and final design.

The Printer assembly was comprised of the Chassis Assembly, the Motion Control Assembly, the Projector and the Ribbed Vat Assembly. The Chassis Assembly served as the main body of the 3D Printer and held all the other components. The Motion Control Assembly moves up and down the chassis. The movement of this subassembly is controlled by the Stepper Motors. The Projector projects UV Light in order to cure the resin in the vat and solidify the liquid. The Ribbed Vat Assembly servers as the container for the resin. The Motion Control Assembly is submerged and raised out of the Ribbed Vat during the systems printing phase.

The Chassis Assembly is currently comprised of 10 unique parts; a Base Plate, a Top Plate, Side Plate Enclosures, Screws, 12mm Rods, Stepper Motors, a Bracket Plate for the Projector, Mounting Plates for the Projector, Lead Screws, & Bearing Lead Screws. The Base Plate & Top Plate sever as fixtures which hold together the main components which make up the Chassis. Furthermore, the Side Plate Enclosures serve as both a stabilizer and light shield which blocks out external light which may over cure the resin. The Screws simply keep the

chassis from falling apart. The 12mm Rods act as the stands of the Chassis and vertical sliders of the Motion Control Assembly. The Stepper Motors control the vertical movement of the Motion Control Assembly which greatly affects the quality of the 3D Print. The Bracket Plate's job is to hold up the Projector(s). The current design allows for a maximum of two Projectors. The Mounting Plates serve as supports for the Bracket Plate holding the Projector(s). The Lead Screws are turned by the Stepper Motors and consequently affect the vertical position of the Motion Control Assembly. The Bearing Lead Screws are found at the Base Plate, and hold the bottom ends of each Lead Screw.

The Motion Control Assembly is currently comprised of 5 different types of parts; a Carriage, a Build Table, 4mm rods, Linear Bearings, & Nuts for the Lead Screws. The Carriage serves as the core component of the Motion Control Assembly, and in turn houses most of the subassembly's components. The Build Table is the area which is submerged within the Resin and holds the part which is being printed. The 4mm Rods connect the carriage to the Build Table. The Linear Bearings allow the subassembly to slide up and down the 12mm Rods on the Chassis. The Nuts connect the subassembly to the Lead Screws.

The Ribbed Vat Assembly is currently comprised of 6 different types of parts; a Vat Base Plate, Wall X, Wall Y, a Lip, Rib Y and Rib X. The Vat Base Plate is the floor plate of the subassembly. The Wall X & Wall Y are wall components of the subassembly. The Lip is the part which rests atop the Bottom Plate of the Chassis. Both Rib Y and Rib X are fixtures within the subassembly that brace together the subassembly.

Furthermore, it was necessary to create a title block in SolidWorks that would meet our team's needs while adhering to both ISO standards and the needs of the Open Source Hardware Community. This title block serves as a template for technical drawings. The title block template was based off the Open Source Ecology title block templates [13].

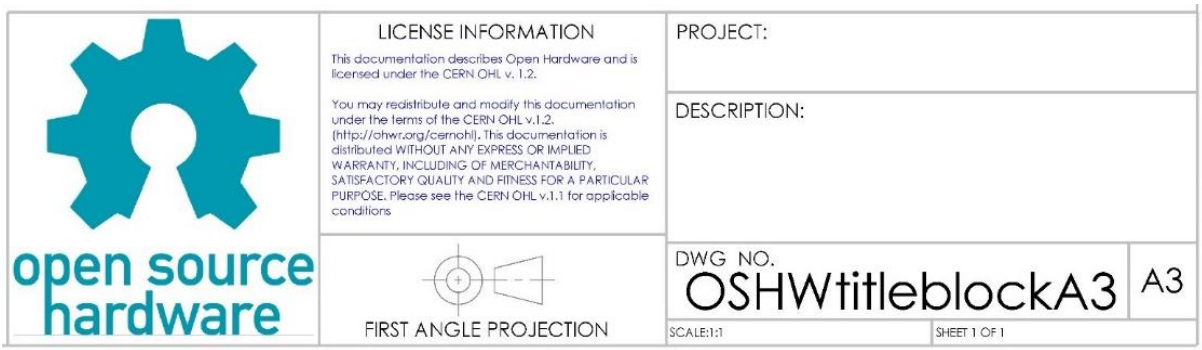

Figure 6. Generic open source hardware title block

In order to provide the Open Source Hardware Community with standard paper sizes several title block & block templates were created: 'A0', 'A1', 'A2', & 'A3.' These templates adhered to the ISO standards for the 'Open Source Hardware Community' which are licensed under Creative Commons Share-Alike 4.0 [14]. Also, the CERN Open Source Hardware license was included in the title block [15].

In total three files were saved under the folder OSHWtitleblocks; SLDDRW, DRWDOT, and slddrt. SLDDRW files are part files, DRWDOT files drawing template files, and slddrt files are format. When creating a new drawing in SolidWorks the user is asked to choose a format prior to importing and dimensioning a part. In order to use formats 'A0', 'A1', 'A2', or 'A3' the respective 'slddrt' files should be placed in the "sheetformat" folder.

The open source hardware Logo experienced pixilation issues when imported as a jpeg file. Therefore the logo was imported as a psd file which took SolidWorks a full minute.

Figure 7. Open Source Hardware Logo

The psd file corrected the pixilation problem and provided the title block with a professional appearance. In short, a psd file is a layer image file used in Adobe PhotoShop. PSD, which stands for Photoshop Document, is the default format that Photoshop uses for saving data. PSD is a proprietary file that allow the user to work with the images' individual layers even after the file has been saved.

6.4 PRINTER CONTROL SOFTWARE: DMO

6.4.1 PROCESS OF DESIGN

Project PAM's printer control software set out to solve the issue of with the recent rise of DLP 3D printing in the hobbyist market there is a need for a more consolidated form of printer control software that is also open source. Originally it was proposed to modify the B9 Creator printer control software and make it more flexible and make the user interface better, as explained in Figure 8.

Figure 8. Proposal for Project PAM printer control software

	B9 Creator	MiiCraft	Creation Workshop	Project PAM
Language	C++ [16]	Python [17]	C# [18]	C++
Cross-platform	✓ [19]	X [20]	✓ [21]	✓
Slicing Software	Custom [16]	Skeinforge [17]	Slic3r [18]	Slic3r
G-Code Support	X [16]	✓ [17]	✓ [18]	✓
CAD File Input	STL [19]	STL [20]	STL, OBJ, 3DS [21]	STL, OBJ, 3DS, STEP, AMF
Ablity to Add Supports	✓ [19]	X [20]	✓ [21]	✓
Image Output	SLC [16]	SVG [22]	SVG [23]	SVG

Figure 8 also shows the comparison of the B9 Creator and Project PAM to additional DLP 3D printer control software on the market. During the time since the B9 Creator software was evaluated there had been multiple updates; however, the updated source code was not being posted to their GitHub. These updates consisted of very important bug fixes and support for more hardware. Eventually the developers of the B9 Creator software were contacted, after multiple attempts through various mediums, and they had decided to not release any additional source code. Their reasoning for this was that they weren't getting any help from the community and doing all the work themselves. This was an unfortunate set back but one that was not a show stopper.

Once it was determined that there would be no newer versions of the B9 Creator printer control software to fork from the newest version was forked and development began. The first step was to change various code formatting problems, for example mixed file formatting, and wrong licensing information in file headers. The B9 Creator software came with a built in updater, which was removed. An attempt at porting the B9Creator software to Qt 5 from Qt 4 was made; however, because of the differences in the OpenGL portions of Qt between the versions were so great that effort was abandoned.

The first big modification that was attempted was to remove the custom slicing software and replace it with Slic3r. It was at this point that it was discovered the custom slicer was so heavily embedded into the software that by removing it would cause more headaches then it would fix, i.e. it was easier to start from scratch then to try to remove the slicer.

Once it was determined that the B9Creator software should not be used as a starting point an in depth evaluation of Slic3r was done. Slic3r supports STL (Sterelithography), AMF (Additive Manufacturing File Format), and OBJ files [23]. Because a goal of the Project PAM printer control software was to add STEP file support and Slic3r only supports mesh based models there would have been no way to modify Slic3r to support STEP files. The only option would have been to convert STEP files into one of the supported file formats when the model was loaded. However, that defeats the whole reason to support STEP files.

The reason STEP needed to be supported was to ensure flexibility, because STEP files are a CAD file interchange format, and to allow for the better printing of curves [24]. The problem of mesh based models is illustrated in Figure 9.

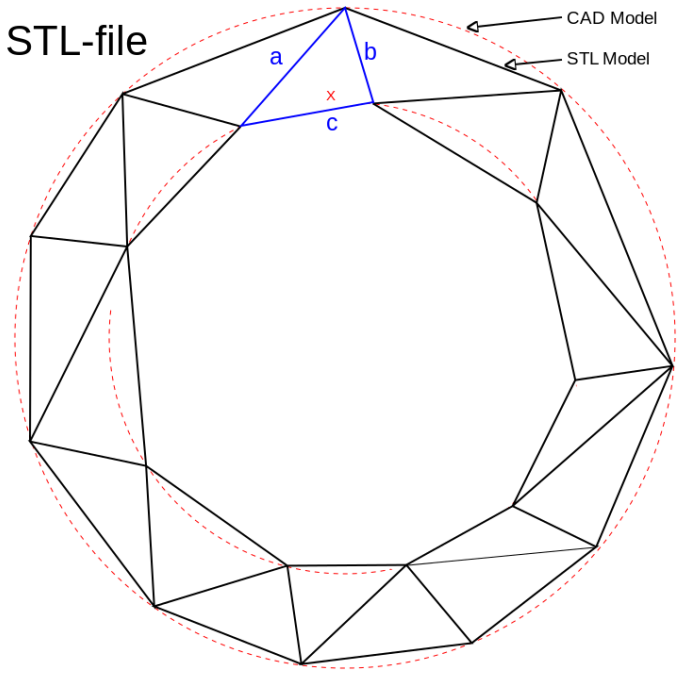

Figure 9. Problem with STL files [25]

Additive Manufacturing File Format (AMF) was released, a superset of STL, by the International Organization of Standards (ISO) and American Society for Testing and Materials (ASTM) as ISO/ASTM 52915:2013 [26]. AMF supports curved triangles that are then recursively subdivided into smaller triangles at import, this allows for "smoother models" and smaller file sizes [26] [27]. Even though AMF is an improvement of STL it still does has the problem of turning curves into triangles and introducing error into the print.

The larger problem with developing an open source 3D printing control software platform is the lack of open source CAM software, which is why the idea of DLP 3D printing control software has grown to become a complete open source CAM platform with a DLP 3D printing plugin. This new software is being called LibreCAM. The main reason this is possible is because there is an open source library called Open CASCADE, which is a C++ platform for 3D CAD/CAM and can be easily integrated into the Qt platform [28].

FreeCAD was evaluated to determine if it was a suitable candidate for fork to create LibreCAM. FreeCAD is written in C++ and uses Open CASCADE [29]. However, FreeCAD uses an outdated 3D visualization library (this feature is now built into Qt), also, FreeCAD was a completely custom user interface [29] [30].

It was decided to start from scratch and define a new platform and user interface. The challenge with was to pick an interface that was strait forward and easily conveyed the steps

the user needed to make something. However, this would have been a lot of rework and would have mediocre results.

6.4.2 DEVELOPMENT PROCESS

KDevelop and the KDevPlatform are a C++/Qt/KDE based IDE and IDE development platform, respectably [31] . Currently these platforms are based on Qt 4 and KDE 4; however, in August of 2014 the process of porting the platforms to Qt 5 and KDE Frameworks 5 had begun [32]. The most recent release from September of 2014 was still based on Qt 4 and KDE 4 [33]. The port to Qt 5 and KDE Frameworks 5 is still in pre-alpha stage, a screenshot of the pre-alpha stage is shown in Figure 10. The developers of KDevelop say that KDevelop 5 will "become the first true cross-platform release of [they're] IDE" [33]. KDevelop 5 is on track to release early 2015 [33].

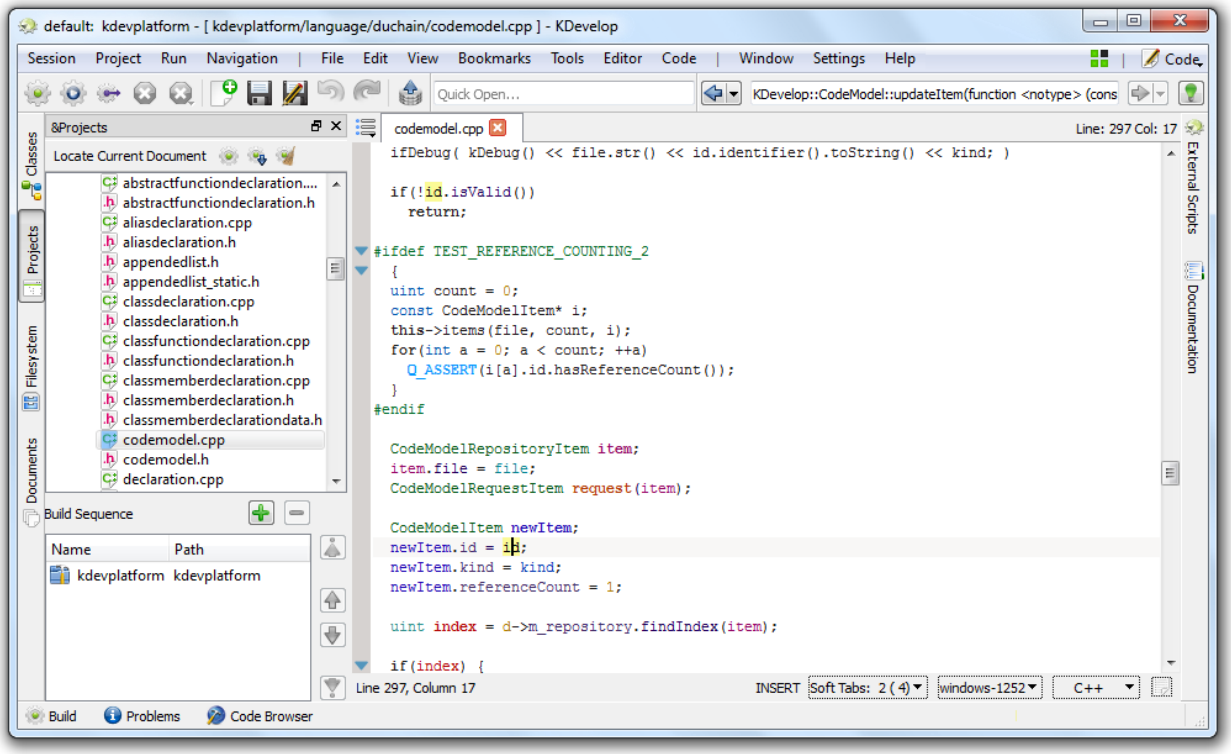

Figure 10. KDevelop 5 pre-alpha on Windows [34]

A great example of a tool built with the KDevPlatform is KTechLab, an IDE for microcontrollers and electronics [35]. A screenshot of KTechLab is shown in Figure 11.

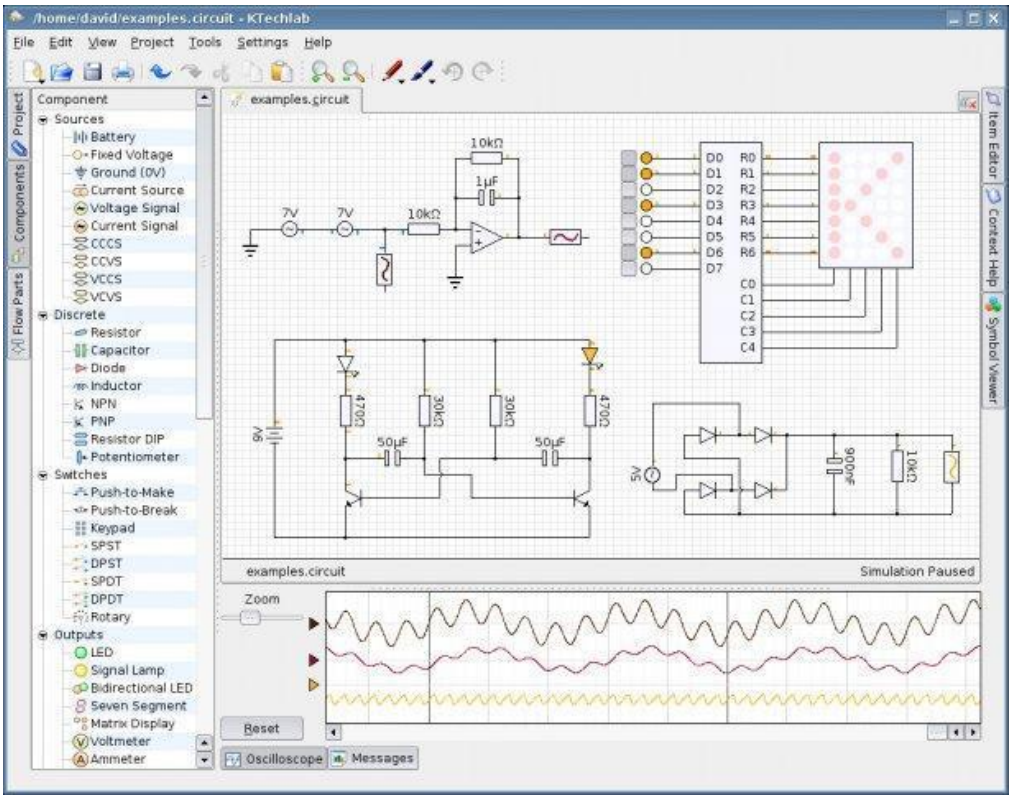

Figure 11. Screenshot of KTechLab

The problem with the current release of KDevelop using Qt 4 instead of Qt 5 is a show stopper. There were massive changes to Qt's OpenGL module between Ot 4 and Qt 5. Because LibreCAM requires Qt's OpenGL support. The QtOpenGL module was deprecated in Qt 5 and completely rewritten to support full OpenGL instead of only OpenGL ES (Embedded Systems) as in Qt 4. If the current version of KDevPlatform was used to create LibreCAM the entire 3D visualization portion would have to be redone early next year when KDevPlatform 5 is released.

6.4.3 DEVELOPMENT SCHEDULE

The first major planned releases of LibreCAM are outlined below.

Ver. 0.1.0: Initial user interface and ability to load in CAD models.

Ver. 1.0.0: Completed user interface, full support for plugins, and support for projects.

The first major planned release of the DLP 3D printer control plugin for LibreCAM, called LibrePAM, are outlined below.

Ver. 0.1.0: Basic slicing to SVG and G-Code and G-Code transmission to firmware.

Ver. 1.0.0: Resin profiles, projector control, projects, and automatic support generation.

Ver. 2.0.0: Parallel slicing and continuous printing.

6.5 HARDWARE-SOFTWARE INTERFACE: NAL

6.5.1 PROCESS OF DESIGN

When testing the motor and shield there are numerous variables to take into account. Testing the motor control with a scaled down build table helped speed up testing while the rest of the system was being constructed. In order to determining the optimum velocity and acceleration of the system, the velocity of the motors was increased until they started to miss-step and get caught in the threads. From there the acceleration was set to one tenth the velocity, to let the motor gain velocity during the movement rather that start at max velocity. In addition to movement control, current control is also monitored. Due to the specifications of the motors, they are meant to draw more current than the power supply can handle. The potentiometers on the drivers were adjusted accordingly to prevent blowing the power supply.

The Adafruit motor shield uses 4 h-bridge drivers, capable of driving 2 stepper motors. It is a cheaper alternative to the CNC Motor Shield that is currently compatible with the Grbl firmware.

In order to interface with the motors there are already libraries supported by Adafruit to drive the motors. The AFMS Library and the AccelStepper library are provided by Adafruit for use with their shield. The AFMS library provides general support for driving the motors with little velocity control. With the AccelStepper library the motors can be driven at slightly higher velocities as well as control for variable acceleration.

Due to limitations of the shield, it is unable to drive the motors at high enough velocities and accelerations required to be implemented into the Grbl firmware. Additionally the CNC shield and AFMS use different pins to send signals to the motors. To implement the AFMS into Grbl would require massive changes in the source code and all of the functions required for stepper control would need to reimplemented for the AFMS.

6.6 MOTORS/MOTOR CONTROL: CWS

6.6.1 PROCESS OF DESIGN

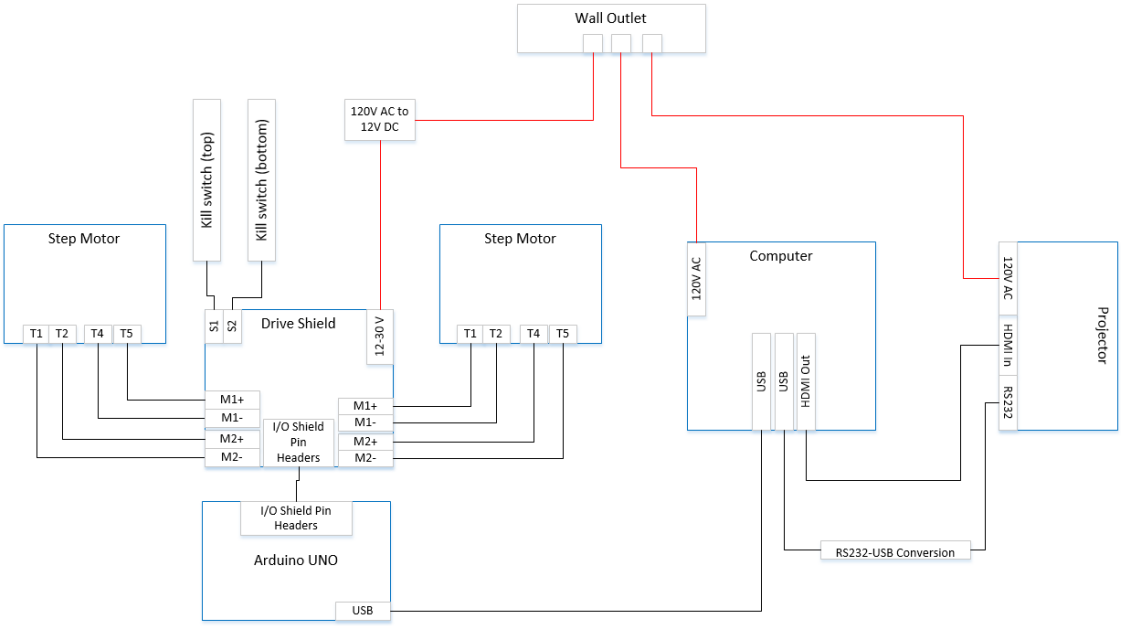

Figure 12. Wire diagram

The lead screws of the printer are driven by two NEMA 17 bi-polar stepper motors. These two lead screws turning in one direction or the other will cause the chassis to move up or down, and thus move the build table up and down. This vertical movement is what always the object to be built layer by layer. The motors each produce a holding torque of 200 mN-m at 12 volts and pull 0.35 A per phase. Full motor specifications are listed in Table 5.

Table 5. Stepper motor data [36]

Drive Method	Bi-Polar
Number of Phases	2
Step Angle	1.8 deg/step
Voltage	0.35 V
Current	0.34 A/phase
Winding Resistance	4.3 I/phase
Inductance	200 mH/phase
Holding Torque	11.8 mN-m
Detent Torque	38 mN-m
Rotor Inertia	0.21 g-cm2
Weights	0.57 g

The motors are controlled by a CNC shield that implements four Pololu motor drivers. The original design called for an Adafruit motor shield that supported H-bridge drive techniques

due to its low cost popularity within the field. However, the Grbl software that sends movement commands to the drive shield requires specific motor acceleration variables that are not supported by H-bridge drivers. Much effort was spent trying to remedy this problem, however we eventually learned that this was not a practical solution. Adding H-bridge support to the system would have required developing brand new firmware from scratch, and our team simply did not have time to complete such an endeavor. After this had been determined, the CNC shield was selected as a replacement solution. The CNC shield is advantageous for our purposes because the shield directly handles all acceleration parameters needed to drive the motors. Another advantage is the Pololu drivers are cheap and are easily replaced if they were to ever be damaged.

6.6.2 HEALTH AND SAFETY CONCERNS

A consequence of stepper motor design is that they pull high current due to the reactance in the winding of the motor. As mentioned previously, each two phase motor is pulling 0.35 A per phase, which means each motor is pulling 0.70 A. The drive shield has a built-in potentiometer which allows the user to adjust the maximum current pulled through the shield however a certain amount of current is needed to maintain holding torque. Even with adjusting the potentiometer the printer has been shown to pull nearly 0.90 A while in operation. This amount of current can be very harmful to a user and can even lead to death through ventricle fibrillation. Because of this risk a user must familiar with electric current be extremely careful when operating the machine.

6.7 RESIN MANAGEMENT: CWB

6.7.1 PROCESS OF DESIGN

As Project PAM was unfolding, the decision to become a photoresin printer emerged. The first design of the resign was to use a custom product from Momentive. Momentive Specialty Chemicals Inc. serves the global wood and industrial markets through a broad range of thermoset technologies, specialty products and technical support for customers in a diverse range of applications and industries [37]. This would have allowed Project PAM complete control over the wavelength needed to cure the resin, over the color, over the density, and over the curing agents.

Because of the goal of the project to be completely open source, this idea was abandon for buying resins that will be more accessible to the open source community. While looking through photoresin system forums, there was one company that had shown up on multiple posts as being reliable and cost effective, MakerJuice Labs [38]. MakerJuice Labs is an American company first started in 2013 with a focus of quality and low cost resins aimed for the hobbyists' community [39]. They have sold over eight-thousand items and have over two-thousand customers since their start [39]. This gave Project PAM the facts it needed to use MakerJuice for the prototype.

6.7.2 HEALTH AND SAFETY ISSUES

Resins by MakerJuice Labs are in compliance of USA and Canada standards [39]. Material safety data sheets (MSDS) for all of their products can be found on their website. The MSDS for the resin G+, ordered by Project PAM can be found in this report at 9.1.

G+ is a category 2 skin corrosion, category 1 serious eye damage, and a category 1 for skin sensitization set by the 2012 OSHA Hazard Communication Standard [39]. The precautionary prevention steps are as follows: Wash face, hands and any exposed skin thoroughly after handling, wear protective gloves/protective clothing/eye protection/face protection, avoid breathing dust/fume/gas/mist/vapors/spray, and contaminated work clothing should not be allowed out of the workplace [39].

The precautionary response steps are as follows: If in the eyes; Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor/physician. If on the skin; Wash with plenty of soap and water. Take off contaminated clothing and wash before reuse. If skin irritation or rash occurs: Get medical advice/attention [39].

6.7.3 RECOMMENDATIONS

There are several different types of resins that are open to the hobbyist community. Some resins cure harder than other resin, but this can result in a longer cure time. Different types of resins can allow for the end print to be flexible, like MakerJuice Lab's Flex [39].

There are a few things to keep in mind while shopping for resin. The first thought is the cost. There are several companies that are based out of the US who have cheaper resins but the shipping cost is sometimes up to triple the cost of their product. Another thought is the shrink percent. MakerJuice Lab's G+ substance has an experimental shrinkage of 3.3%, while their G substance has an 8% experimental shrinkage [39]. Shrinkage is the most common problem with prints with a build volume over $100cm^3$ [38]. The G+ was $45.00 a liter, and the G was $40 a liter in May of 2014 [39]. The user will have to decide if it is worth the extra $5 to ensure precise prints.

To help offset the use of resin several hobbyist have had success of using saltwater [38]. The resin floats on top of the saltwater. This means that a hobbyist only needs to put as much resin in the vat as what is needed for the build or the layer thickness. With the price of most resins being around $50, this idea is a great way to save resin and money.

6.8 OPTICS: CWB

6.8.1 DESIGN

The project is the biggest investment of the project. There are several things to keep in mind when making a choice on what projector to go with. There are several different types of projectors. The two main projectors are light-emitting diode (LED) and digital light processing (DLP). For the truest and highest quality of prints the best choice to use is DLP. DLP uses a mirror for each pixel in the projected image. This allows each pixel to be controlled individually unlike the LED were groups of pixels work together to make an image.

Another big decision is the native pixel resolution. The resolution will directly decide the quality of the prints and the size of the build area. The higher the number, the higher the max build area and better the quality. A full HD 1080p is actually at the ratio of 1920 by 1080 pixels. This allows a max build area with a 100µm precision to be 20 cm by 10 cm.

Another major component of the projector that will impacted the quality of the prints is the throw ratio. This effects the screen size or in printing terms the build area. Personal off-the-shelf projectors are not made for projecting images less than a foot away from the lens. The farther back the projector is from the build area will mean a larger build area, but at the sacrifice of pixel resolution. Depending on the projector this may be fixed by opening up the projector and modifying or replacing the lens to account for the shorter distance [1].

Aside from the pixel resolution is the lumen output. Depending on the type of resin that is used for the print will decide how many lumens it takes to cure. MakerJuice's resin takes 2000 lumens to cure [39].

6.8.2 RECOMMENDATIONS

Though Project PAM's design is flexible to allow use of almost all consumer projectors, the prototype used View Sonic's PJD7820HD 1080p 3D Home Theater Projector. This projector outputs 3000 lumens allowing faster build times. It has a 15000:1 contrast between a fully on pixel and off pixel. It supports HDMI in, dual VGA in, and VGA out giving great flexibility to the user. The projector has a filter-less design. It also has a 3-year limited warranty on parts and labor; and a 1-year warranty on the lamp. All of this comes in a 4 lb plastic case, making it ideal for mounting it over head. [40]

Most importantly the 1.2x Optical Zoom lens and throw ratio of 1.25-1.5:1 is able to give Project PAM the build area and resolution without modifying the lens [40]. This was found by doing a test. The project was set 21 cm away from the screen to simulate the space between the build layer and the lens. The zoom was then set to give a build area of 10.2 cm by 18.4 cm, which is close to the desired 10 cm by 20 cm. The focus was then adjusted until font size 8 was easily readable.

7 TEST PRINT RESULTS: CWB

Project PAM has had several different successful prints. The first print attempted by Project PAM was a robot that can be seen on the right side in Figure 13. Robot Test Print. The projector was not calibrated correctly and this led to the aspect ratio to be wrong. The left robot in Figure 13 is the second print and as can be seen, is of much better quality. The was accomplished by fixing the aspect ratio, increasing the down and up travel from 1mm to 2mm, and doubling the move speed to 50 mm/min down and 100 mm/min up.

Though the robots were a good starting point to prove full system success, Project PAM aimed to quantify test. This led to the printing of 20 mm cubs that can be easily measured and compared. In Figure 14 the first printed cube is on the left and the second cube printed is on the right. Cube #1 had 2 second cure time layers, 50 µm layer thickness, and move speed of 200 mm/min down and 200 mm/min up. The actual print came out to be 19.4x19.6x

unmeasurable (um) mm. The first couple of layers where ruined when removing the build from the build table. There is also imprecise edges do to over curing the resin giving a bleed effect. The error of the cube is 3x2xum %. Cube #2, right side of Figure 14, has the same parameters but with a 1 second cure time and a 100µm layer thickness. Not only did this cut the build time in half, but it gave a much higher quality print with less bleed. The actual dimensions are the same as Cube #1 but the edges are almost a true 90^0. Both of these cubes are smaller than the set dimensions do to the shrinkage percentage from the resin. More testing is being done to find what the shrink percentage is so that prints can be compensated in the software.

Figure 13. Robot Test Print

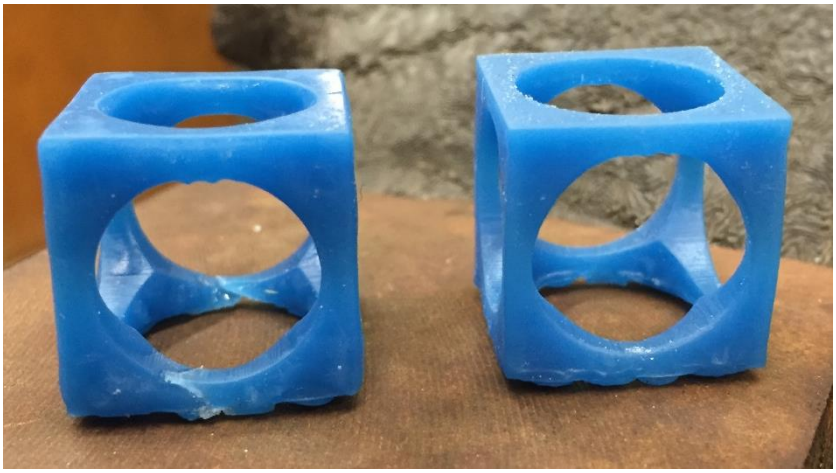

Figure 14. 20 mm Cube Test Print

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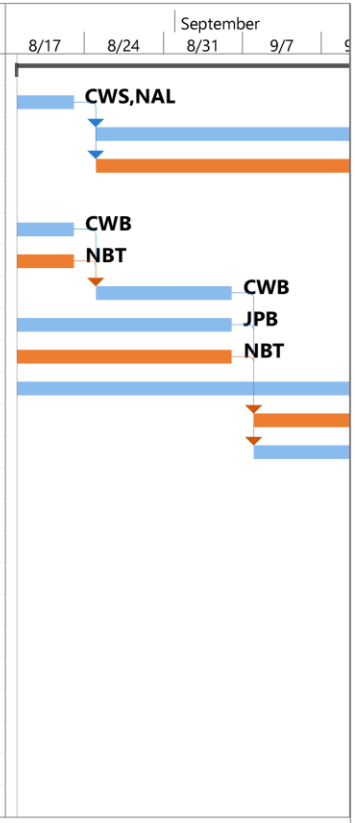
9 APPENDIX

9.1 SCHEDULES

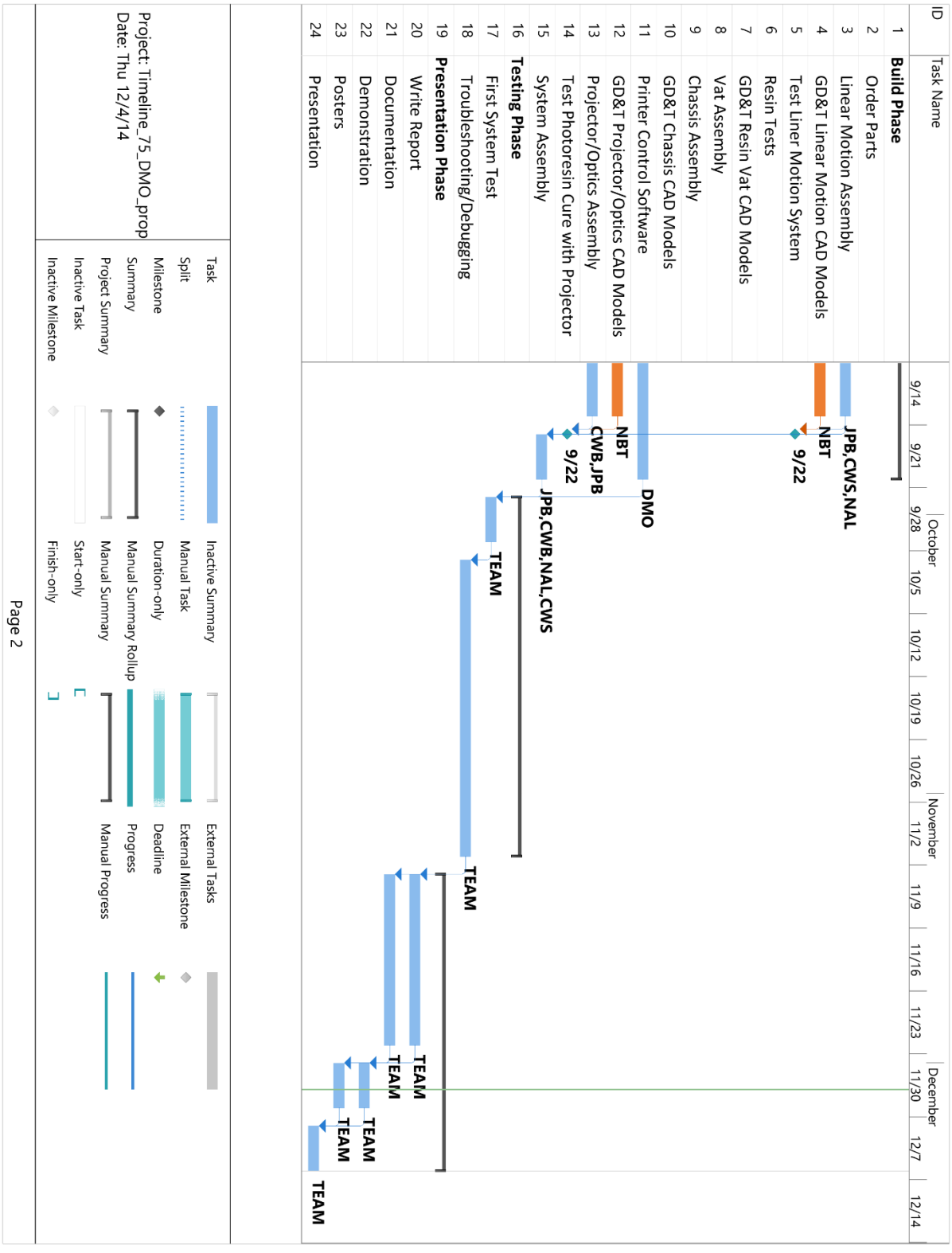
9.1.1 PROPOSED AND REWORKED

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**Build Phase**	**30 days**	**Mon 8/18/14**	**Fri 9/26/14**		
2	Order Parts	5 days	Mon 8/18/14	Fri 8/22/14		CWS,NAL
3	Linear Motion Assembly	20 days	Mon 8/25/14	Fri 9/19/14	2	JPB,CWS,NAL
4	GD&T Linear Motion CAD Models	20 days	Mon 8/25/14	Fri 9/19/14	2	NBT
5	Test Liner Motion System	0 days	Mon 9/22/14	Mon 9/22/14	3,4	JPB,CWS,NAL
6	Resin Tests	5 days	Mon 8/18/14	Fri 8/22/14		CWB
7	GD&T Resin Vat CAD Models	5 days	Mon 8/18/14	Fri 8/22/14		NBT
8	Vat Assembly	10 days	Mon 8/25/14	Fri 9/5/14	6,7	CWB
9	Chassis Assembly	15 days	Mon 8/18/14	Fri 9/5/14		JPB
10	GD&T Chassis CAD Models	15 days	Mon 8/18/14	Fri 9/5/14		NBT
11	Printer Control Software	30 days	Mon 8/18/14	Fri 9/26/14		DMO
12	GD&T Projector/Optics CAD Models	10 days	Mon 9/8/14	Fri 9/19/14	8,9,10	NBT
13	Projector/Optics Assembly	10 days	Mon 9/8/14	Fri 9/19/14	9,8,10	CWB,JPB
14	Test Photoresin Cure with Projector	0 days	Mon 9/22/14	Mon 9/22/14	13,12	
15	System Assembly	5 days	Mon 9/22/14	Fri 9/26/14	13,3	JPB,CWB,NAL,CWS
16	**Testing Phase**	**30 days**	**Mon 9/29/14**	**Fri 11/7/14**		
17	First System Test	5 days	Mon 9/29/14	Fri 10/3/14	15,11	TEAM
18	Troubleshooting/Debugging	25 days	Mon 10/6/14	Fri 11/7/14	17	TEAM
19	**Presentation Phase**	**25 days**	**Mon 11/10/14**	**Fri 12/12/14**		
20	Write Report	15 days	Mon 11/10/14	Fri 11/28/14	18	TEAM
21	Documentation	15 days	Mon 11/10/14	Fri 11/28/14	18	TEAM
22	Demonstration	5 days	Mon 12/1/14	Fri 12/5/14	21,20	TEAM
23	Posters	5 days	Mon 12/1/14	Fri 12/5/14	21,20	TEAM
24	Presentation	5 days	Mon 12/8/14	Fri 12/12/14	22,23	TEAM



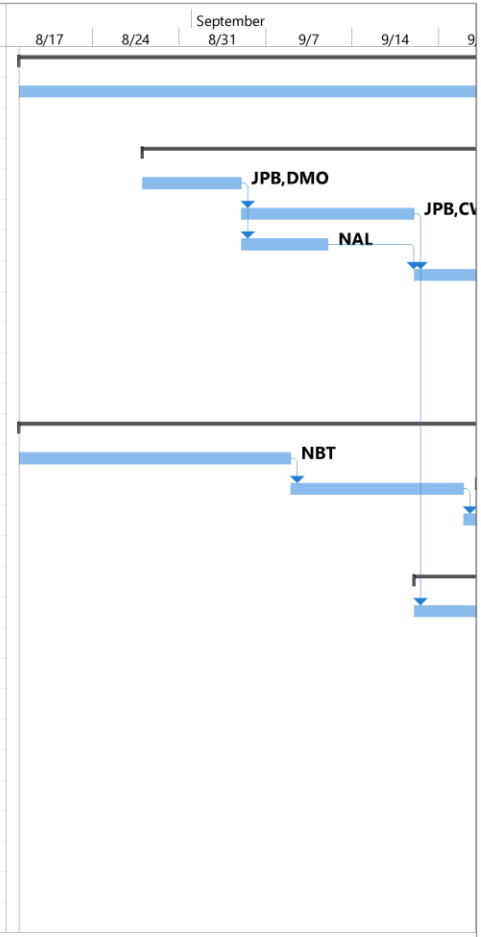
Project: Timeline_75_DMO_prop
Date: Thu 12/4/14

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	



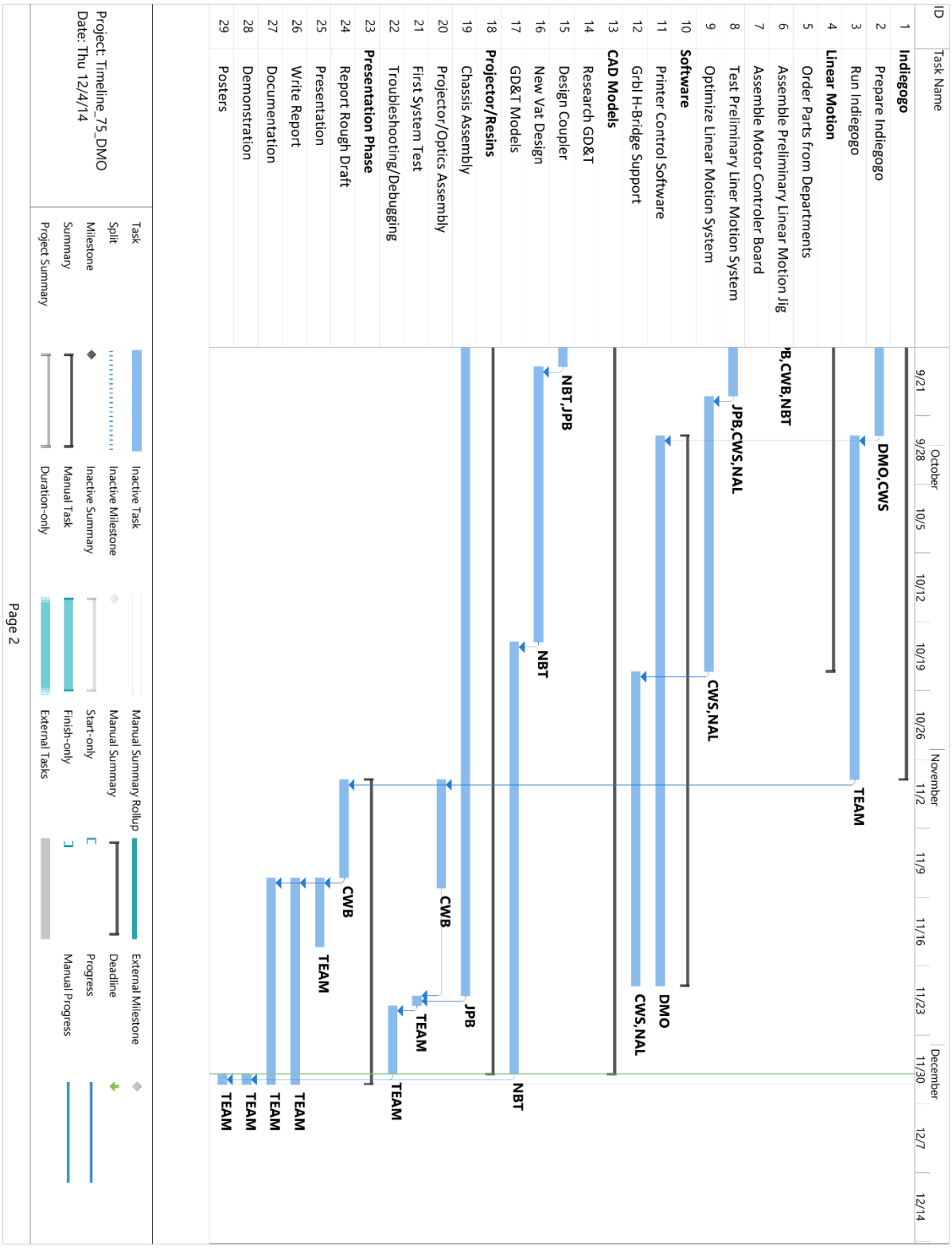
9.1.2 AS WORKED

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**Indiegogo**	**56 days**	**Mon 8/18/14**	**Mon 11/3/14**		
2	Prepare Indiegogo	31 days	Mon 8/18/14	Mon 9/29/14		DMO,CWS
3	Run Indiegogo	25 days	Tue 9/30/14	Mon 11/3/14	2	TEAM
4	**Linear Motion**	**41 days**	**Thu 8/28/14**	**Thu 10/23/14**		
5	Order Parts from Departments	6 days	Thu 8/28/14	Thu 9/4/14		JPB,DMO
6	Assemble Preliminary Linear Motion Jig	10 days	Fri 9/5/14	Thu 9/18/14	5	JPB,CWB,NBT
7	Assemble Motor Controler Board	5 days	Fri 9/5/14	Thu 9/11/14	5	NAL
8	Test Preliminary Liner Motion System	5 days	Fri 9/19/14	Thu 9/25/14	6,7	JPB,CWS,NAL
9	Optimize Linear Motion System	20 days	Fri 9/26/14	Thu 10/23/14	8	CWS,NAL
10	**Software**	**40 days**	**Tue 9/30/14**	**Mon 11/24/14**		
11	Printer Control Software	40 days	Tue 9/30/14	Mon 11/24/14	2	DMO
12	Grbl H-Bridge Support	22 days	Fri 10/24/14	Mon 11/24/14	9	CWS,NAL
13	**CAD Models**	**78 days**	**Mon 8/18/14**	**Wed 12/3/14**		
14	Research GD&T	16 days	Mon 8/18/14	Mon 9/8/14		NBT
15	Design Coupler	10 days	Tue 9/9/14	Mon 9/22/14	14	NBT,JPB
16	New Vat Design	20 days	Tue 9/23/14	Mon 10/20/14	15	NBT
17	GD&T Models	32 days	Tue 10/21/14	Wed 12/3/14	16	NBT
18	**Projector/Resins**	**54 days**	**Fri 9/19/14**	**Wed 12/3/14**		
19	Chassis Assembly	48 days	Fri 9/19/14	Tue 11/25/14	6	JPB
20	Projector/Optics Assembly	9 days	Tue 11/4/14	Fri 11/14/14	3	CWB
21	First System Test	1 day	Wed 11/26/14	Wed 11/26/14	20,19	TEAM
22	Troubleshooting/Debugging	5 days	Thu 11/27/14	Wed 12/3/14	21	TEAM
23	**Presentation Phase**	**23 days**	**Tue 11/4/14**	**Thu 12/4/14**		
24	Report Rough Draft	8 days	Tue 11/4/14	Thu 11/13/14	3	CWB
25	Presentation	5 days	Fri 11/14/14	Thu 11/20/14	24	TEAM
26	Write Report	15 days	Fri 11/14/14	Thu 12/4/14	24	TEAM
27	Documentation	15 days	Fri 11/14/14	Thu 12/4/14	24	TEAM
28	Demonstration	1 day	Thu 12/4/14	Thu 12/4/14	22,17	TEAM
29	Posters	1 day	Thu 12/4/14	Thu 12/4/14	22	TEAM



Project: Timeline_75_DMO
Date: Thu 12/4/14

Task	Inactive Task	Manual Summary Rollup	External Milestone
Split	Inactive Milestone	Manual Summary	Deadline
Milestone	Inactive Summary	Start-only	Progress
Summary	Manual Task	Finish-only	Manual Progress
Project Summary	Duration-only	External Tasks	



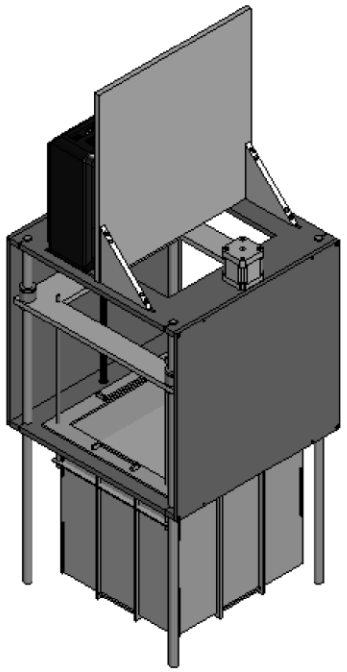
9.2 BILL OF MATERIALS

Item #	Qty	Unit	P/N
1	1	Count	50
2	1	Count	1438
3	2	Count	324
4	1	Count	85
5	1	Count	798
6	1	Count	5438
7	2	Count	3726
8	2	Count	3871
9	1	Liter	gplus
10	1	Pack of 100	E-FFR250N-100
11	1	Pack of 4	LME12UU
12	1	Count	7549K1
13	2	Count	6459K29
14	1		8579K28
15	1		
16	2		
17	2	Count	6655K52
18	1	1 Meter	90024A040
19	1	Pack of 25	93070A071
20	1		
21	1		9255T42
22	1		
23	2		9246K23
24	1		9246K13
	1		9062K31
25	1		
26	1	Pack of 50	91290A176

Item #	Description	Subsystem
1	Arduino Uno R3	Hardware software interface
2	Adafruit Motor Shield for Arduino	
3	NEMA 17 Stepper Motor	Motors/motor control
4	Shield stacking headers for Arduino	
5	12V 1A Power Supply	Motors/motor control
6	3 ft USB 2.0 A Male to B Male	Hardware software interface
7	3 ft USB to RS232	Projector
8	3 ft HDMI Cable Black	Projector
9	G+ Resin Blue	Resin
10	22/18-Gauge Female Quick Disconnects	Motors/motor control
11	Linear Motion 12 mm Ball Bushings, Closed Type, Metric	Motion control
12	Metric Precision Threaded Rod, 10mm Diameter, 2mm/Turn Screw, 1750mm Long	Motion control
13	Hardened Precision 400 Series Stainless Steel Metric Shaft, 12 mm Diameter, 1200 mm Length	Chassis
14	PTFE-Filled Delrin ® Acetal Resin Rod 1"x12"	Motion control
15	Arduino CNC Shield V3.03	Motors/motor control
16	Pololu DRV8825	Motors/motor control
17	Steel Thrust Ball Bearing, Steel Washers, for 6 mm Shaft Diameter, 14 mm OD	Motion control
18	Type 18-8 Stainless Steel Fully Threaded Rod, M3 Thread, 0.5mm Pitch, 1 Meter Long	Chassis
19	Low-Profile Socket Head Cap Screw, Class 8.8 Steel, M3 Size, 14 mm Length, .5mm Pitch	Chassis
20	M3 Socket Head Cap Screws	Chassis
21	Steel Perforated Sheet, .156" Hole Diameter, 63% Open, 22 Gauge, .03" Thick, 24" X 24"	Chassis
22	Gaffers Tape	Chassis
23	Multipurpose 6061 Aluminum, 3/8" Thick, 12" x 12"	Chassis
24	Multipurpose 6061 Aluminum, 1/4" Thick, 12" x 12"	Chassis
	Multipurpose 6061 Aluminum, Precision-Ground, 1/2" Diameter	Chassis
25	Plastic Film	Chassis
26	Black-Oxide Class 12.9 Socket Head Cap Screw, Alloy Steel, M4 Thread, 25mm Length, 0.70mm Pitch	Motion control

Item #	$/Unit	$ Amount	Link
1	$24.95	$24.95	http://www.adafruit.com/product/50
2	$19.95	$19.95	http://www.adafruit.com/products/1438
3	$14.00	$28.00	http://www.adafruit.com/products/324
4	$1.95	$1.95	http://www.adafruit.com/products/85
5	$8.95	$8.95	http://www.adafruit.com/products/798
6	$1.02	$1.02	http://www.monoprice.com/Product?c_id=103&cp_id=10303&cs_id=1030301&p_id=5437&seq=1&format=2
7	$5.71	$11.42	http://www.monoprice.com/Product?c_id=103&cp_id=10311&cs_id=1031104&p_id=3726&seq=1&format=2
8	$3.82	$7.64	http://www.monoprice.com/Product?c_id=102&cp_id=10240&cs_id=1024008&p_id=3871&seq=1&format=2
9	$45.00	$45.00	http://www.makerjuice.com/product/gplus/
10	$7.98	$7.98	http://www.amazonsupply.com/dp/B00M4D0DU8?ref_=sr_1_1_txt
11	$24.81	$24.81	http://www.amazonsupply.com/lme12uu-linear-motion-bushings-closed/dp/B002BBJUIO
12	$58.88	$58.88	http://www.mcmaster.com/#7549k1/=tjuroh
13	$69.30	$138.60	http://www.mcmaster.com/#6459k29/=tjuslw
14	$17.10	$17.10	http://www.mcmaster.com/#8579k28/=rahhhr
15	$20.00	$20.00	
16	$8.95	$17.90	
17	$2.83	$5.66	
18	$4.27	$4.27	
19	$5.96	$5.96	
20	$12.00	$12.00	
21	$20.77	$20.77	
22	$13.00	$13.00	http://www.mcmaster.com/#7612a56/=rahkny
23	$36.92	$73.84	http://www.mcmaster.com/#9246k495/=rlav9s
24	$30.39	$30.39	
	$7.16	$7.16	
25	$10.00	$10.00	
26	$6.87	$6.87	
	Total:	$624.07	

9.3.1 PRINTER



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LICENSE INFORMATION

FIRST ANGLE PROJECTION

PROJECT: Printer

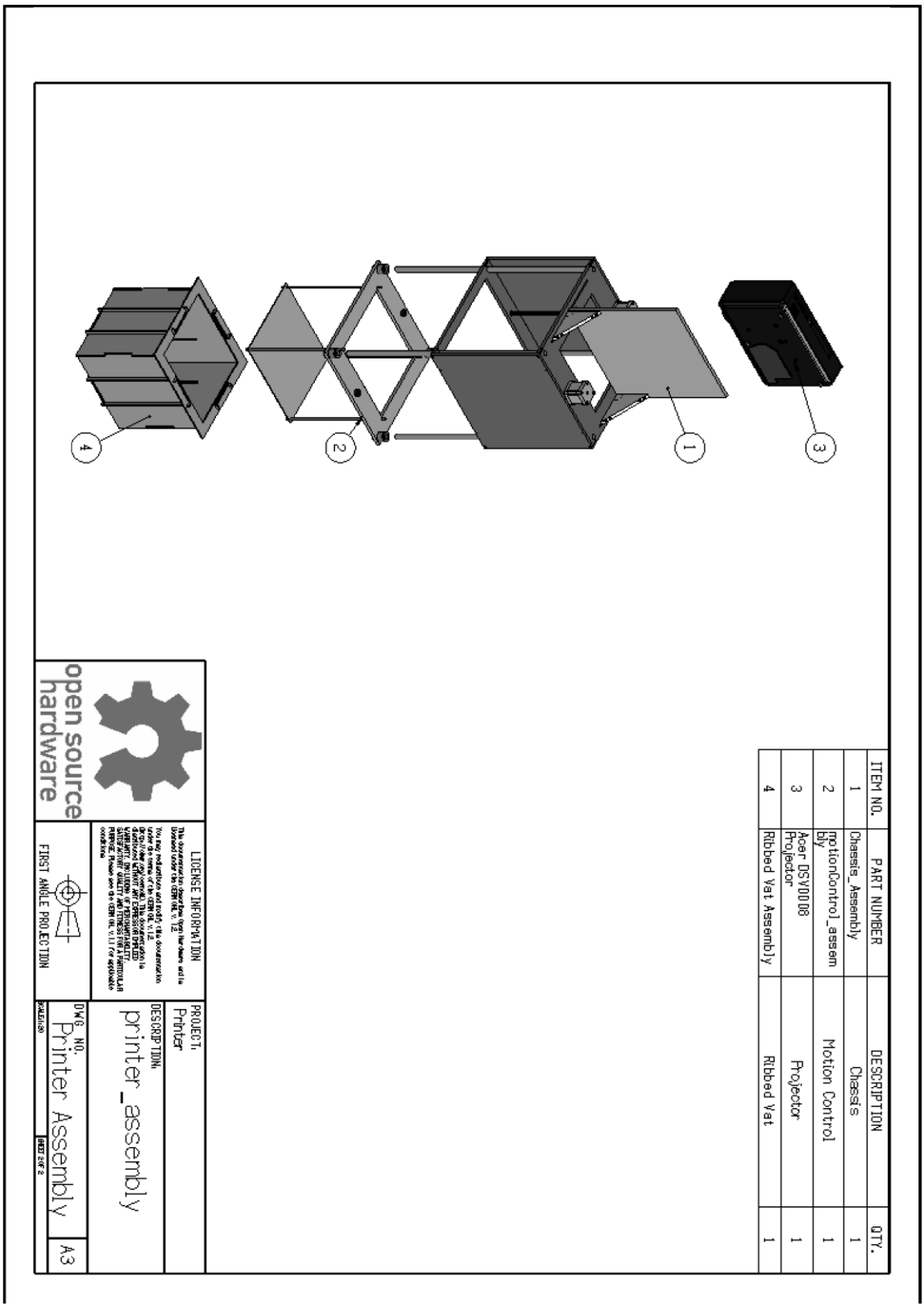
DESCRIPTION: printer_assembly

DWG NO. Printer Assembly

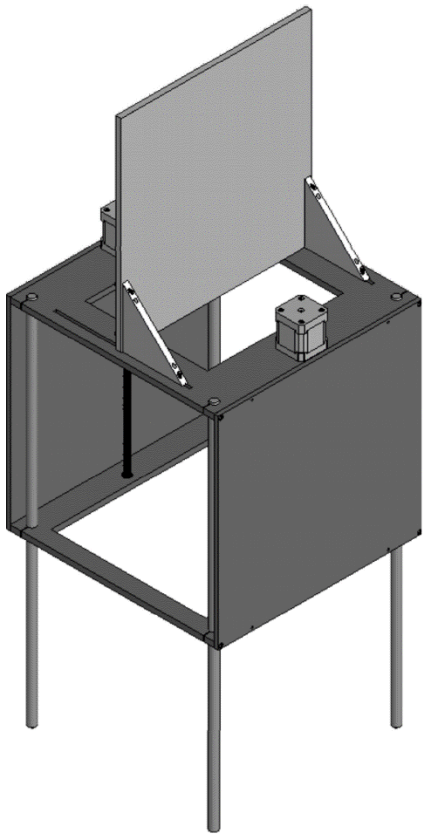
A3

SCALE: 1:20

SHEET 1 OF 2


ITEM NO. PART NUMBER DESCRIPTION QTY.
1 Chassis_Assembly Chassis 1
2 motionControl_assembly Motion Control 1
3 Acer D5V1008 Projector Projector 1
4 Ribbed Vat Assembly Ribbed Vat 1
1
2
3
4
open source hardware
LICENSE INFORMATION
PROJECT:
Printer
DESCRIPTION:
printer_assembly
DWG. NO.
Printer Assembly
A3
FIRST ANGLE PROJECTION
SHEET 1 OF 2

9.3.2 CHASSIS



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LICENSE INFORMATION

FIRST ANGLE PROJECTION

PROJECT: Chassis

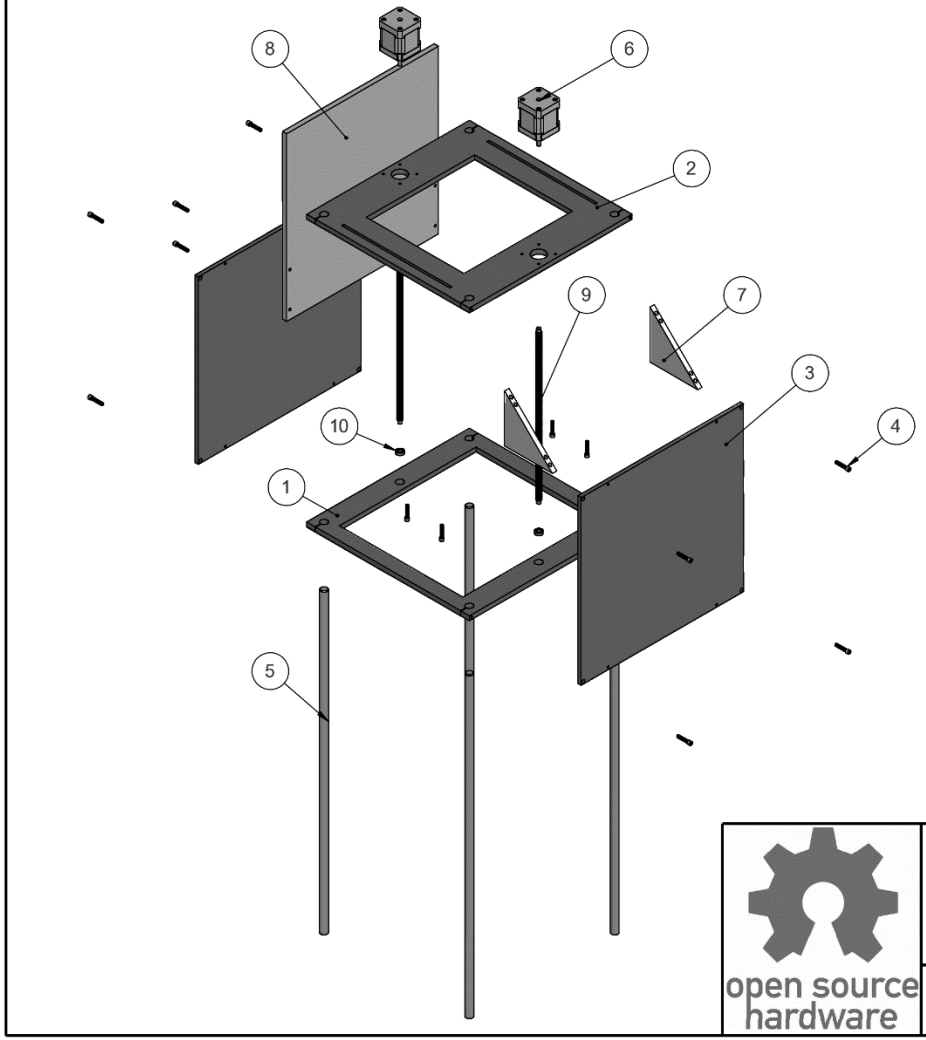
DESCRIPTION: Chassis_Assembly

DWG NO. Chassis

A3

SCALE:1:10

SHEET 1 OF 11



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	plateBottom	Base Plate	1
2	plateTop	Top Plate	1
3	side	Side plate - Enclosure	2
4	screwM4-10mm	Screw	16
5	6112K52	rod 12mm	4
6	NEMA 17 Stepper Motor	Stepper Motor	2
7	bracketPlateProjector	Bracket Plate Projector	2
8	plateProjectorMount	Mounting Plate for Projector	1
9	lead screw	Lead Screw	2
10	7804K112	Bearing Lead Screw	2

FIRST ANGLE PROJECTION

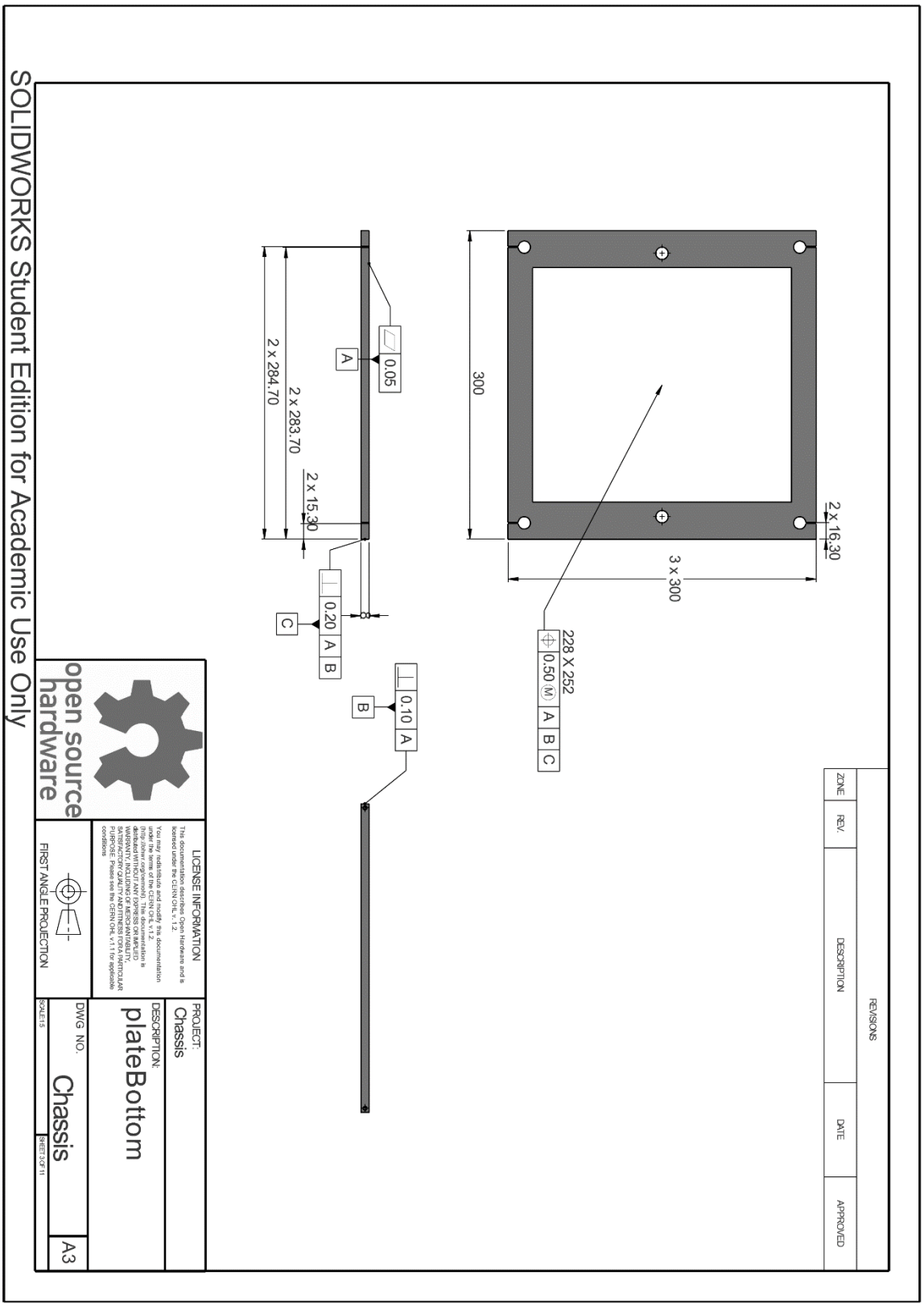
PROJECT: Chassis

DESCRIPTION: Chassis_Assembly

DWG NO. Chassis

A3

SCALE:1:10 SHEET 2 OF 11



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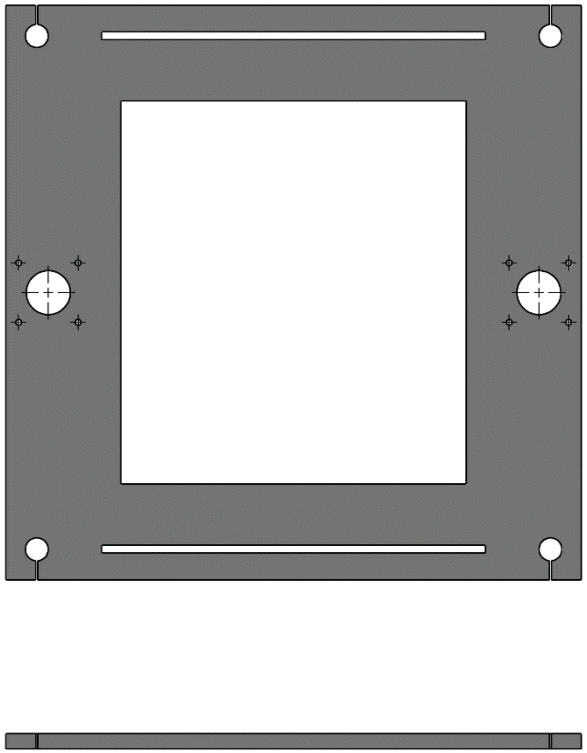

REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED

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LICENSE INFORMATION

FIRST ANGLE PROJECTION

PROJECT: Chassis

DESCRIPTION: plateTop

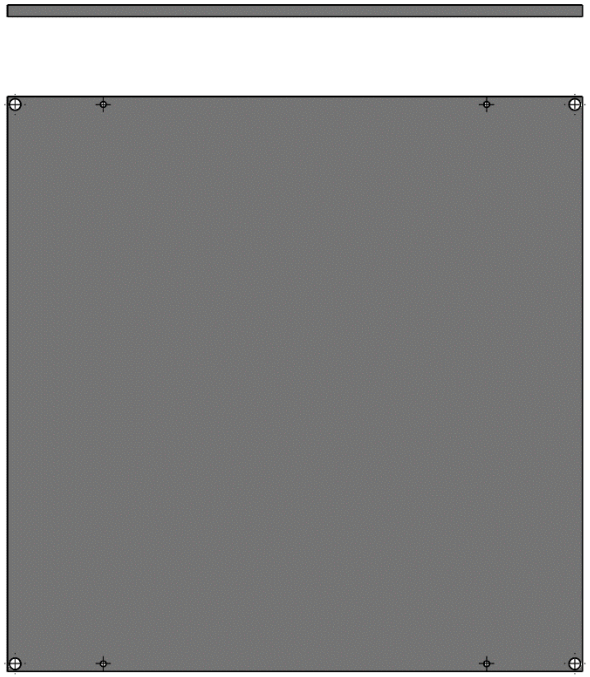
DWG NO. Chassis

A3

SCALE:1:5

SHEET 4 OF 11

REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED



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FIRST ANGLE PROJECTION

PROJECT: Chassis

DESCRIPTION: side

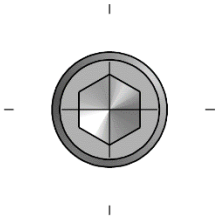
DWG NO. Chassis

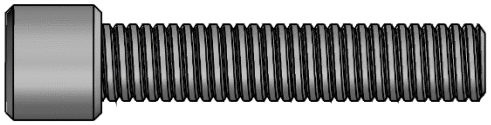
A3

SCALE:1:2

SHEET 5 OF 11

REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED





FIRST ANGLE PROJECTION

PROJECT: Chassis

DESCRIPTION: screwM4-10mm

DWG NO. Chassis

A3

SCALE:5:1

SHEET 6 OF 11

REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED

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FIRST ANGLE PROJECTION

PROJECT: Chassis

DESCRIPTION: rod-12mm

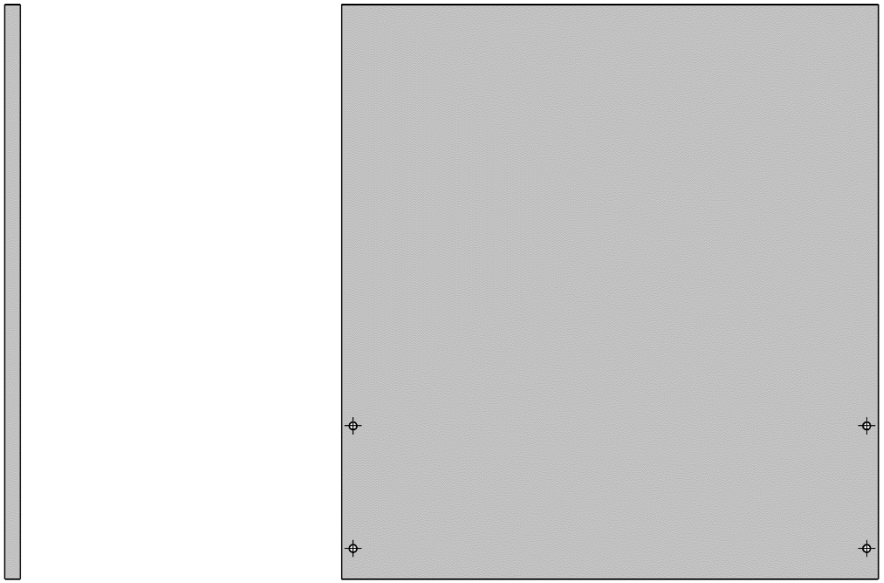
DWG NO. Chassis

A3

SCALE:1:5

SHEET 7 OF 11

REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED



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FIRST ANGLE PROJECTION

PROJECT: Chassis

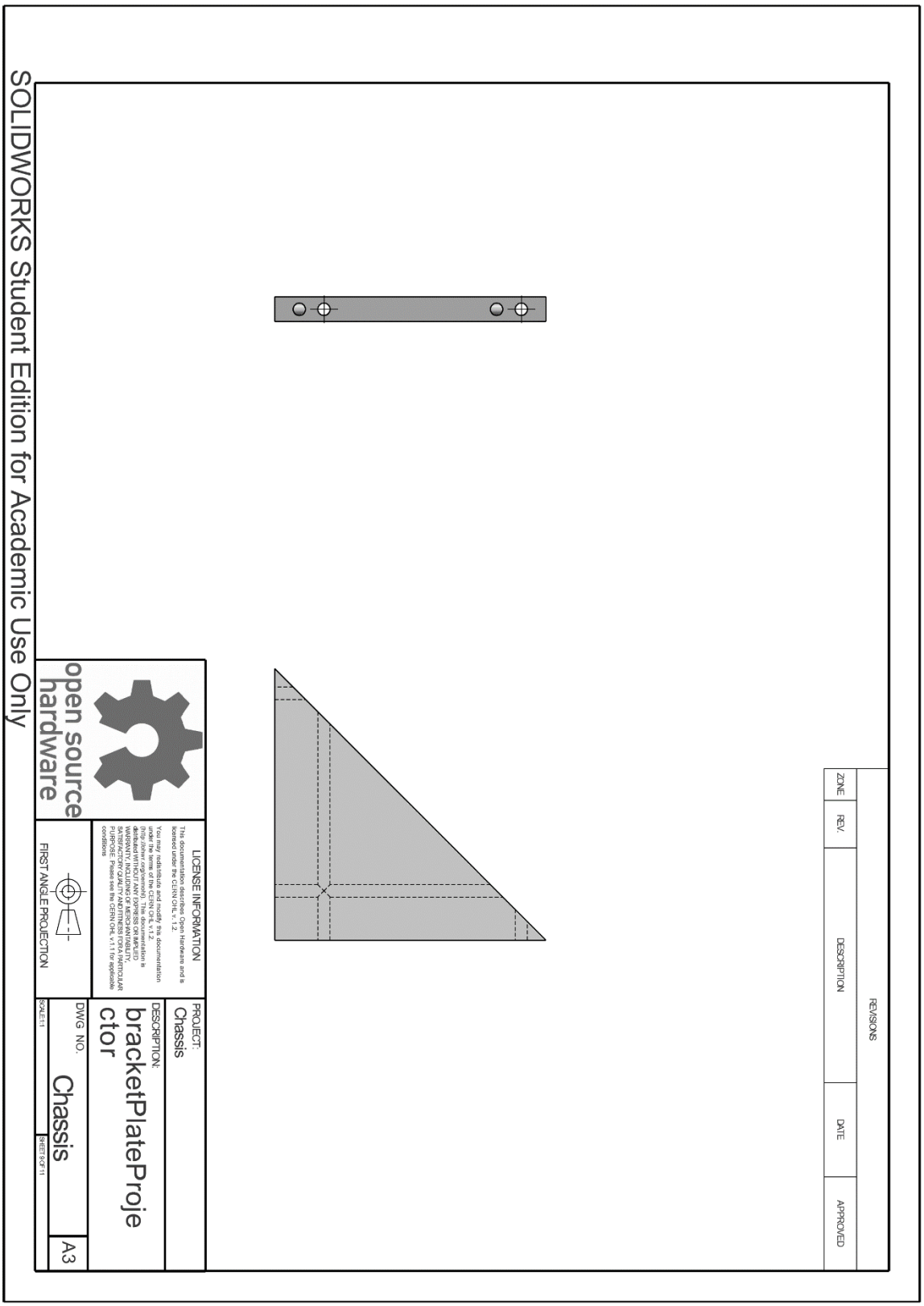
DESCRIPTION: plateProjectorMount

DWG NO. Chassis

A3

SCALE:1:5

SHEET 8 OF 11



REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED

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FIRST ANGLE PROJECTION

PROJECT: Chassis

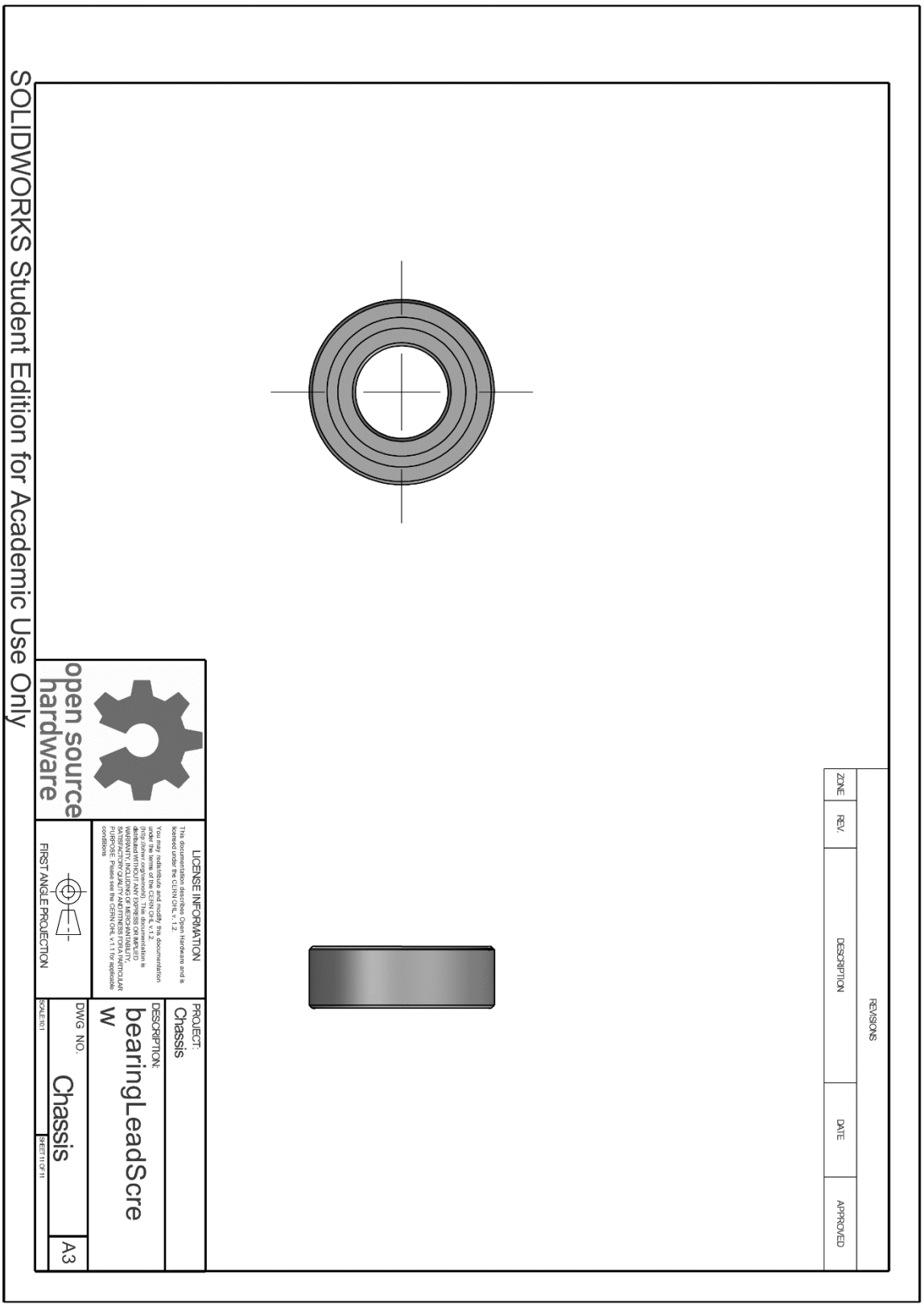
DESCRIPTION: lead screw

DWG NO. Chassis

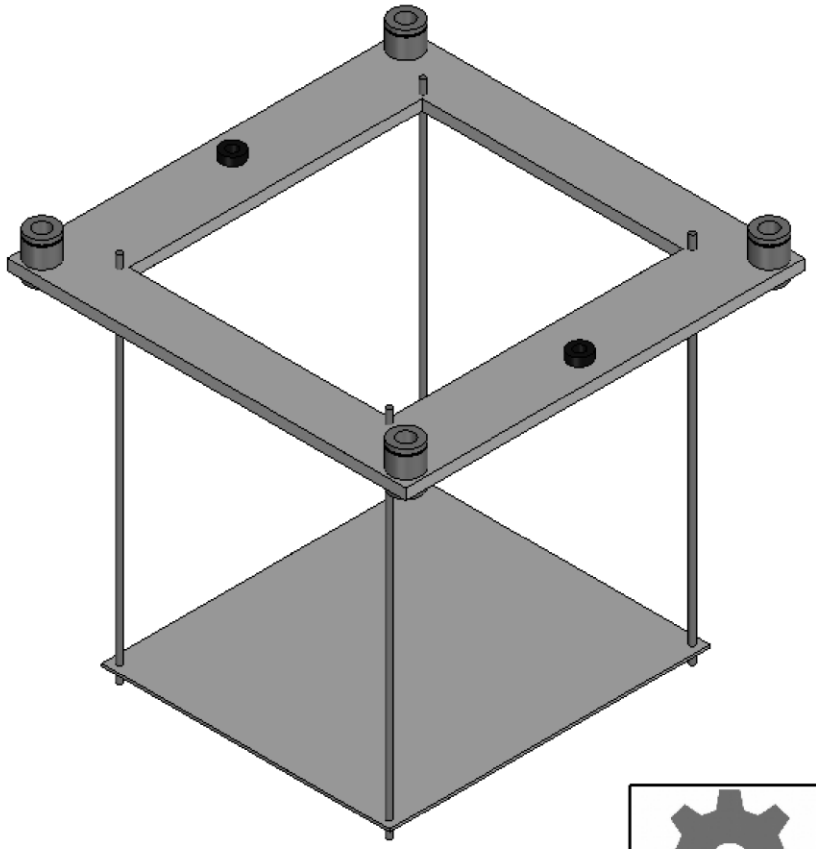
A3

SCALE:1:2

SHEET 10 OF 11



9.3.3 MOTION CONTROL



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FIRST ANGLE PROJECTION

PROJECT: Motion Control

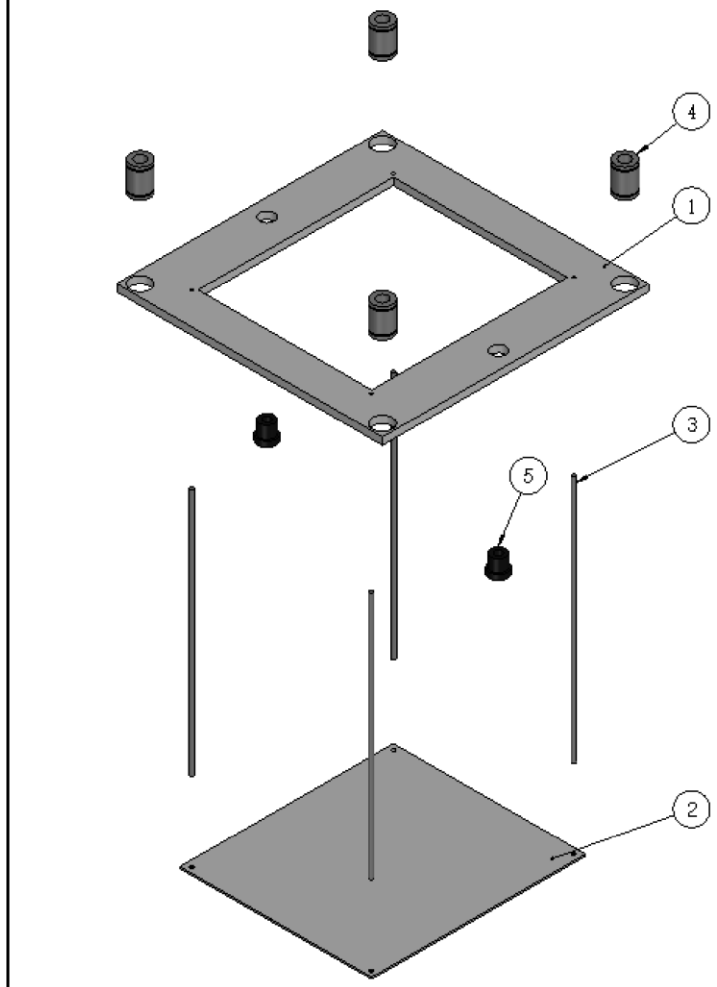
DESCRIPTION: motionControl_assembly

DWG NO. motionControl

A3

SCALE: n.a.

SHEET 1 OF 7



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	carriage	Carriage	1
2	buildTable	Build Table	1
3	rod-4mm	4mm rods	4
4	bearingLinear12mm	Linear Bearings	4
5	nutLeadScrew	nut for the Lead Screw	2

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FIRST ANGLE PROJECTION

PROJECT:
Motion Control

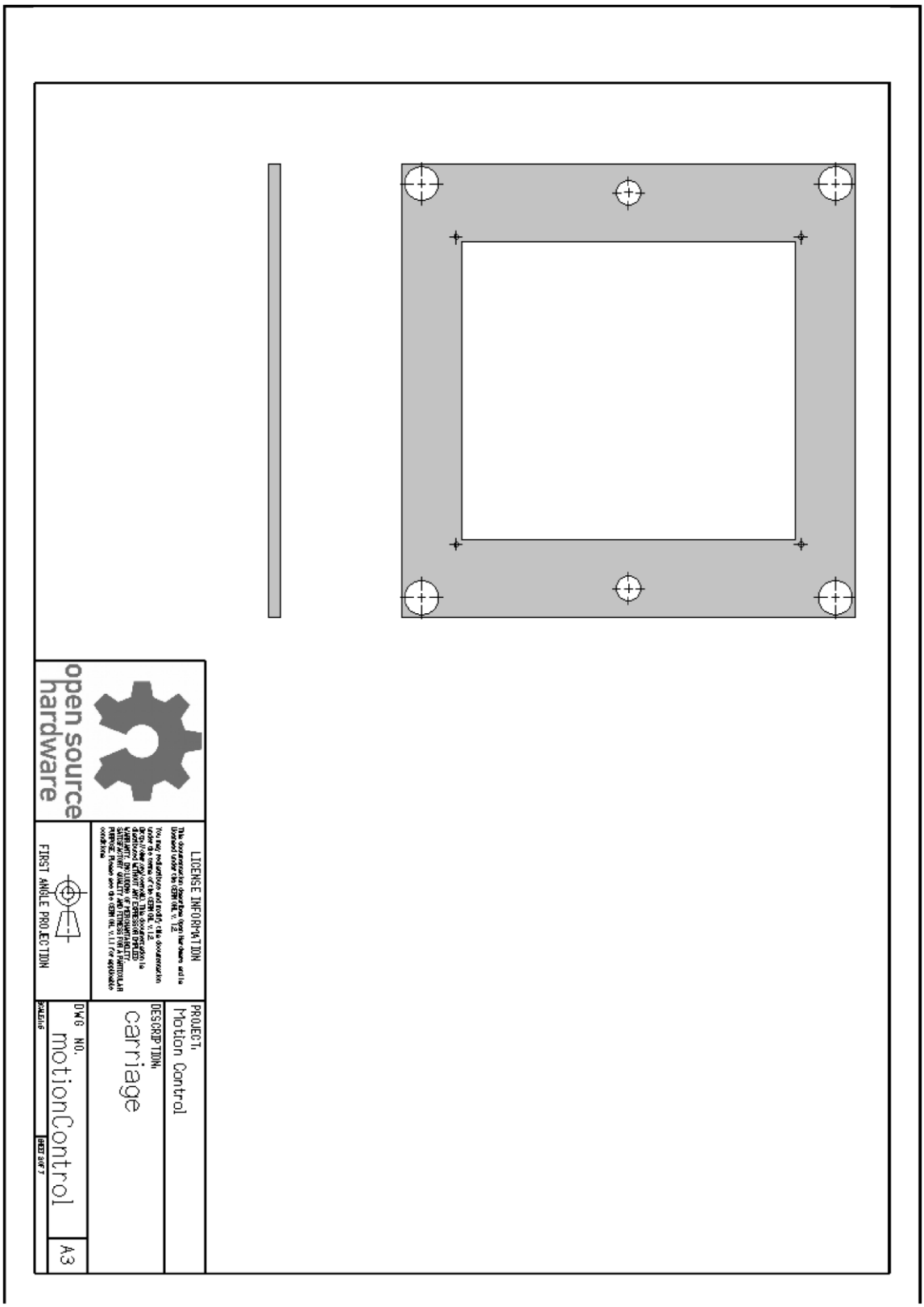
DESCRIPTION:
motionControl_assembly

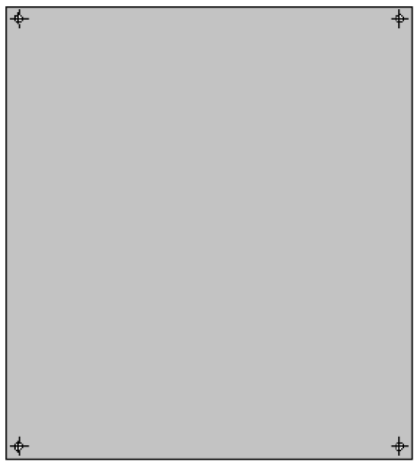
DWG NO.
motionControl

A3

SCALE:1:5

SHEET 2 OF 7


LICENSE INFORMATION
PROJECT:
Motion Control
DESCRIPTION:
carriage
DWG NO.
motionControl
A3
FIRST ANGLE PROJECTION
open source
hardware



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FIRST ANGLE PROJECTION

PROJECT: Motion Control

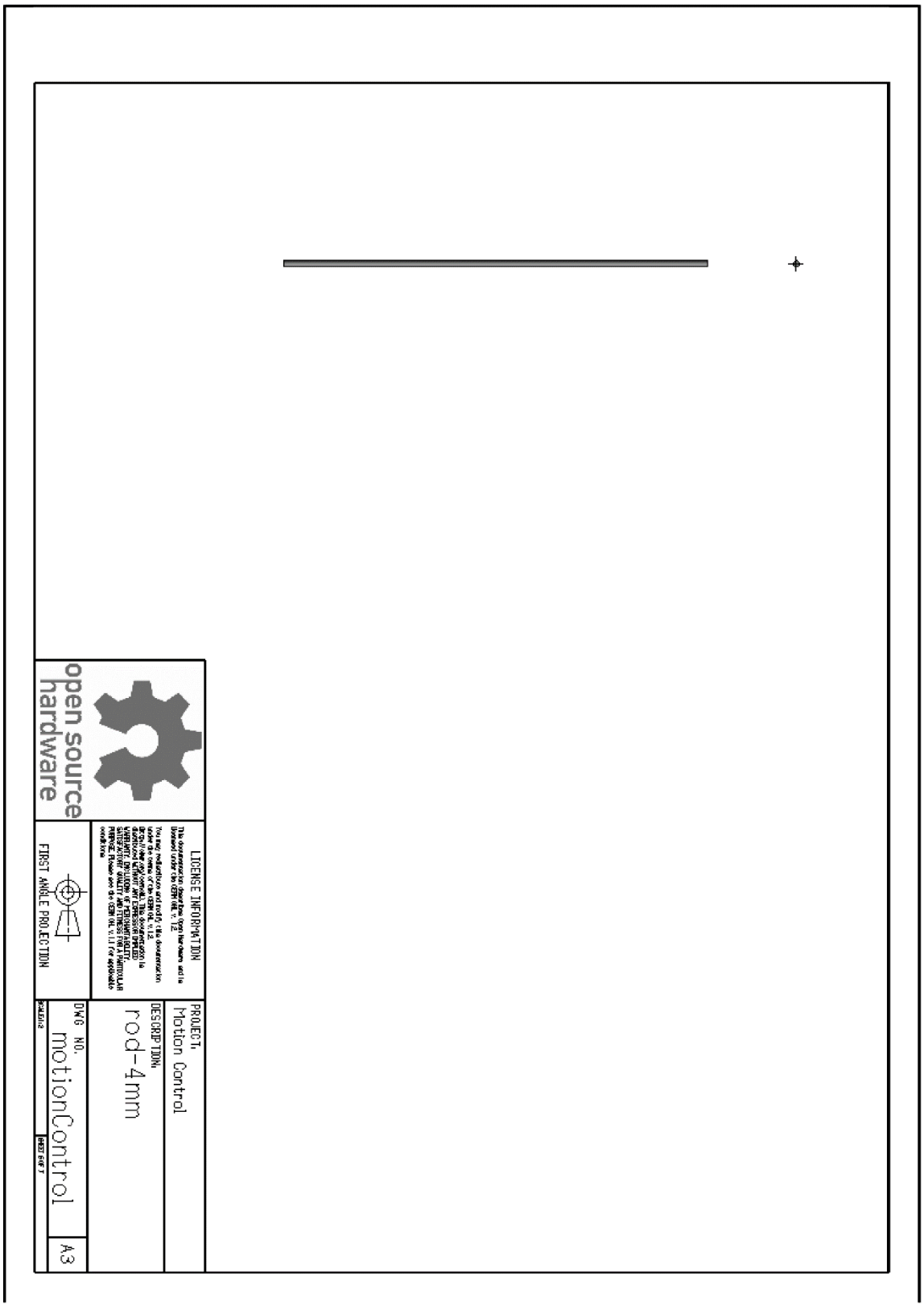
DESCRIPTION: buildTable

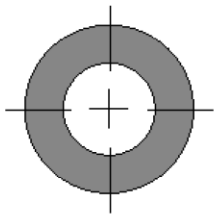
DWG NO. motionControl

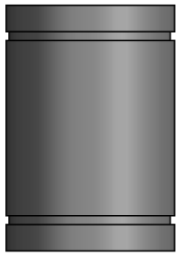
A3

SCALE: n:2

SHEET 4 OF 7


LICENSE INFORMATION
PROJECT:
Motion Control
DESCRIPTION:
rod-4mm
DWG NO.
motionControl
A3
FIRST ANGLE PROJECTION
open source
hardware





open source hardware

FIRST ANGLE PROJECTION

PROJECT:
Motion Control

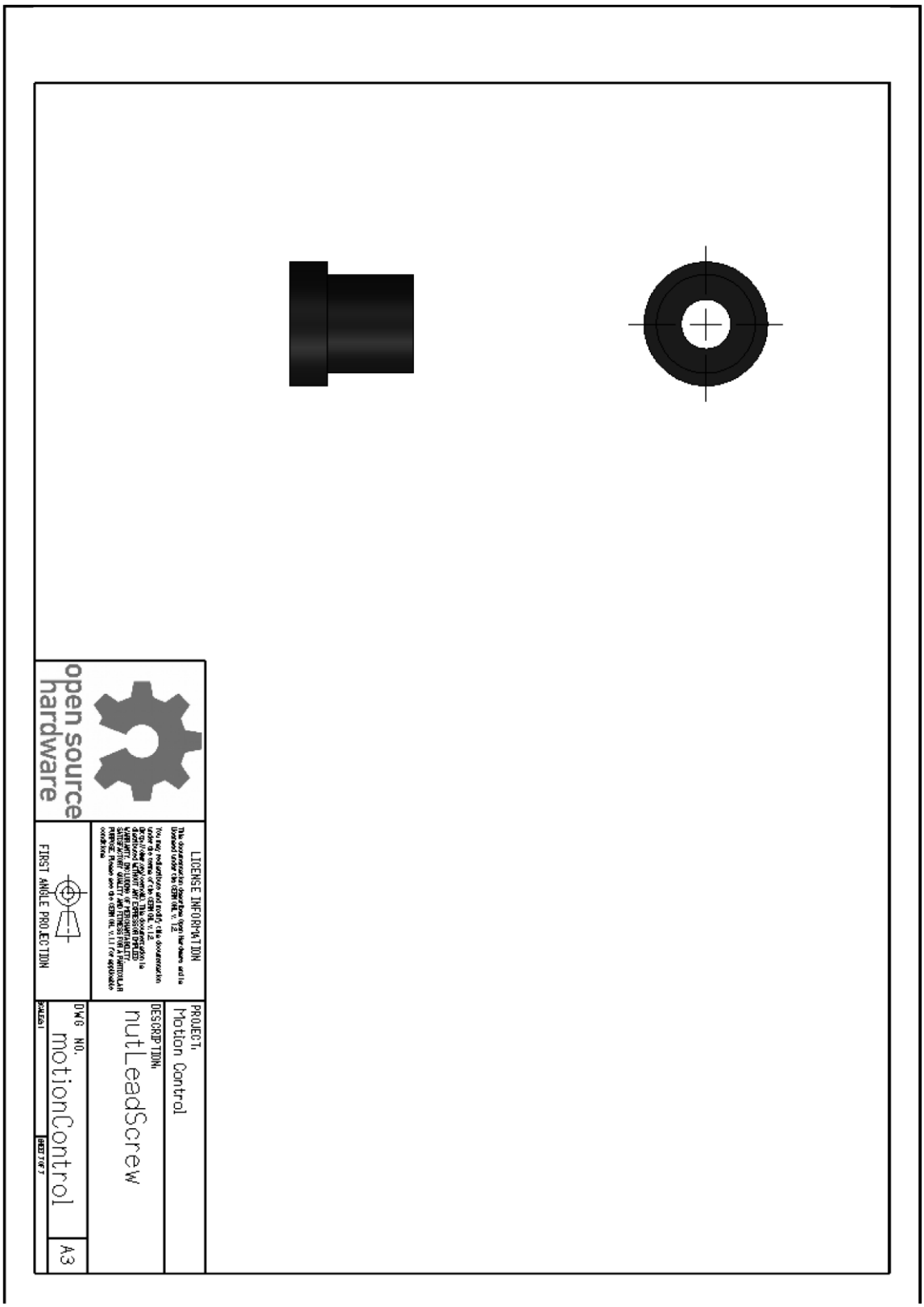
DESCRIPTION:
bearingLinear12mm

DWG NO.
motionControl

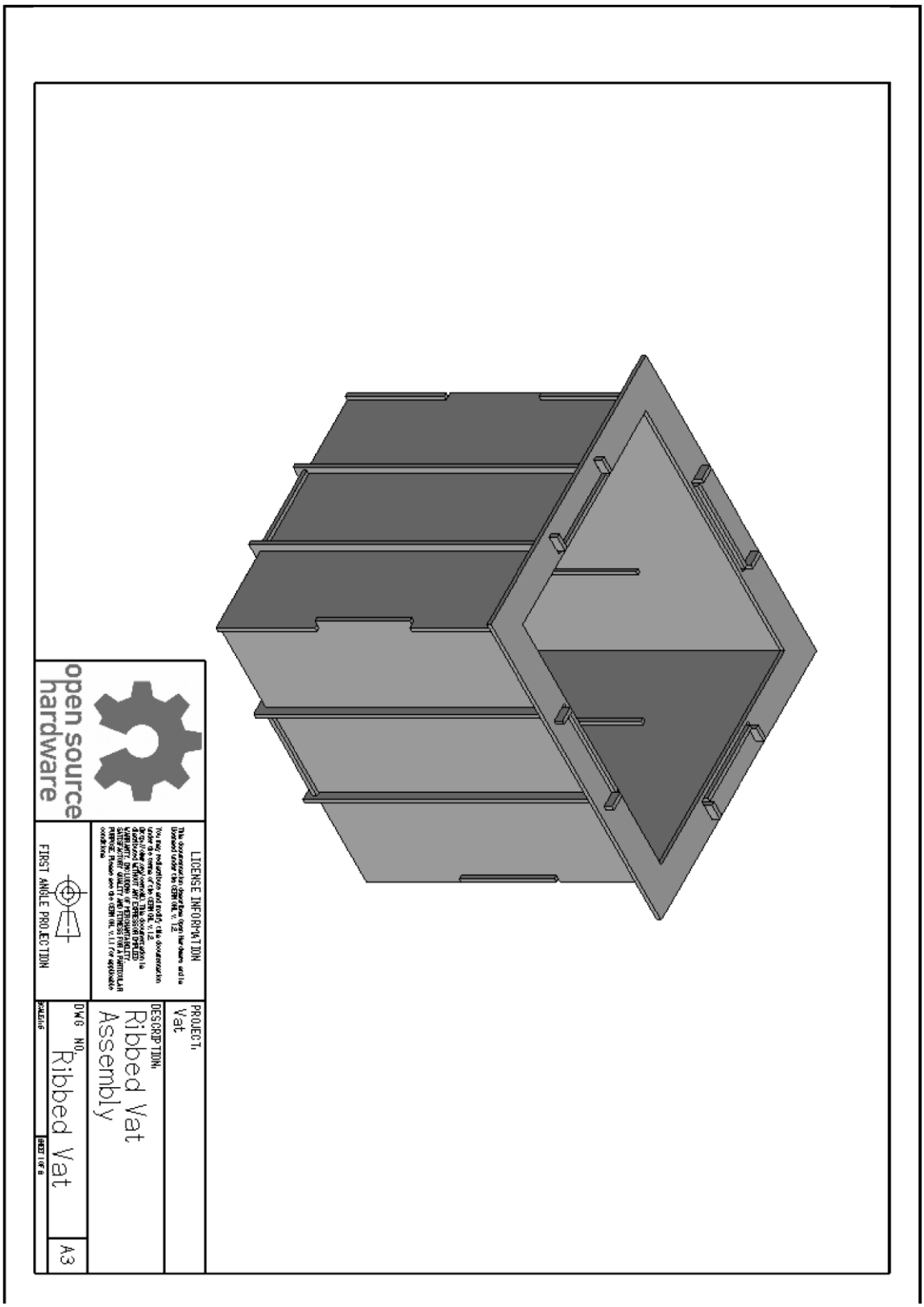
A3

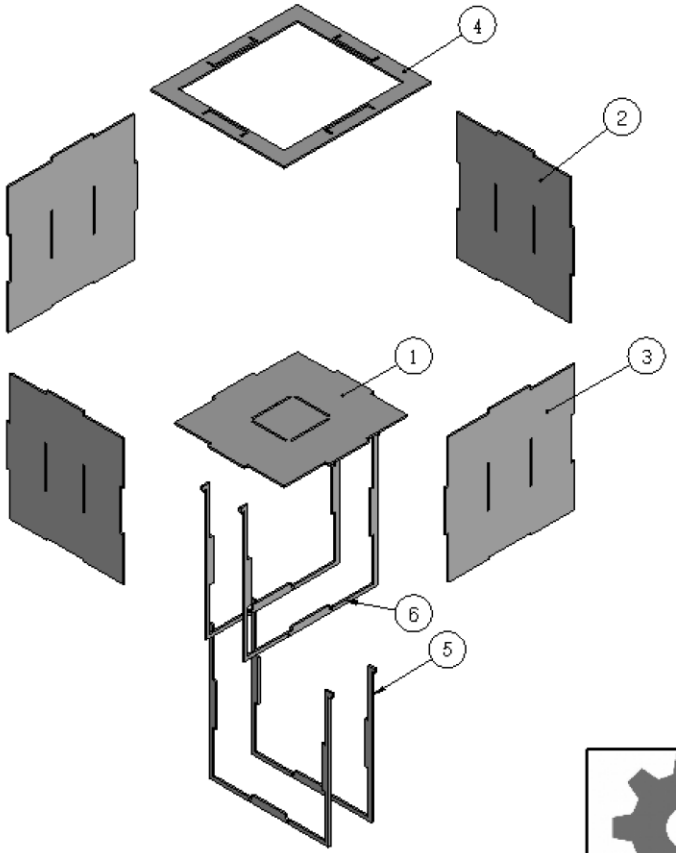
SCALE: 1

SHEET 8 OF 7



9.3.4 RIBBED VAT


LICENSE INFORMATION
PROJECT:
Vat
DESCRIPTION:
Ribbed Vat
Assembly
open source
hardware
FIRST ANGLE PROJECTION
DWG NO.
Ribbed Vat
A3



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	floor	Vat Base Plate	1
2	wallX	Wall X	2
3	wallY	Wall Y	2
4	lip	Lip	1
5	supportX	Rib Y	2
6	supportY	Rib X	2

open source hardware

LICENSE INFORMATION

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FIRST ANGLE PROJECTION

PROJECT: Vat

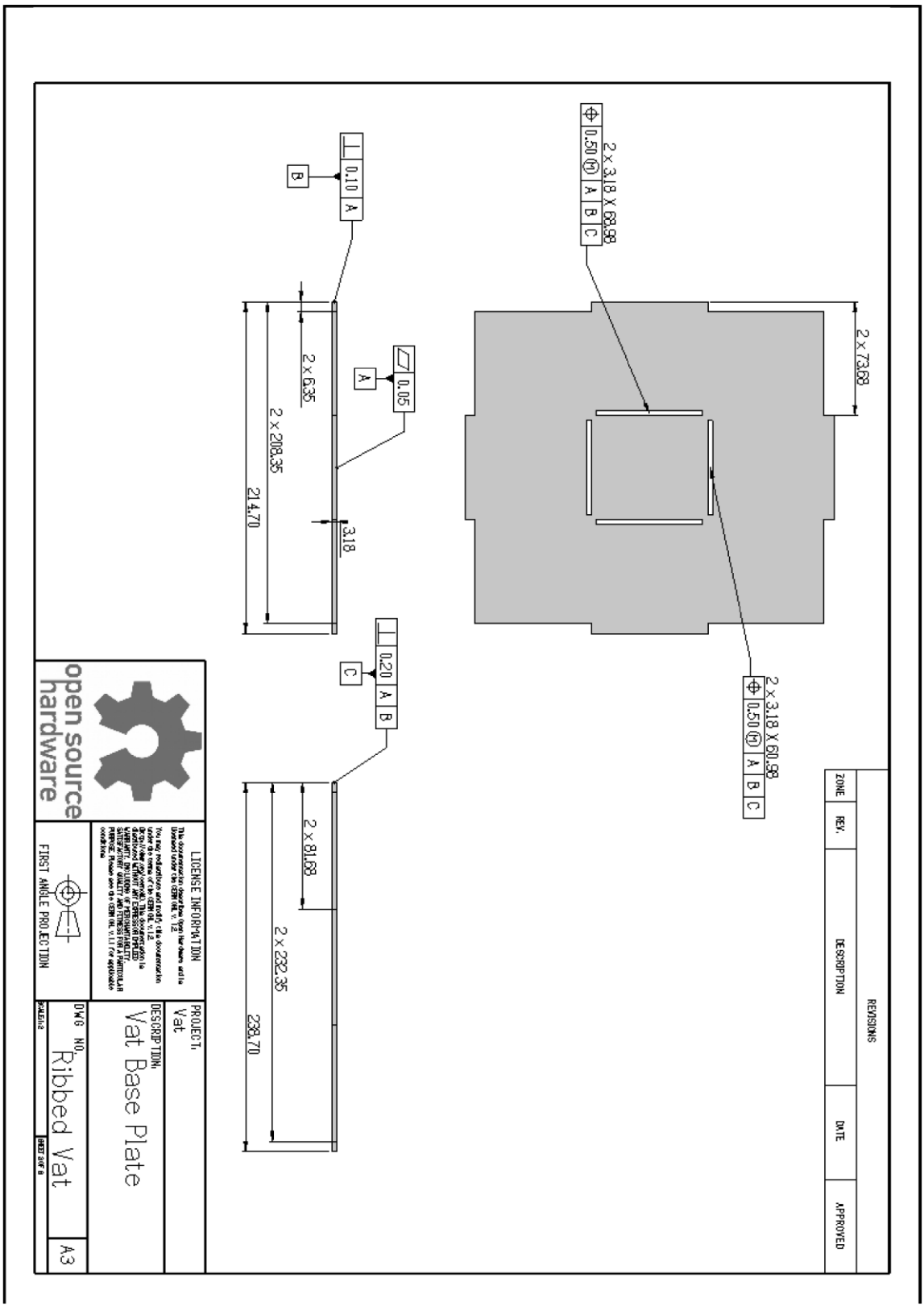
DESCRIPTION: Ribbed Vat

DWG NO. Ribbed Vat

A3

SCALE: 1:5

SHEET 2 OF 8


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
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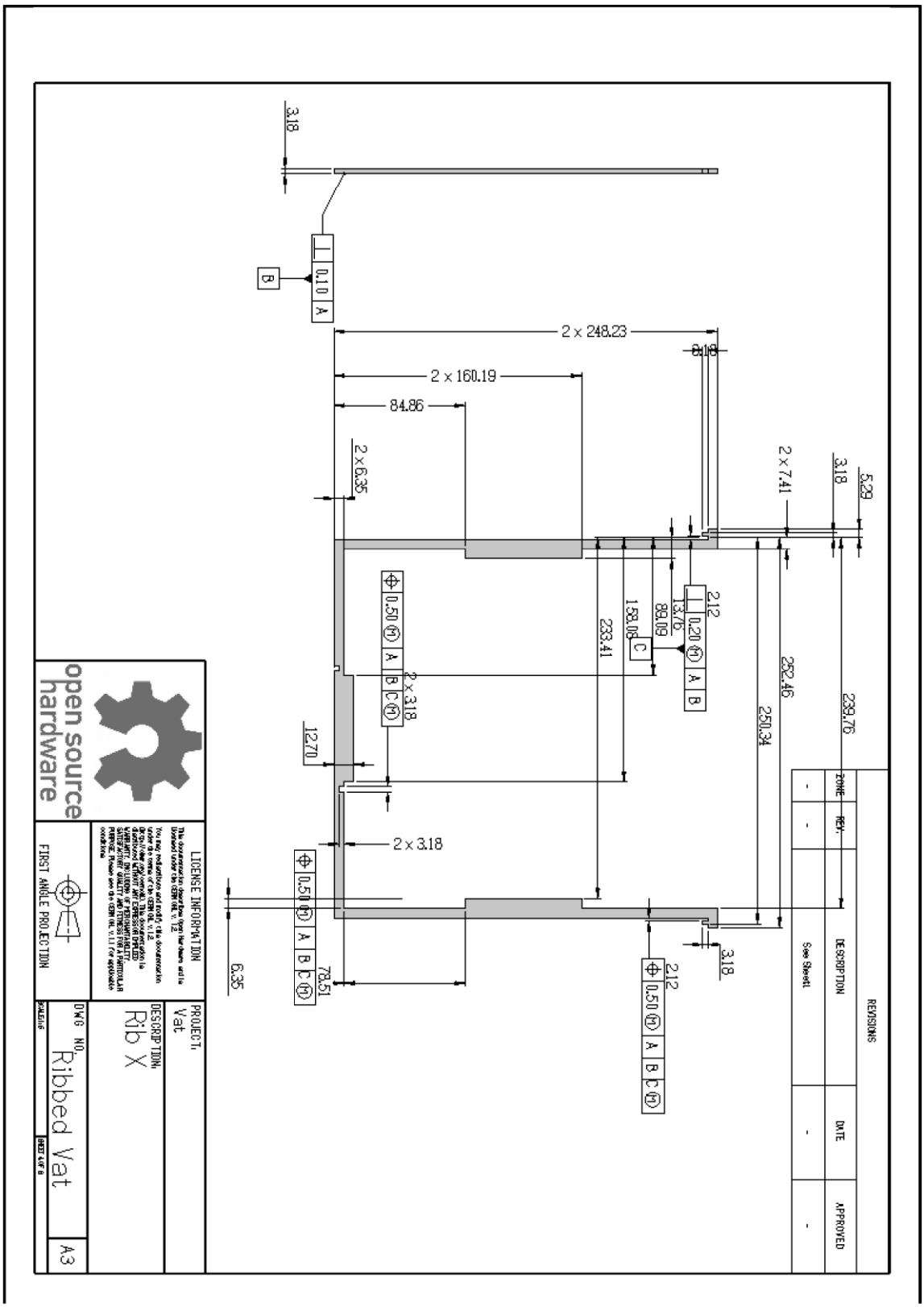
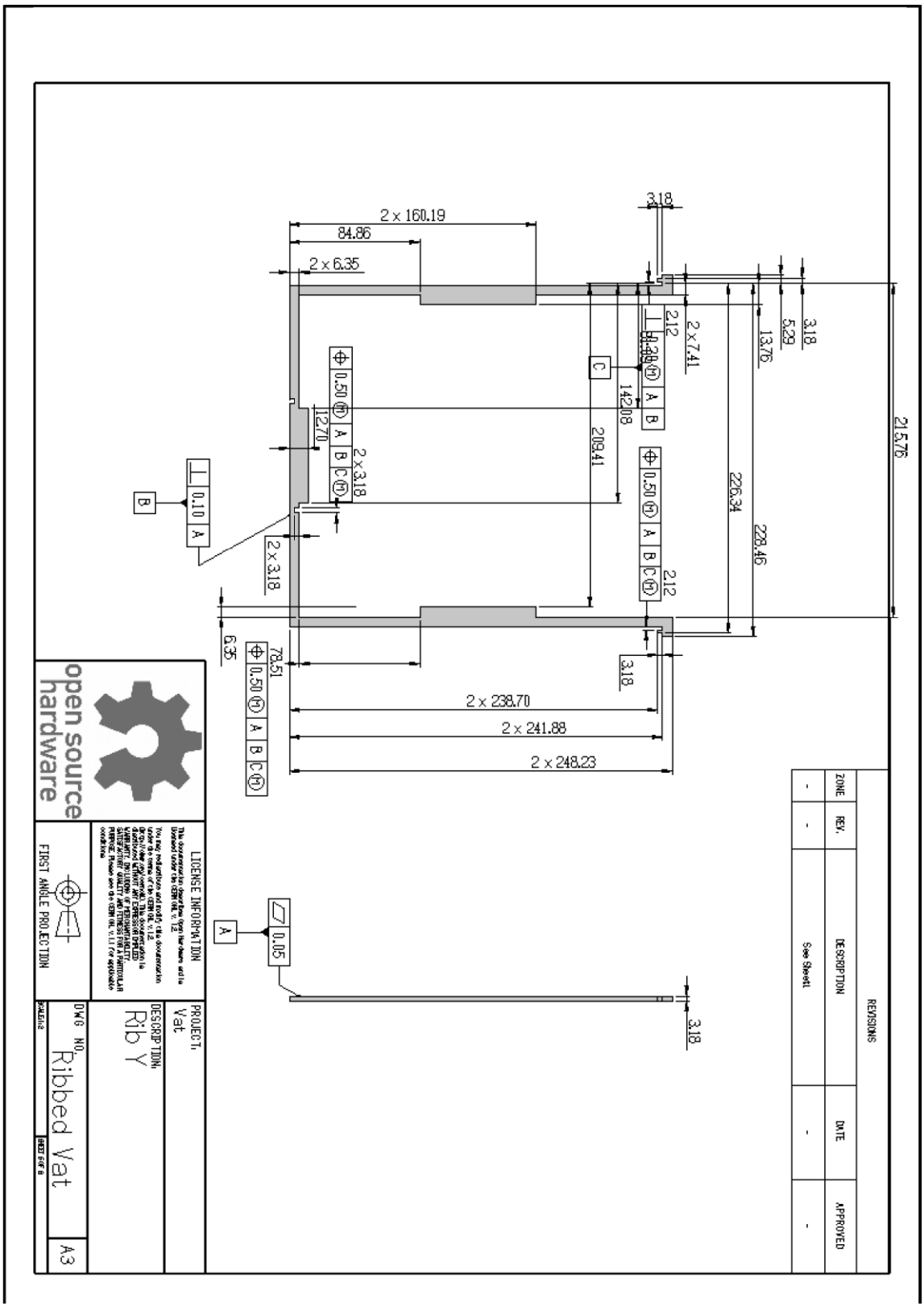
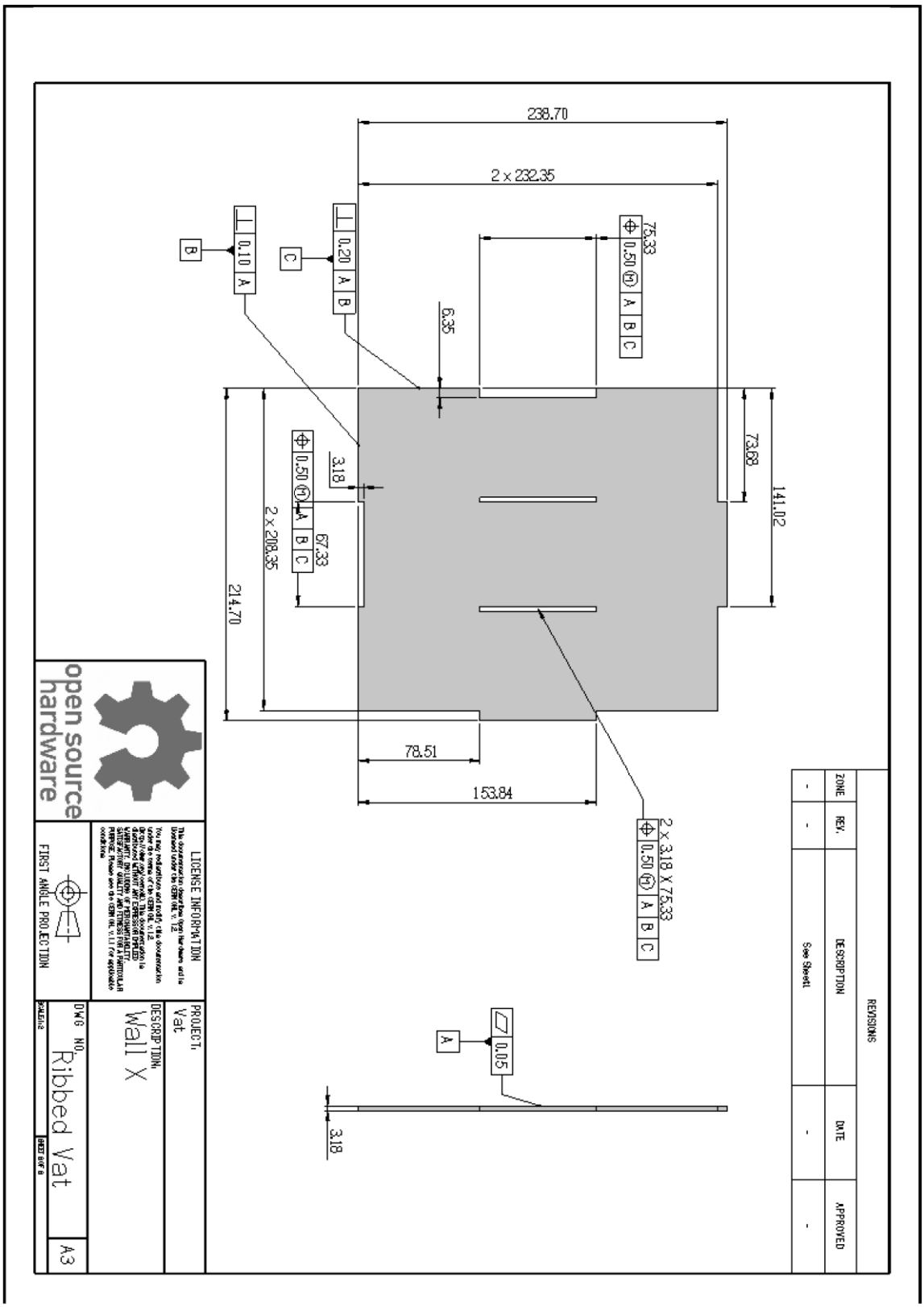
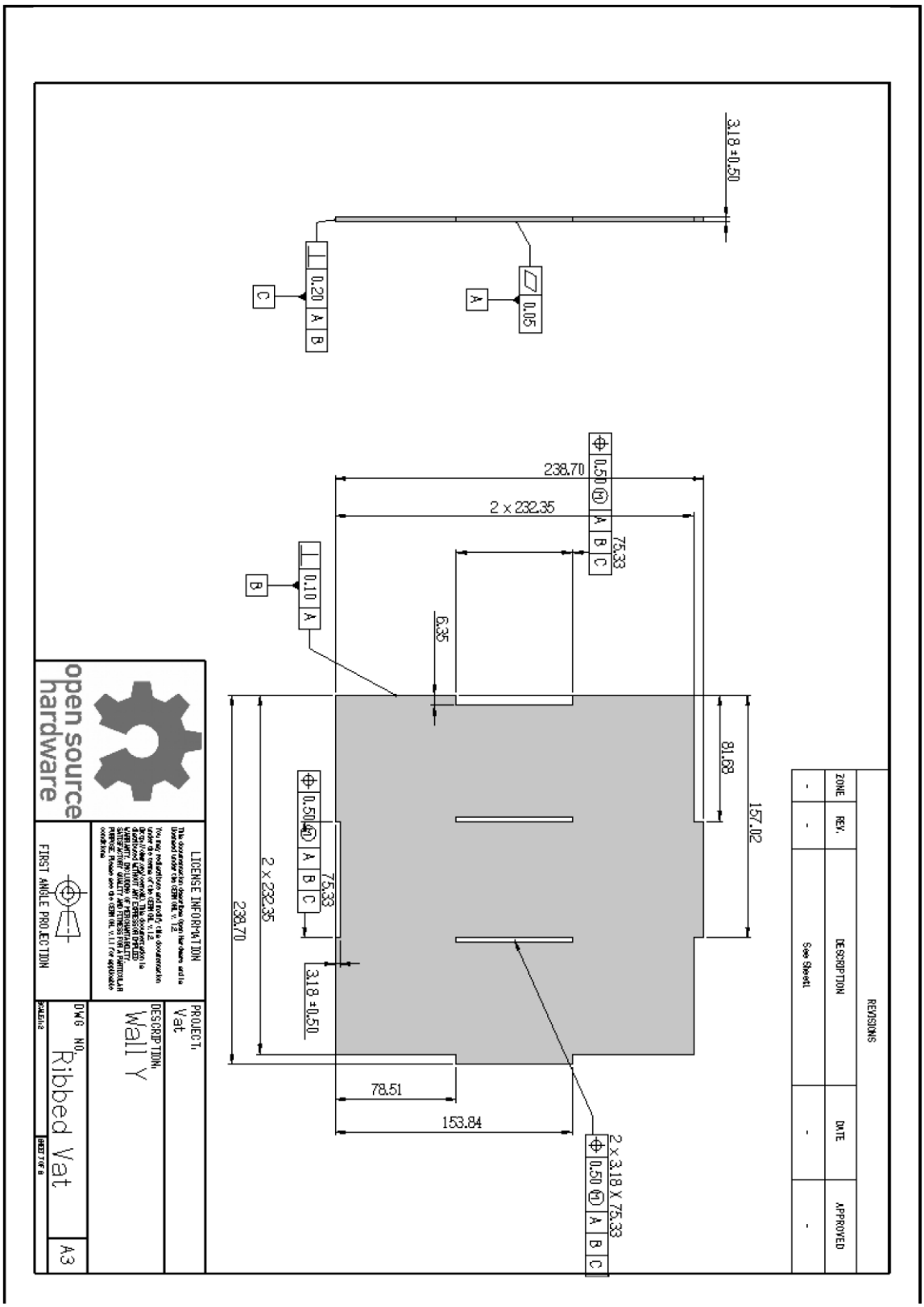
2 x 3.18 X 68.98
0.50 Ⓜ A B C
2 x 3.18 X 60.98
0.50 Ⓜ A B C
0.10 A
B
2 x 6.35
0.05
A
2 x 208.35
214.70
3.18
0.20 A B
C
2 x 81.68
2 x 232.35
238.70
LICENSE INFORMATION
PROJECT:
Vat
DESCRIPTION:
Vat Base Plate
DWG NO.
Ribbed Vat
A3
SHEET 1 OF 1
FIRST ANGLE PROJECTION
open source hardware


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
See Sheet1
open source hardware
LICENSE INFORMATION
PROJECT:
Vat
DESCRIPTION:
Rib X
DWG NO.
Ribbed Vat
A3
FIRST ANGLE PROJECTION
SHEET 1 OF 1
2 x 248.23
2 x 160.19
84.86
2 x 6.35
2 x 7.41
3.18
5.29
239.76
252.46
250.34
233.41
159.08
88.09
13.76
2 x 3.18
12.70
78.51
6.35


2 x 160.19
84.86
2 x 6.35
3.18
5.29
13.76
2 x 7.41
212
142.08
209.41
226.34
228.46
215.76
2 x 3.18
12.70
6.35
79.51
2 x 238.70
2 x 241.88
2 x 248.23
0.10 A
0.50 M A B C M
0.05 A
REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
See Sheet1
open source hardware
FIRST ANGLE PROJECTION
PROJECT:
Vat
DESCRIPTION:
Rib Y
DWG NO.
Ribbed Vat
A3


238.70
2 x 232.35
75.33
0.50 M A B C
0.20 A B
C
0.10 A
B
6.35
73.68
141.02
3.18
0.50 M A B C
67.33
2 x 208.35
214.70
78.51
153.84
2 x 3.18 X 75.33
0.50 M A B C
A
0.05
3.18
REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
-
-
See Sheet1
-
-
LICENSE INFORMATION
PROJECT:
Vat
DESCRIPTION:
Wall X
DWG NO.
Ribbed Vat
A3
FIRST ANGLE PROJECTION
open source hardware


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
See Sheet1
3.18 ±0.50
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0.05
238.70
2 x 232.35
75.33
0.10 A
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2 x 232.35
238.70
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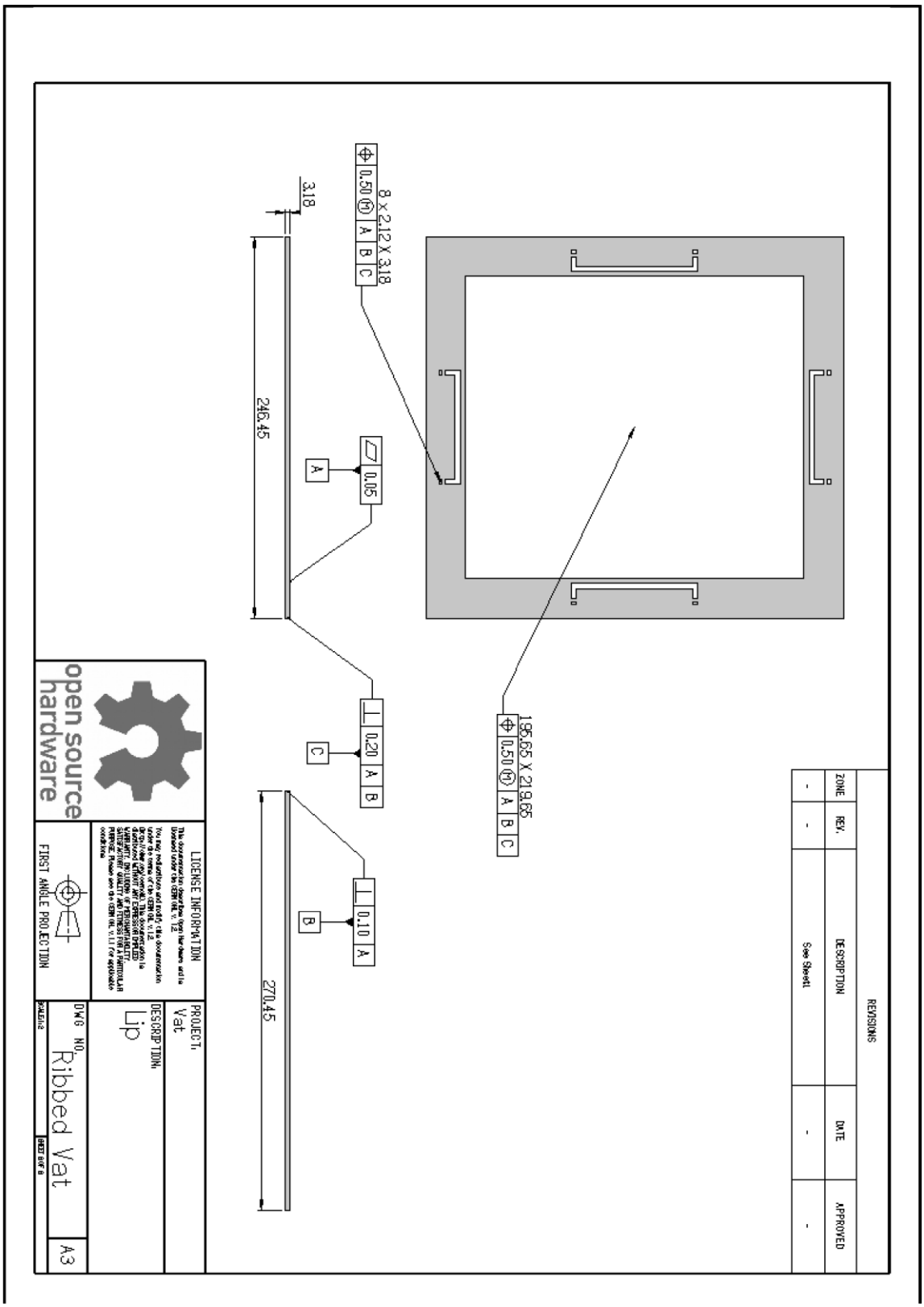
153.84
2 x 3.18 X 75.33
LICENSE INFORMATION
open source hardware
FIRST ANGLE PROJECTION
PROJECT:
Vat
DESCRIPTION:
Wall Y
DWG NO.
Ribbed Vat
A3



9.4 MAKERJUICE G+ SAFETY DATA SHEET

MakerJuice LABS

SAFETY DATA SHEET

Issue Date 19-Nov-2013 **Revision Date** 22-May-2014 **Version** 2

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Product identifier
Product Name SUBSTANCE G+

Other means of identification
Synonyms SubG+

Recommended use of the chemical and restrictions on use
Recommended Use General Purpose UV Cure Resin
Uses advised against No information available

Details of the supplier of the safety data sheet
Manufacturer Address
MakerJuice Labs LLC
14100 Santa Fe Trail Drive
Suite #105
Lenexa, KS 66215 USA

Email: josh@makerjuice.com
Website: http://www.makerjuice.com

Emergency telephone number
Company Phone Number (913) 777-4996 [9-5PM CST, M-F]

2. HAZARDS IDENTIFICATION

Classification

OSHA Regulatory Status
This chemical is considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Skin corrosion/irritation	Category 2
Serious eye damage/eye irritation	Category 1
Skin sensitization	Category 1

Label elements

Emergency Overview

Danger

Hazard statements
Causes skin irritation
Causes serious eye damage
May cause an allergic skin reaction

Appearance viscous **Physical state** liquid **Odor** Ester

Precautionary Statements - Prevention
Wash face, hands and any exposed skin thoroughly after handling
Wear protective gloves/protective clothing/eye protection/face protection
Avoid breathing dust/fume/gas/mist/vapors/spray
Contaminated work clothing should not be allowed out of the workplace

Precautionary Statements - Response
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
Immediately call a POISON CENTER or doctor/physician
IF ON SKIN: Wash with plenty of soap and water
Take off contaminated clothing and wash before reuse
If skin irritation or rash occurs: Get medical advice/attention

Precautionary Statements - Disposal
Dispose of contents/container to an approved waste disposal plant

Hazards not otherwise classified (HNOC)
Not Applicable

Other Information
Unknown Acute Toxicity 0% of the mixture consists of ingredient(s) of unknown toxicity

3. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Name	CAS No.	Weight-%	Trade Secret
acrylate ester	proprietary	>60	*
photoinitiator	proprietary	<1	*

* If CAS number is "proprietary", the specific chemical identity has been withheld as a trade secret. The exact percentage (concentration) of composition has been withheld as a trade secret.

4. FIRST AID MEASURES

First aid measures

General advice If symptoms persist, call a physician.

Eye contact Immediately flush with plenty of water. After initial flushing, remove any contact lenses and continue flushing for at least 15 minutes. Keep eye wide open while rinsing. If symptoms persist, call a physician.

Skin Contact Avoid UV-radiation/sunlight. Wash off immediately with soap and plenty of water while removing all contaminated clothes and shoes. If skin irritation persists, call a physician. Wash contaminated clothing before reuse.

Inhalation If fumes from reactions are inhaled, move to fresh air immediately. If symptoms persist, call a physician.

Ingestion Rinse mouth. Drink plenty of water. Do NOT induce vomiting. Call a physician immediately.

Self-protection of the first aider Use personal protective equipment as required.

Most important symptoms and effects, both acute and delayed

Symptoms May cause allergic skin reaction.

Indication of any immediate medical attention and special treatment needed

Note to physicians May cause sensitization of susceptible persons. Treat symptomatically.

5. FIRE-FIGHTING MEASURES

Suitable extinguishing media
Dry chemical, CO2, alcohol-resistant foam or water spray.

Unsuitable extinguishing media: Do not use a solid water stream as it may scatter and spread fire.

Specific hazards arising from the chemical
In the event of fire and/or explosion do not breathe fumes. May cause sensitization by inhalation and skin contact. Thermal decomposition can lead to release of irritating and toxic gases and vapors.

Hazardous combustion products: Formaldehyde.

Explosion data
Sensitivity to Mechanical Impact: None.
Sensitivity to Static Discharge: None.

Protective equipment and precautions for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Personal precautions	Ensure adequate ventilation, especially in confined areas. Use personal protective equipment as required. Avoid contact with eyes and skin. Evacuate personnel to safe areas. Keep people away from and upwind of spill/leak.

Environmental precautions

Environmental precautions	Do not flush into surface water or sanitary sewer system. See Section 12 for additional ecological information.

Methods and material for containment and cleanup

Methods for containment	Prevent further leakage or spillage if safe to do so.
Methods for cleaning up	Soak up with inert absorbent material. Pick up and transfer to properly labeled containers. After cleaning, flush away traces with water.

7. HANDLING AND STORAGE

Precautions for safe handling

Advice on safe handling	Use only in well-ventilated areas. Avoid breathing fumes from hot material. Use personal protective equipment as required. Do not breathe dust/fume/gas/mist/vapors/spray.

Conditions for safe storage, including any incompatibilities

Storage Conditions	Keep out of the reach of children. Keep containers tightly closed in a cool, well-ventilated place. Keep in properly labeled containers. Protect from direct sunlight and ultraviolet (UV). Keep away from heat.
Incompatible materials	Strong oxidizing agents. Strong acids. Strong bases.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

Exposure Guidelines This product, as supplied, does not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.

Appropriate engineering controls

Engineering Controls Ensure adequate ventilation, especially in confined areas.

Individual protection measures, such as personal protective equipment

Eye/face protection Tight sealing safety goggles.

Skin and body protection Wear protective nitrile rubber gloves.

Respiratory protection In case of insufficient ventilation, wear suitable respiratory equipment.

General Hygiene Considerations When using do not eat, drink or smoke. Wash face, hands and any exposed skin thoroughly after handling. Wash contaminated clothing before reuse. Regular cleaning of equipment, work area and clothing is recommended.

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Physical state	liquid		
Appearance	viscous	**Odor**	Ester
Color	red, yellow, green, blue, black, white	**Odor threshold**	No information available

Property	Values	Remarks • Method
pH	No information available	
Melting point/freezing point	No information available	
Boiling point / boiling range	No information available	
Flash point	> 100 °C (> 212 °F)	
Evaporation rate	No information available	
Flammability (solid, gas)	No information available	
Flammability Limit in Air		
Upper flammability limit:	No information available	
Lower flammability limit:	No information available	
Vapor pressure	No information available	
Vapor density	No information available	
Specific Gravity	Approx. 1	
Water solubility	Low solubility	
Solubility in other solvents	No information available	
Partition coefficient	No information available	
Autoignition temperature	No information available	
Decomposition temperature	No information available	
Kinematic viscosity	No information available	
Dynamic viscosity	90 cP	@ 20 °C
Explosive properties	No information available	
Oxidizing properties	No information available	
Softening point	No information available	
Molecular weight	No information available	
VOC Content (%)	No information available	
Density	No information available	
Bulk density	No information available	

10. STABILITY AND REACTIVITY

Reactivity
No data available

Chemical stability
Stable under recommended storage conditions.

Possibility of Hazardous Reactions
None under normal processing.

Conditions to avoid
Heat, flames and sparks. Extremes of temperature and direct sunlight. To avoid thermal decomposition, do not overheat. UV-radiation/sunlight.

Incompatible materials
Strong oxidizing agents. Strong acids. Strong bases.

Hazardous Decomposition Products
Formaldehyde.

11. TOXICOLOGICAL INFORMATION

Information on likely routes of exposure

Product Information

Inhalation	No data available.
Eye contact	Risk of serious damage to eyes.
Skin Contact	May cause sensitization by skin contact.
Ingestion	No data available.

Component Information

Chemical Name	Oral LD50	Dermal LD50	Inhalation LC50
acrylate ester	= 4600 mg/kg (Rat)	> 2 g/kg (Rabbit)	-

Information on toxicological effects

Symptoms May cause an allergic skin reaction.

Delayed and immediate effects as well as chronic effects from short and long-term exposure

Corrosivity	Risk of serious damage to eyes.
Sensitization	May cause sensitization by skin contact.
Germ cell mutagenicity	No information available.
Carcinogenicity	May release formaldehyde when heated to high temperatures [> 150 °C (> 212 °F)] in the presence of air. Formaldehyde is a known skin and lung sensitizer and is regulated as a carcinogen.
Reproductive toxicity	No information available.
STOT - single exposure	No information available.
STOT - repeated exposure	No information available.
Aspiration hazard	No information available.

Numerical measures of toxicity - Product Information

Unknown Acute Toxicity 0% of the mixture consists of ingredient(s) of unknown toxicity

12. ECOLOGICAL INFORMATION

Ecotoxicity

Toxic to aquatic life

Persistence and degradability
No information available.

Bioaccumulation
No information available.

Other adverse effects No information available

13. DISPOSAL CONSIDERATIONS

Waste treatment methods

Disposal of wastes Disposal should be in accordance with applicable regional, national and local laws and regulations.

Contaminated packaging Do not reuse container.

14. TRANSPORT INFORMATION

DOT Not regulated

TDG Not regulated

IATA Not regulated

IMDG Not regulated

ADR Not regulated

15. REGULATORY INFORMATION

International Inventories
TSCA Complies

Legend:
TSCA - United States Toxic Substances Control Act Section 8(b) Inventory

US Federal Regulations
SARA 313
Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372

SARA 311/312 Hazard Categories

Acute health hazard	Yes
Chronic Health Hazard	No
Fire hazard	No
Sudden release of pressure hazard	No
Reactive Hazard	No

CWA (Clean Water Act)
This product does not contain any substances regulated as pollutants pursuant to the Clean Water Act (40 CFR 122.21 and 40 CFR 122.42)

CERCLA
This material, as supplied, does not contain any substances regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material

US State Regulations

California Proposition 65
This product does not contain any Proposition 65 chemicals

U.S. State Right-to-Know Regulations

This product does not contain any substances regulated by state right-to-know regulations

Canada

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR WHMIS Hazard Class

D2B - Toxic materials 

16. OTHER INFORMATION

NFPA	**Health hazards** 2	**Flammability** 0	**Instability** 0	**Physical and Chemical Properties** -
HMIS	**Health hazards** 2	**Flammability** 0	**Physical hazards** 0	**Personal protection** X

Issue Date	19-Nov-2013
Revision Date	22-May-2014

Disclaimer
The information provided in this Material Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

End of Safety Data Sheet

9.5 MAKERJUICE G+ TECHINCAL DATA SHEET

MakerJuice
7308 Metcalf Ave
Overland Park, KS 66204
USA

Substance G+

DATA**SHEET**

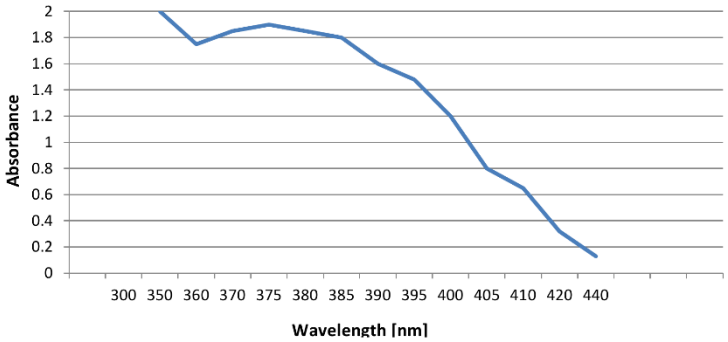
High Performance, General Purpose UV Cure Resin

Descriptors:
Hard, tough, fast cure speed.

Colors Available:
Red, Orange, Yellow, Green, Cyan, Indigo, Purple, Black

Sizes Available:
500mL (0.55 KG), 1 Liter (1.1 KG)
Larger sizes available upon request, for special order.

Technical Data:
Experimental Shrink: 3.3%
Ash Content: < 0.2%
Surface Tension: 36.5 Dynes/cm
Tensile Strength: 9100 PSI, 6% Elongation
Shore Hardness: 75 D
Glass Transition Temperature: 104°C
Uncolored Reactivity: 423 mJ/cm^2
Water content: < 0.23%
Viscosity @ 20°C: 90 cP
Acidity: < 0.31 mg KOH/g
Density @ 25°C: 1.1 g/cm^3
UV Absorption:



Storage:
Store in a tightly closed, opaque container in a properly vented storage area under dry conditions away from heat, sparks, and open flames. Shelf-life is 6 months from receipt.

Safety:
For additional information please see the Material Safety Data Sheet.

9.6 WEBSITE (GITHUB PAGES)

9.6.1 HOME PAGE

Project PAM

Open Source DLP 3D Printer

Follow us on GitHub

Home Hardware Software

/// Welcome to Project PAM.

PAM stands for Photoresin Additive Manufacturing. This type of 3D printing gets away from the extruded plastic spaghetti machines that we're all familiar with and instead uses light-curing resins to build your models. This means higher resolutions, fewer moving parts, and faster build times and the only jam to worry about is the kind you eat with peanut butter.

Project PAM is seeking to take DLP 3D printing in a new direction of higher build volumes and lower costs without sacrificing resolution. The goal for this project is to produce a high resolution DLP printer that is fully open sourced using off-the-shelf hardware and that is well documented. All design material can be found in either the Hardware Repo or the Software Repo.

If you would like to donate to Project PAM visit our Indiegogo campaign. Any and all donations would be greatly appreciated.

/// Why Open Source?

We at Project PAM believe that open source is the future. Open source allows people to freely share ideas and information and concentrate on improving the world around us. We are not driven in any way by money, profit margins; but instead motivated by the desire to better the open source and 3D printing community.

There have been many attempts at an open source DLP 3D printer, yet many of those attempts have patents associated to the design, non-commercial licensing, or do not properly host and share their designs. Our first priority when starting out was to keep everything open-source; this includes both hardware and software. To ensure this, we have followed the Open Source Hardware (OSHW) Definition set by the Open Source Hardware Association (OSHA).

Open Source Hardware (OSHW) Statement of Principles 1.0:

Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it. Ideally, open source hardware uses readily-available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware. Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.

The licenses Project PAM uses are:

- Hardware: CERN OHL v1.2
- Software: GNU GPL 3.0
- Documentation: CC BY-SA 4.0

/// Tired of Those Stupid Spaghetti Machines?

Photoresin additive manufacturing printers have many advantages over fused deposition manufacturing (FDM) printers. There are fewer moving parts, faster build times, and no jams. Currently there are DLP 3D printers on the market; however, most have either high cost or small build volumes. Our design is low cost ($1000) and also features a build volume comparable to leading FDM printers.

Help fund us on:

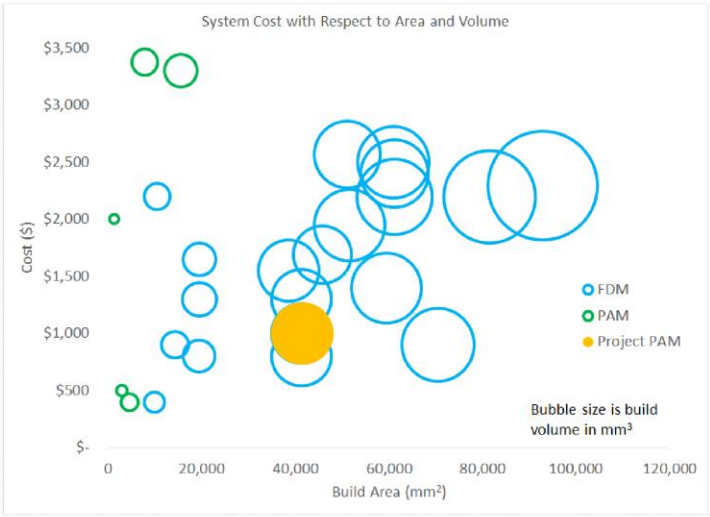
INDIEGOGO

Find us on:

Project PAM

is maintained by ProjectPAM.

This page was generated by GitHub Pages using the Architect theme by Jason Long.



/// How is our design more flexible?

Project PAM has a build volume of just under 9 liters. We are able to accomplish this by supporting dual 1080p projectors; however, the system is designed to be compatible with projectors of any resolution and also a single projector.

We have designed Project PAM to use mostly off-the-shelf parts that can be bought through Adafruit, Amazon, and industrial supply warehouses. An advantage to using off-the-shelf parts is that the design can be easily modified to suit any needs. We have also used the off-the-self mentality when it comes to the resins we use through the use of Maker Juice G+ resin.

The software Project PAM will be using is based off of the software for the B9 Creator. The software will be modified to be compatible with all projectors and resins. Project PAM will be using Grbl firmware, which unlike the software does not need to be modified to increase compatibility.

/// Releases

First Release Coming Soon!

/// Who We Are

We are a team of undergraduate engineering students working on a Senior Design Project at Southern Illinois University Carbondale. We have great passion for advancing the open source and 3D printing community.

- Jeffery Burdick (@burdickjp): Mechanical Engineer, Project Manager
- Nathaniel Tyler (@ntyler): Mechanical Engineer

- Chance Baker (@MrBaker452): Electrical Engineer
- Casey Spencer (@cspence182): Electrical Engineer
- Nicholas Lowman (@namwol): Computer Engineer
- Daniel Olsen (@dan-olsen): Computer Engineer

/// Contact Us

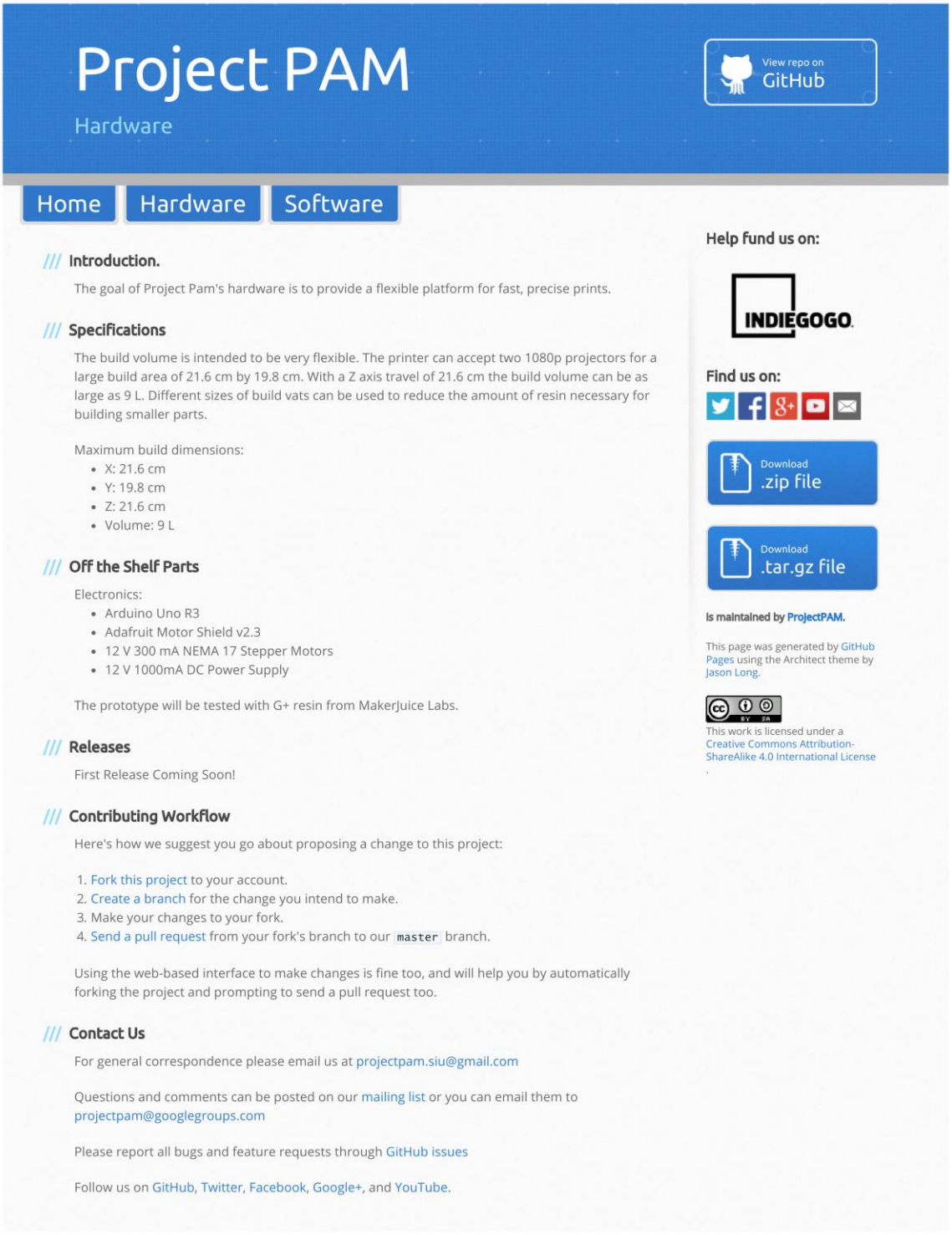
For general correspondence please email us at projectpam.siu@gmail.com

Questions and comments can be posted on our mailing list or you can email them to projectpam@googlegroups.com

Please report all bugs and feature requests through GitHub issues either on the Software Repo or the Hardware Repo respectably.

Follow us on GitHub, Twitter, Facebook, Google+, and YouTube.

9.6.2 HARDWARE PAGE



Project PAM

Hardware

View repo on GitHub

Home | Hardware | Software

/// Introduction.

The goal of Project Pam's hardware is to provide a flexible platform for fast, precise prints.

/// Specifications

The build volume is intended to be very flexible. The printer can accept two 1080p projectors for a large build area of 21.6 cm by 19.8 cm. With a Z axis travel of 21.6 cm the build volume can be as large as 9 L. Different sizes of build vats can be used to reduce the amount of resin necessary for building smaller parts.

Maximum build dimensions:

- X: 21.6 cm
- Y: 19.8 cm
- Z: 21.6 cm
- Volume: 9 L

/// Off the Shelf Parts

Electronics:

- Arduino Uno R3
- Adafruit Motor Shield v2.3
- 12 V 300 mA NEMA 17 Stepper Motors
- 12 V 1000mA DC Power Supply

The prototype will be tested with G+ resin from MakerJuice Labs.

/// Releases

First Release Coming Soon!

/// Contributing Workflow

Here's how we suggest you go about proposing a change to this project:

1. Fork this project to your account.
2. Create a branch for the change you intend to make.
3. Make your changes to your fork.
4. Send a pull request from your fork's branch to our `master` branch.

Using the web-based interface to make changes is fine too, and will help you by automatically forking the project and prompting to send a pull request too.

/// Contact Us

For general correspondence please email us at projectpam.siu@gmail.com

Questions and comments can be posted on our mailing list or you can email them to projectpam@googlegroups.com

Please report all bugs and feature requests through GitHub issues

Follow us on GitHub, Twitter, Facebook, Google+, and YouTube.

Help fund us on:

INDIEGOGO

Find us on:

Download .zip file

Download .tar.gz file

Is maintained by ProjectPAM.

This page was generated by GitHub Pages using the Architect theme by Jason Long.

9.6.3 SOFTWARE PAGE

9.6.4 GOOGLE ANALYTICS REPORTS

Google Analytics

Project PAM GitHub - http://projectpa... Go to this report
All Web Site Data

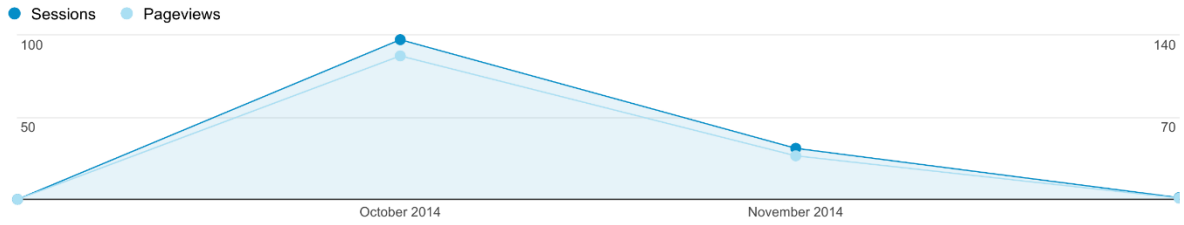
Audience Overview

Sep 1, 2014 - Dec 2, 2014

All Sessions
100.00%

+ Add Segment

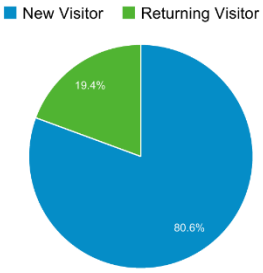
Overview



Sessions	Users	Pageviews
129	104	160

Pages / Session	Avg. Session Duration	Bounce Rate
1.24	00:00:42	83.72%

% New Sessions
80.62%



	Language	Sessions	% Sessions
1.	en-us	80	62.02%
2.	zh-cn	14	10.85%
3.	en-gb	5	3.88%
4.	de	4	3.10%
5.	it	4	3.10%
6.	ca	3	2.33%
7.	es-es	3	2.33%
8.	fr	2	1.55%
9.	it-it	2	1.55%
10.	ja	2	1.55%

Google Analytics

Project PAM GitHub - http://projectpa...
All Web Site Data

Go to this report

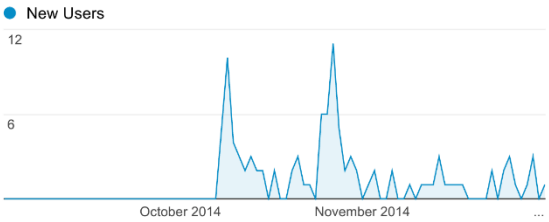
My Dashboard

Sep 1, 2014 - Dec 2, 2014

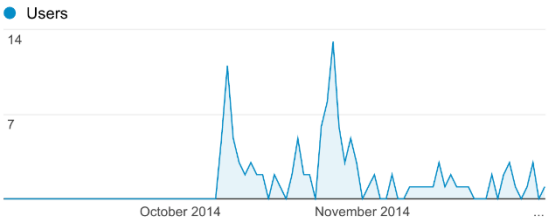
All Sessions
100.00%

+ Add Segment

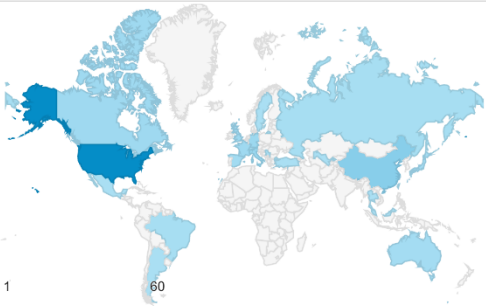
New Users



Users



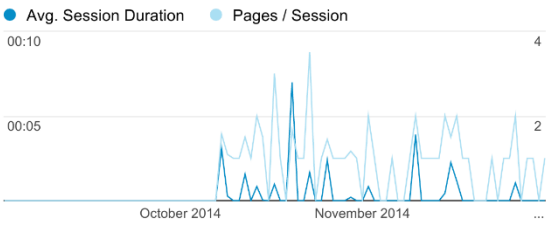
Sessions



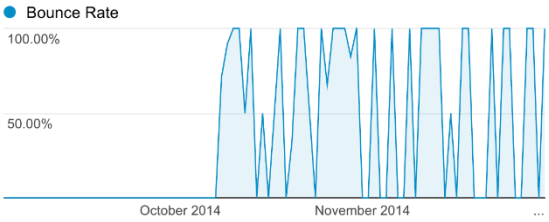
Sessions by Browser

Browser	Sessions
Chrome	78
Firefox	29
Internet Explorer	10
Safari	10
"Mozilla	1
Opera	1

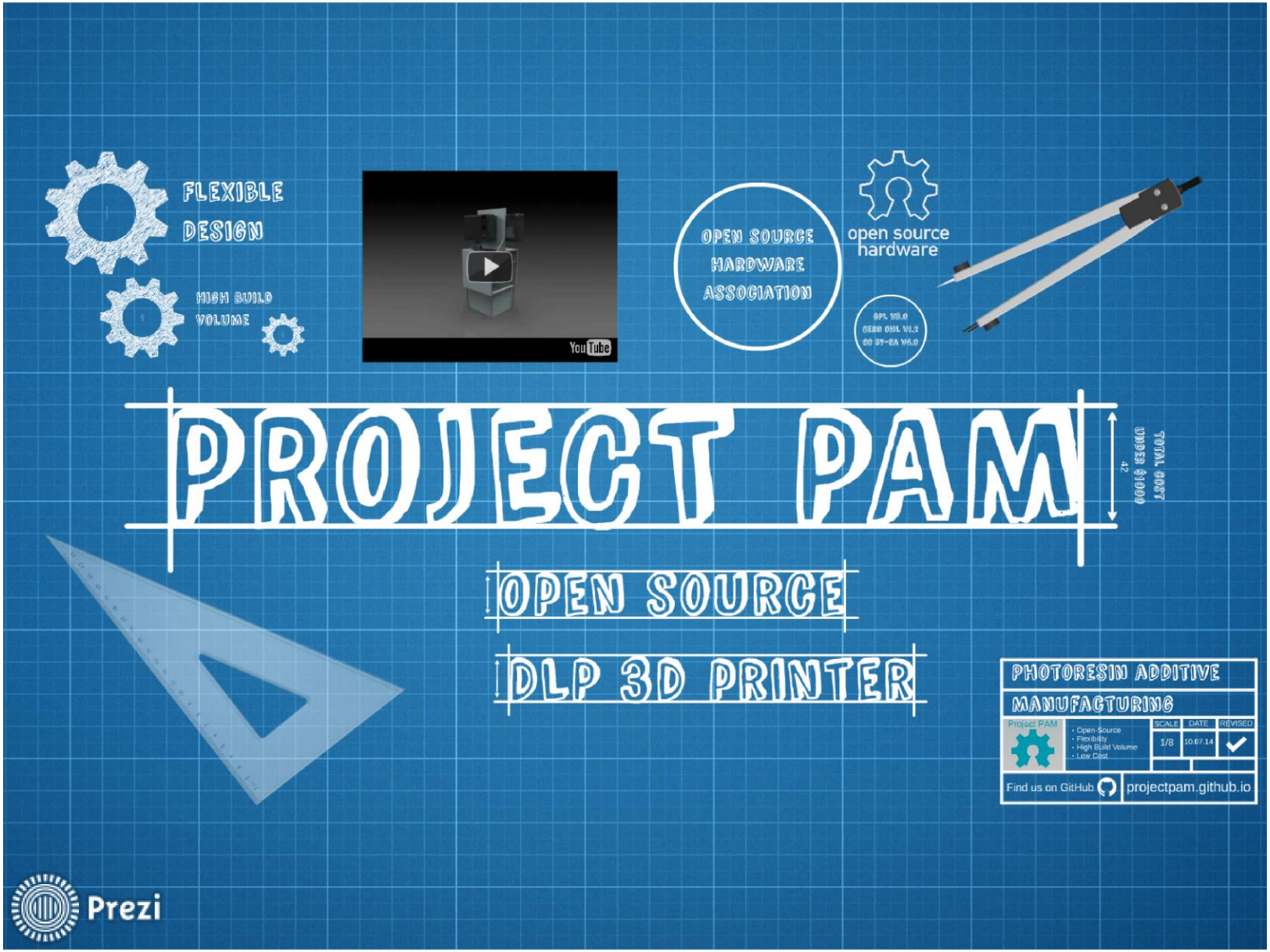
Avg. Session Duration and Pages / Session

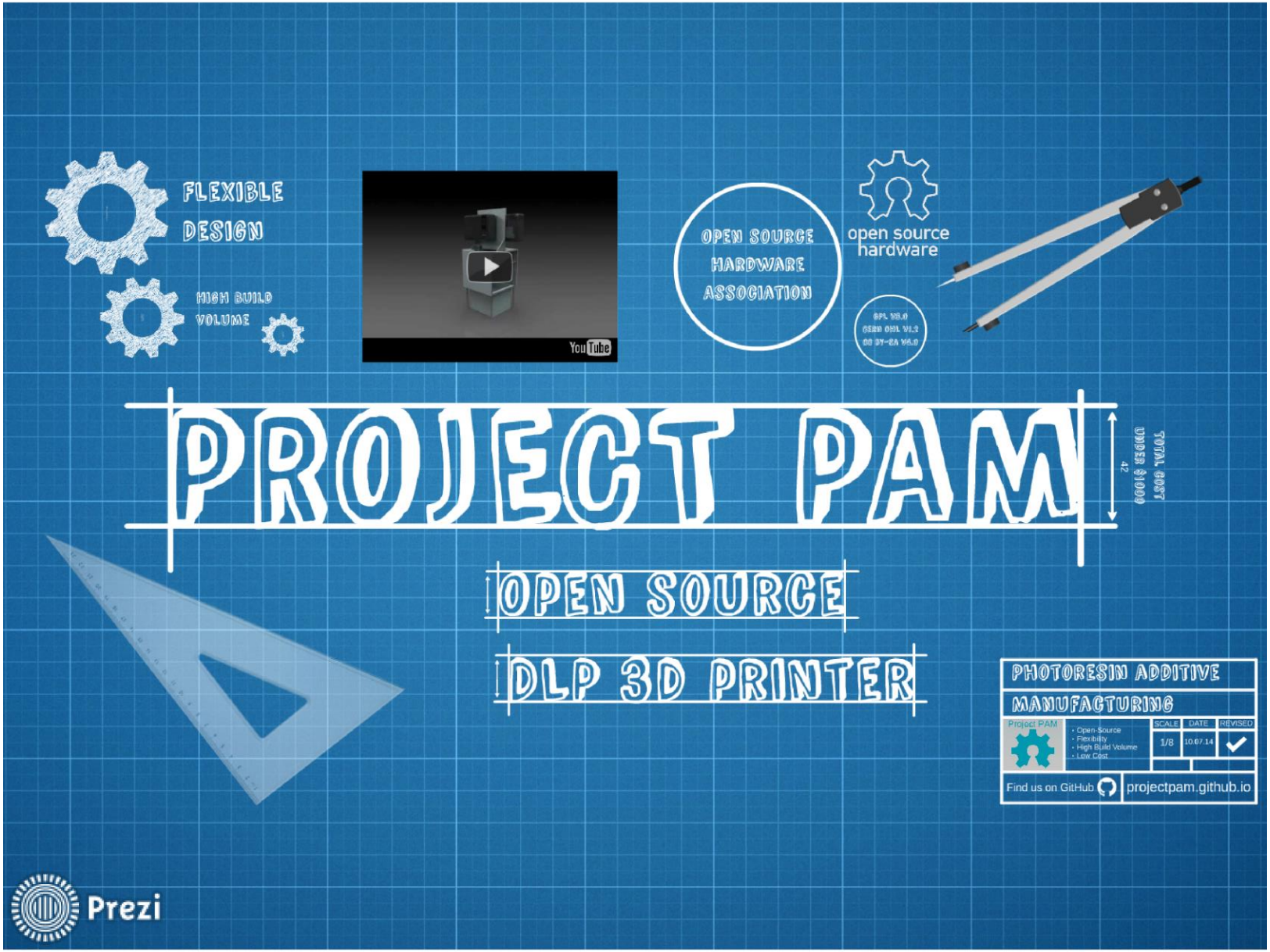


Bounce Rate



9.7 PROJECT PAM PREZI


FLEXIBLE
DESIGN
HIGH BUILD
VOLUME
YouTube
OPEN SOURCE
HARDWARE
ASSOCIATION
open source
hardware
PROJECT PAM
TOTAL COST
UNDER $1000
42
OPEN SOURCE
DLP 3D PRINTER
PHOTORESIN ADDITIVE
MANUFACTURING
Project PAM
• Open-Source
• Flexibility
• High Build Volume
• Low Cost
SCALE
DATE
REVISED
1/8
10.07.14
Find us on GitHub
projectpam.github.io
Prezi


FLEXIBLE DESIGN
HIGH BUILD VOLUME
YouTube
OPEN SOURCE HARDWARE ASSOCIATION
open source hardware
GPL V3.0
CERN OHL V1.2
CC BY-SA V4.0
PROJECT PAM
TOTAL COST UNDER $1000
42
OPEN SOURCE
DLP 3D PRINTER
PHOTORESIN ADDITIVE MANUFACTURING
Project PAM
• Open-Source
• Flexibility
• High Build Volume
• Low Cost
SCALE
DATE
REVISED
1/8
10.07.14
Find us on GitHub
projectpam.github.io
Prezi

PHOTORESIN ADDITIVE MANUFACTURING

Project PAM

- Open-Source
- Flexibility
- High Build Volume
- Low Cost

SCALE	DATE	REVISED
1/8	10.07.14	✓

Find us on GitHub 

projectpam.github.io

Prezi

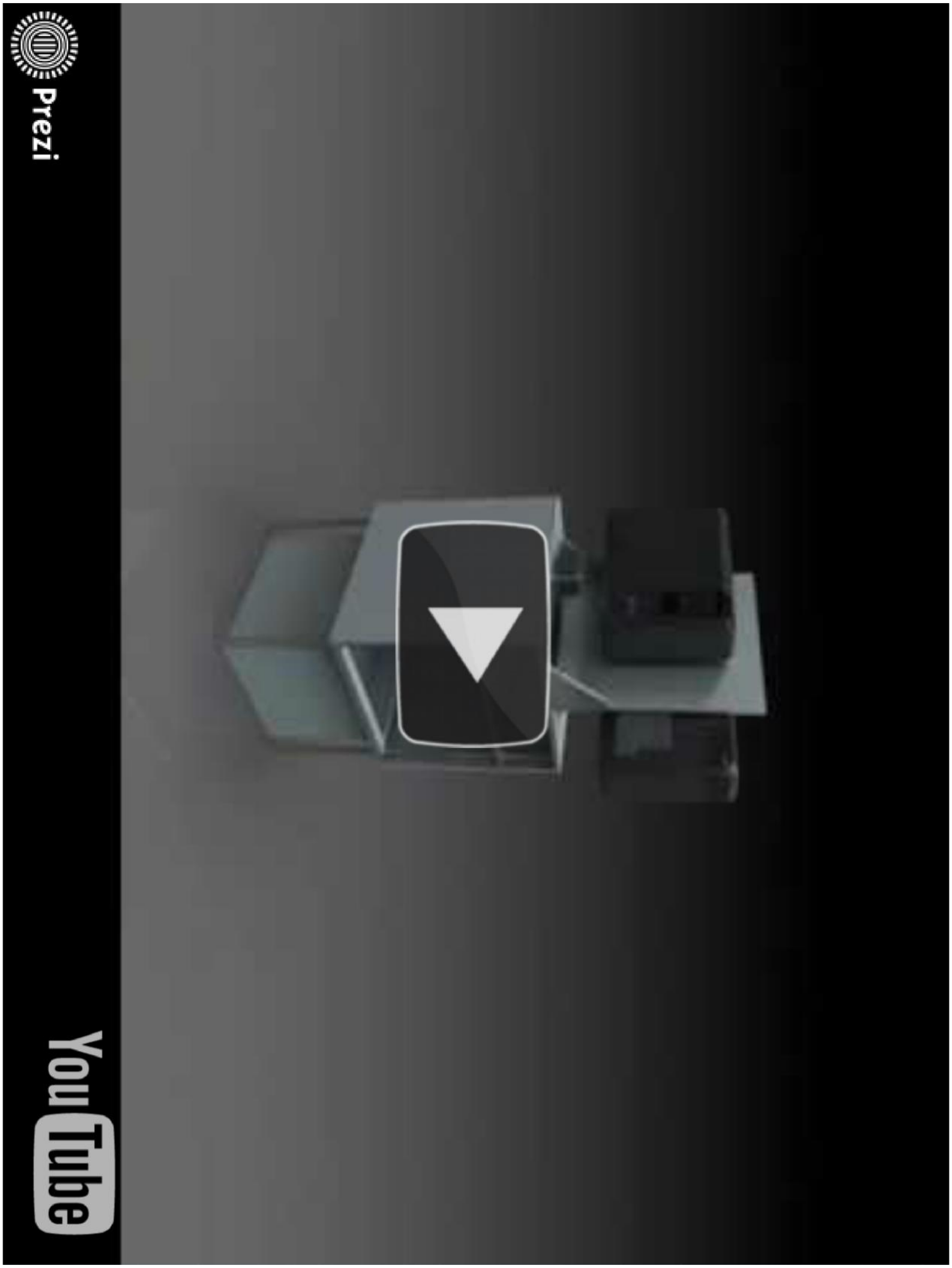
MANUFACTURIN

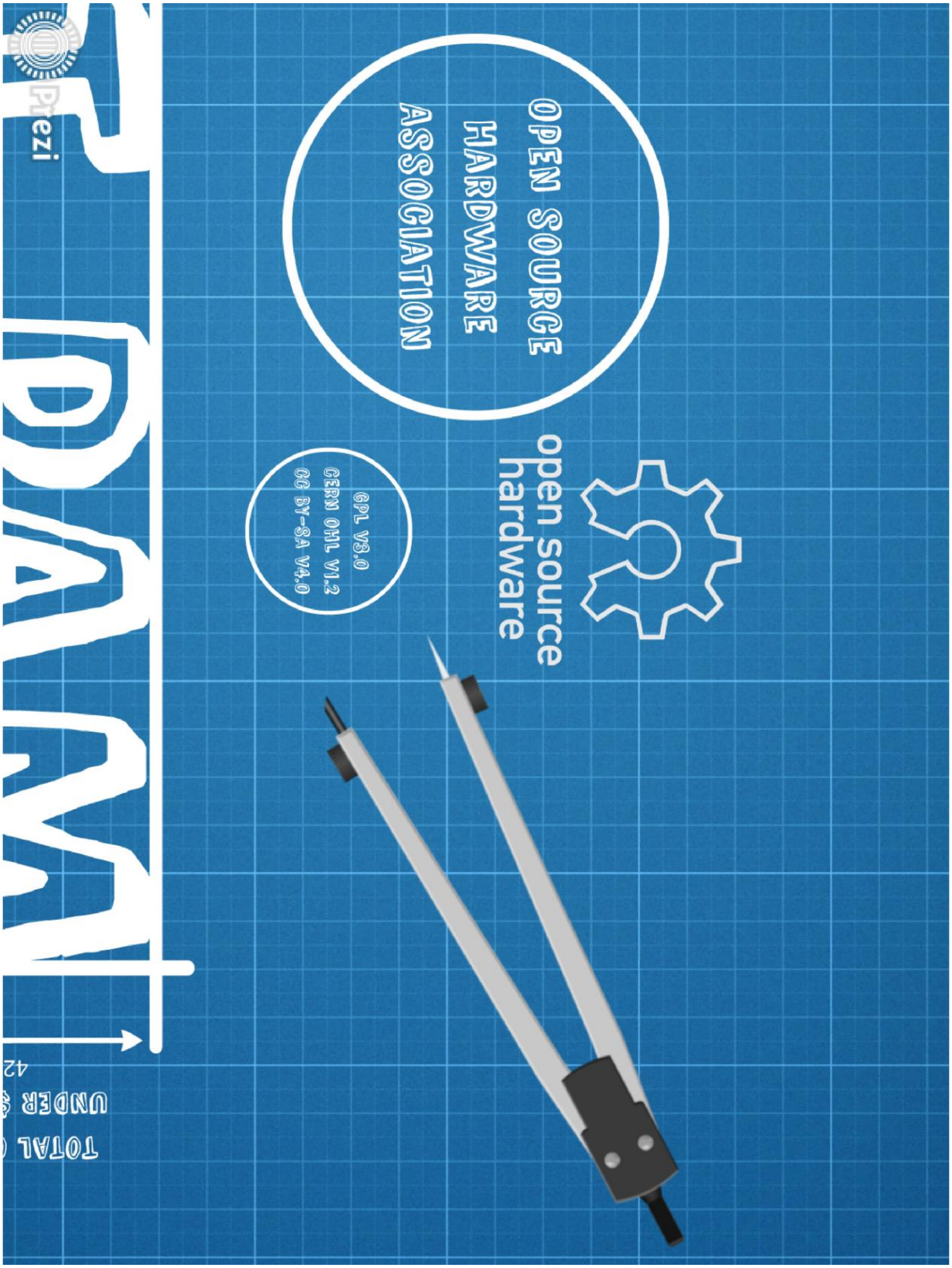
Project PAM

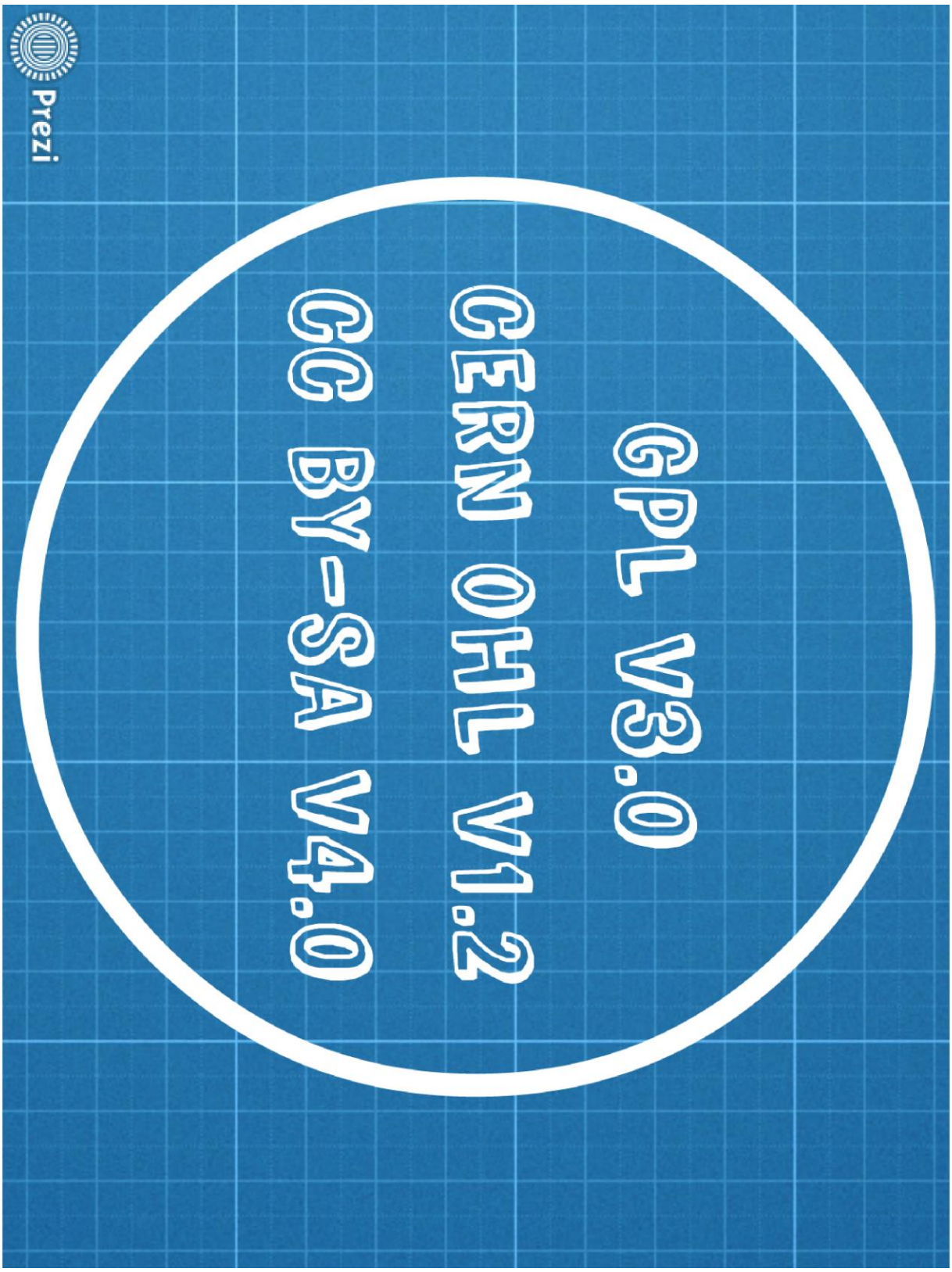
- Open-Source
- Flexibility
- High Build Volume
- Low Cost

Find us on GitHub

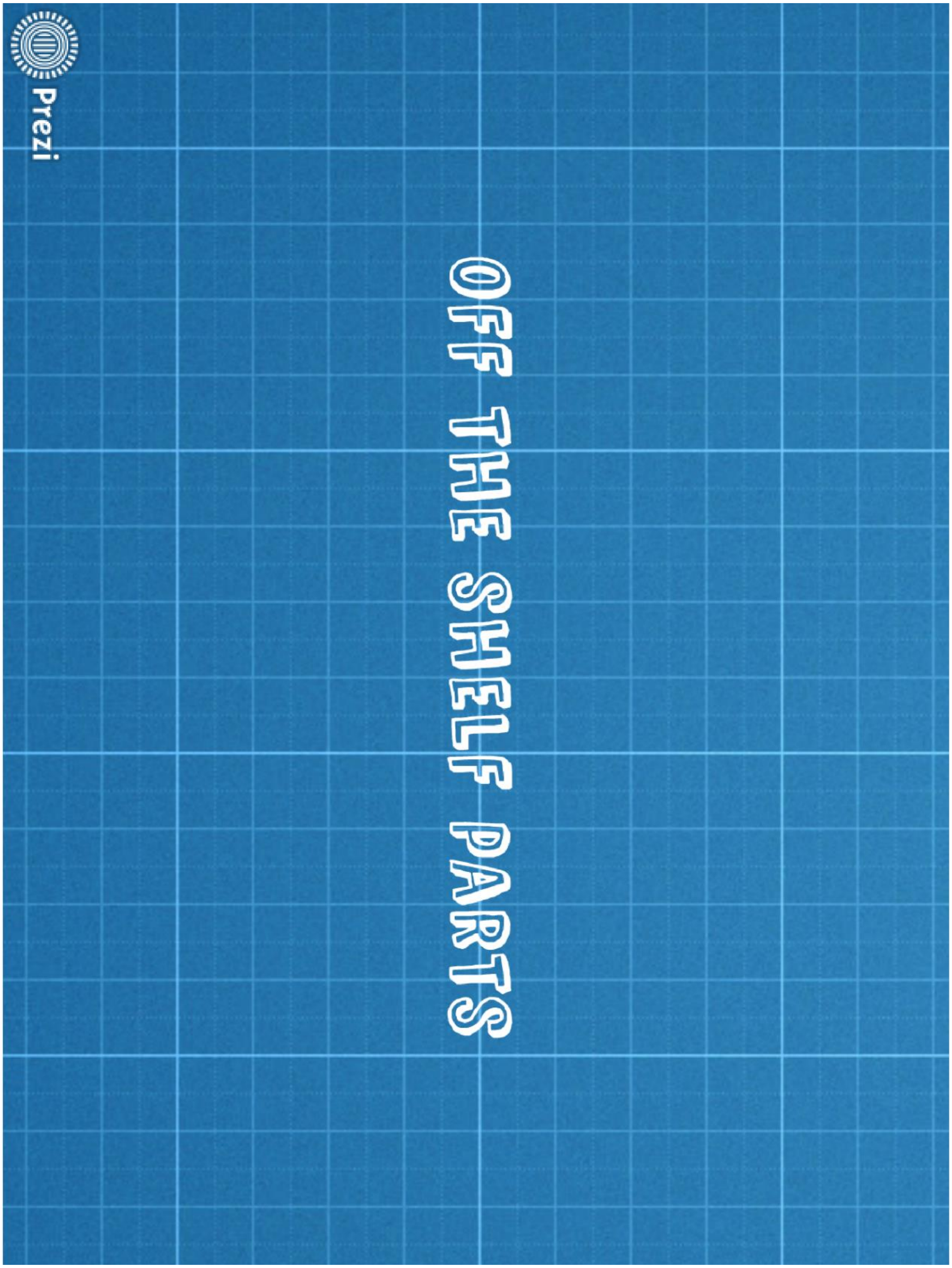
proje

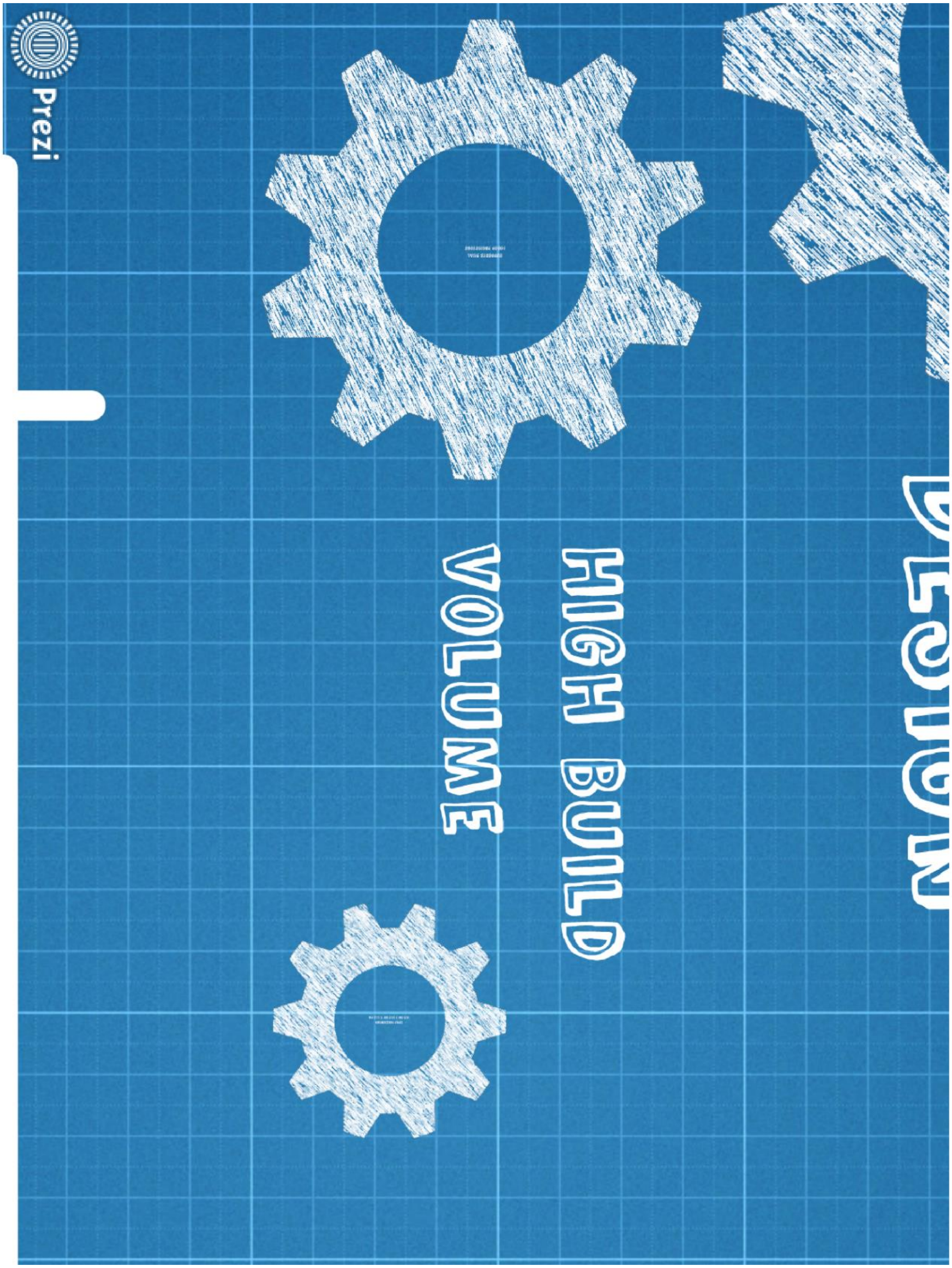

Prezi
YouTube

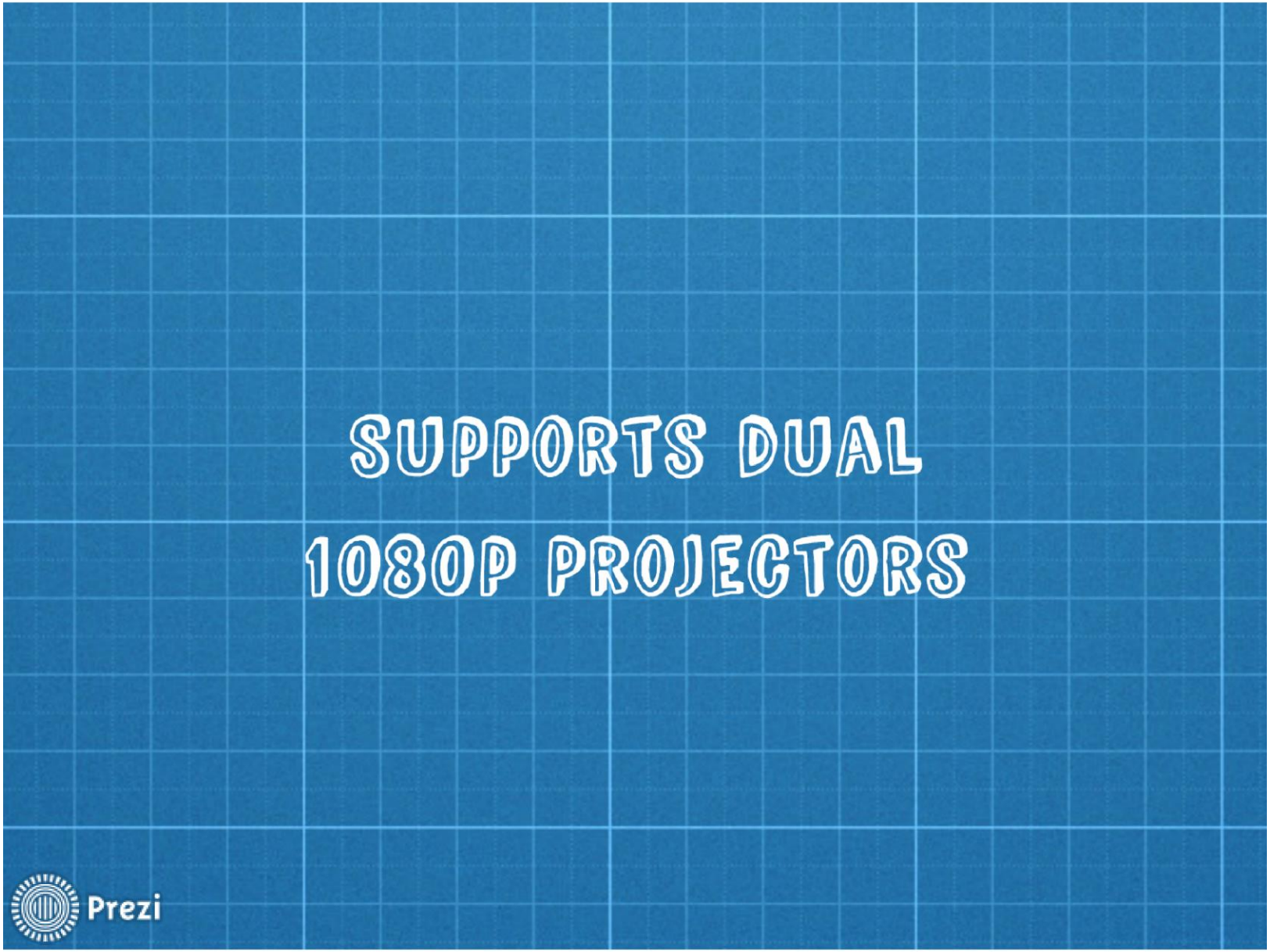

OPEN SOURCE
HARDWARE
ASSOCIATION
open source
hardware
GPL V3.0
CERN OHL V1.2
CC BY-SA V4.0
Prezi

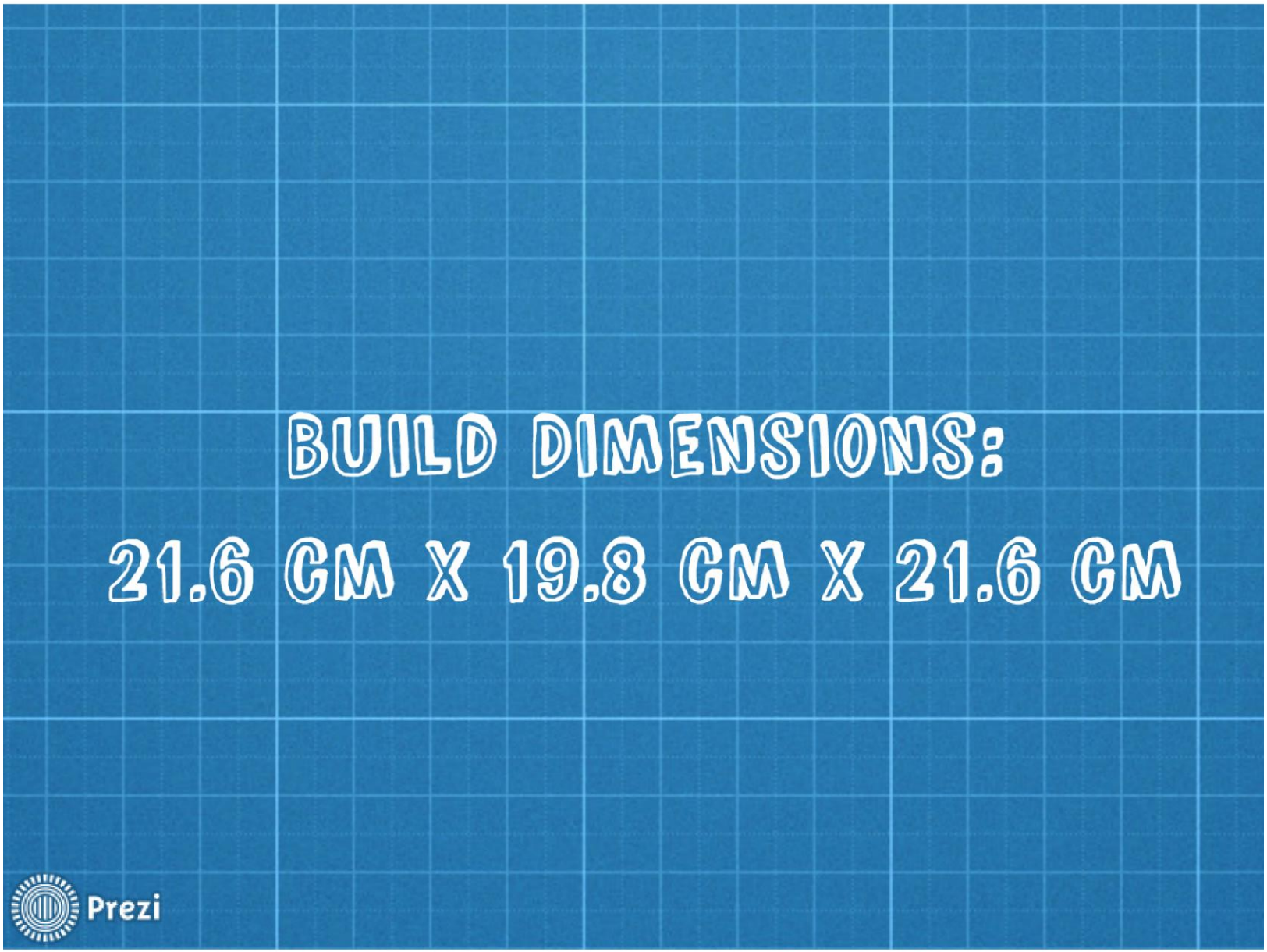

Prezi
GPL V3.0
CERN OHL V1.2
CC BY-SA V4.0


Prezi
FLEXIBLE
DESIGN
HIGH BUILD

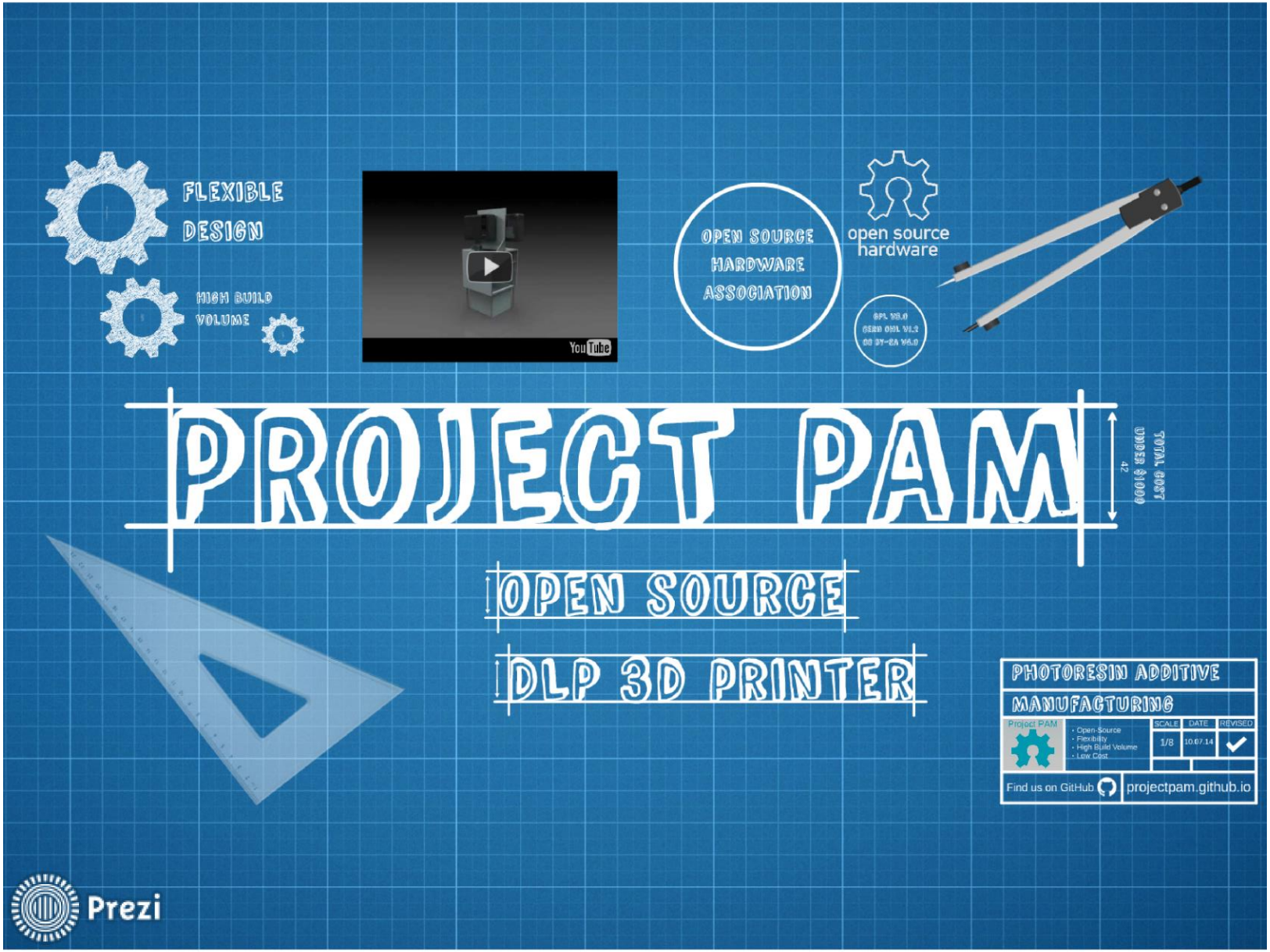

Prezi
OFF THE SHELF PARTS


Prezi
HIGH BUILD
VOLUME


SUPPORTS DUAL
1080P PROJECTORS
Prezi


BUILD DIMENSIONS:
21.6 CM X 19.8 CM X 21.6 CM
Prezi


TOTAL COST
UNDER $1000
42
Prezi


FLEXIBLE
DESIGN
HIGH BUILD
VOLUME
YouTube
OPEN SOURCE
HARDWARE
ASSOCIATION
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PROJECT PAM
TOTAL COST
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SCALE
DATE
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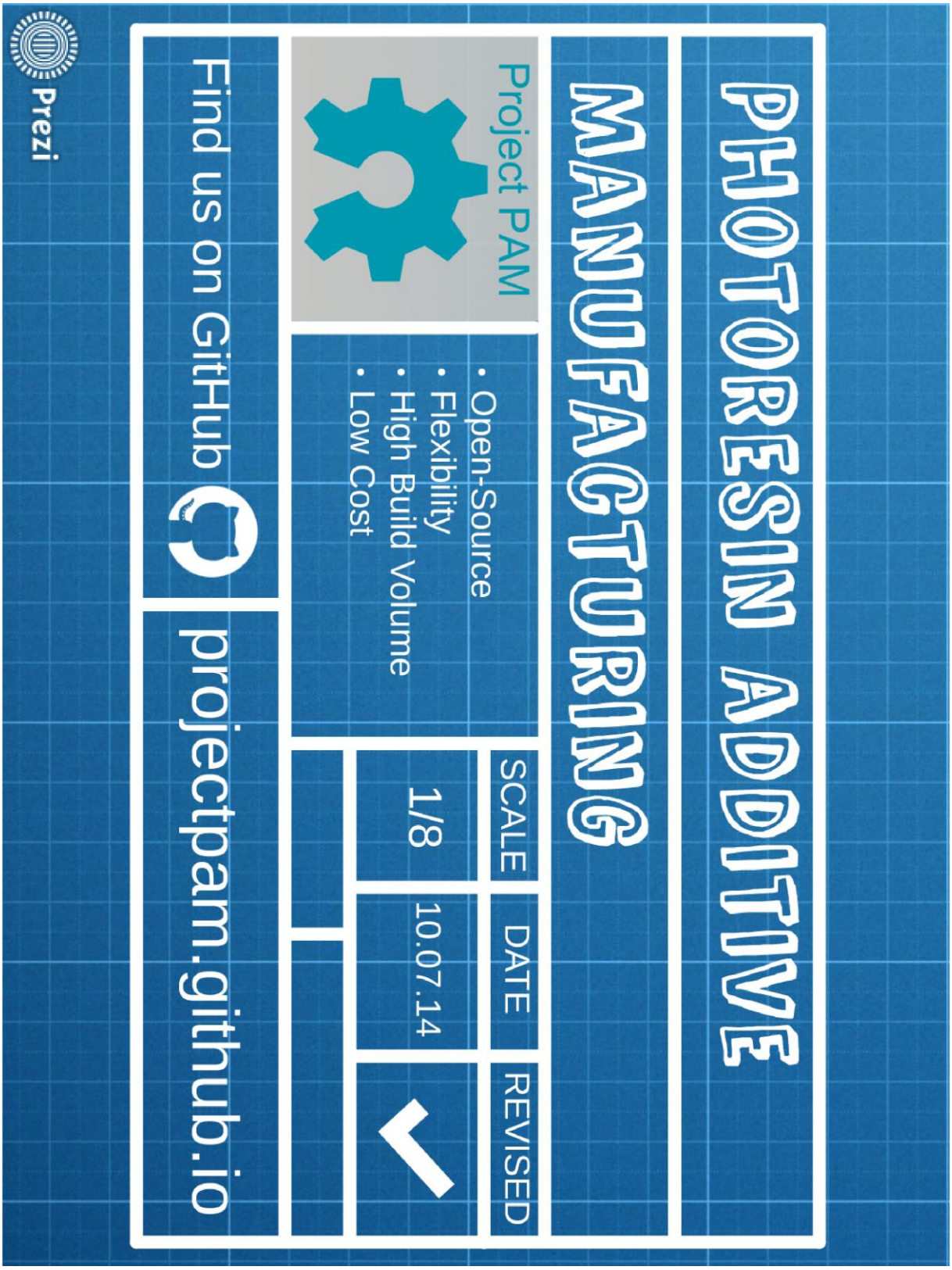


9.8 INDIEGOGO

9.8.1 STORY

Project PAM

Story | Updates 0 | Comments 0 | Funders 11 | Gallery 4

The world's first open source hardware DLP 3D printer.

Carbondale, Illinois, United States Technology

Welcome to Project PAM.

We are a team of undergraduate engineering students working on a Senior Design Project at Southern Illinois University Carbondale. We have great passion for advancing the open source and 3D printing community. Project PAM is hosted on GitHub at projectpam.github.io.

PAM stands for Photoresin Additive Manufacturing. This type of 3D printing gets away from the extruding spaghetti machines we're all familiar with and instead uses light-curing resins to build your models. This means higher resolution, fewer moving parts, and faster build times. The only jam to worry about is the kind you eat with peanut butter.

The goal for this project is to produce a high resolution DLP printer which is fully open sourced using available or easy to fabricate hardware in a flexible, well documented design. Project PAM takes DLP 3D printing in a new direction.

$741 USD
RAISED OF $2,500 GOAL

30% 0 time left

This campaign started on Sep 30 and closed on October 28, 2014 (11:59pm PT).

Flexible Funding

CAMPAIGN CLOSED
This campaign ended on October 28, 2014

SELECT A PERK

$5 USD

Thank You

For contributing $5.00 or more you will receive a personalized thank you email from the team and you will be immortalized as a funder on our website.

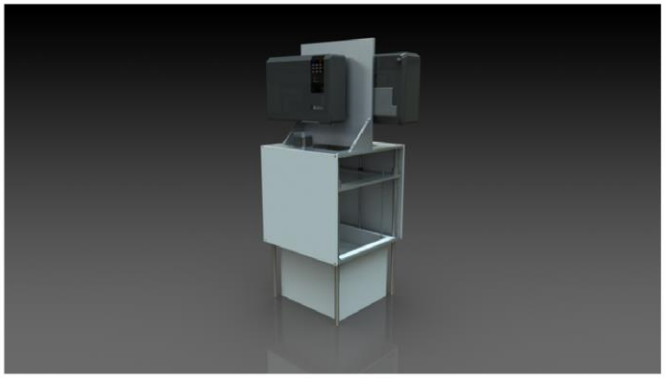
0 claimed

$25 USD

Key Chains

For a contribution of $25.00 or more you will receive one Open Source Hardware Association logo key chain AND one Open Source Initiative logo key chain. Our intent is to 3D print these key chains with the Project PAM prototype.

providing the largest build area of any hobbyist DLP 3D printer on the market without sacrificing resolution.



Crowdsourcing

Project PAM is a Senior Design Project that has been funded in part by the SIU Engineering Departments. However, they are not capable of providing any additional funds to allow us to complete a working prototype. With the Departments help and support we are asking the community to help us successfully build and fully test a reference design. This prototype will showcase a hardware configuration which proves our design and provides the community with a complete and fully capable DLP 3D printing solution. Any left over funds will go towards creating a student makerspace within the SIU College of Engineering.

We would like to express our appreciation to our donors through the time honored crowdfunding tradition of perks. Our tiers include 3D printed keychains, bound prints of documentation and plans (on paper), up to a full unassembled hardware kit. The unassemmbled hardware kit will include the chassis, all linear motion parts, a resin vat, all electronics, and an enclosure. Basically all parts excluding projector(s). Our eventual goal for the project is for this hardware to be less than $1000 for consumers to assemble. Our perk point for this kit is $1500 to include money for prototyping, testing, and iterating our hardware design. This is the intention of this campaign, after all!

Why Open Source?

Our first priority when starting out was to keep everything open-source; this includes both hardware and software. To ensure this, we have followed the Open Source Hardware (OSHW) Definition set by the Open Source Hardware Association (OSHA).

Open Source Hardware (OSHW) Statement of Principles 1.0:

Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it. Ideally, open source hardware uses readily-available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware. Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.

(Additional cost of $10 for international shipping.)

Estimated delivery: **January 2015**

7 claimed

$250 USD

Bound Documentation of Design

For a contribution of $250.00 or more you will receive all documentation associated with the design professionally bound and well presented. Also includes $25 perk. (Additional cost of $50 for international shipping.)

Estimated delivery: **January 2015**

1 claimed

$1,500 USD

Full Kit and Documentation

For a contribution of $1,500.00 or more you will receive a full unassembled build kit for the printer. (The kit does not include projectors.) Also includes $25 perk and $250 perk. (Additional cost of $300 for international shipping.)

Estimated delivery: **January 2015**

0 claimed

Do you think this campaign contains prohibited content? Let us know.

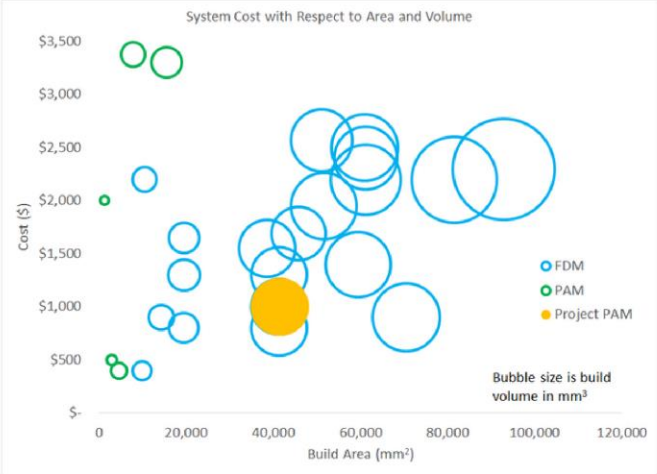
The licenses Project PAM use are:

- Hardware: CERN OHL v1.2
- Software: GNU GPL 3.0
- Documentation: CC BY-SA 4.0

Many DLP 3D printers claim to be open source, yet have patents associated to the design, non-commercial licensing, or do not properly host and share their designs.

Tired of Those Stupid Spaghetti Machines?

Photoresin additive manufacturing printers have many advantages over fused deposition manufacturing (FDM) printers. There are fewer moving parts, faster build times, and no jams. Currently there are DLP 3D printers on the market; however, most have either high cost or small build volumes. Our design is low cost ($1000) and also features a build volume comparable to leading FDM printers.



How is our design more flexible?

Project PAM has a max build volume of just under 9 liters. We are able to accomplish this by supporting dual 1080p projectors; however, the system is designed to be compatible with projectors of any resolution and also a single projector.

Maximum build dimensions:

- X: 21.6 cm
- Y: 19.8 cm
- Z: 21.6 cm
- Volume: 9 L

We have designed Project PAM to use mostly off-the-shelf parts that can be bought through Adafruit, Amazon, and industrial supply warehouses. An advantage to using off-the-shelf parts is that the design can be easily modified to suit any needs. One aspect that can be easily modified is the size of the build table and resin vat.

We have also used the off-the-self mentality when it comes to the resins we use through the use of Maker Juice G+ resin.

Our hardware design should be compatible with some currently available software

and firmware. For our reference design we will be forking software from B9 Creations. This fork will be compatible with as compatible as possible with available projectors and resins. We will be using Grbl firmware for motion control in our reference design. If funds allow, we intend on incorporating H-bridge hardware compatibility into our Grbl implementation. This would allow our reference design to be compatible with many more motor controllers.

Featured On

3DPrint.com: Project PAM – College Students Look to Create an Entirely Open Source DLP 3D Printer

3DPrintingIndustry.com: Help The Open Sourced DLP 3D Printer called Project Pam on Indiegogo?

WSIU: SIU Engineering Students Use Crowdfunding for 3D Printer

Contact Us

For general correspondence please email us at projectpam.siu@gmail.com

Questions and comments can be posted on our mailing list or you can email them to projectpam@googlegroups.com.

Follow us on GitHub, Twitter, Facebook, Google+, and YouTube.

Find This Campaign On

Facebook Twitter YouTube Website

Team

Jeffrey Burdick
Project Manager

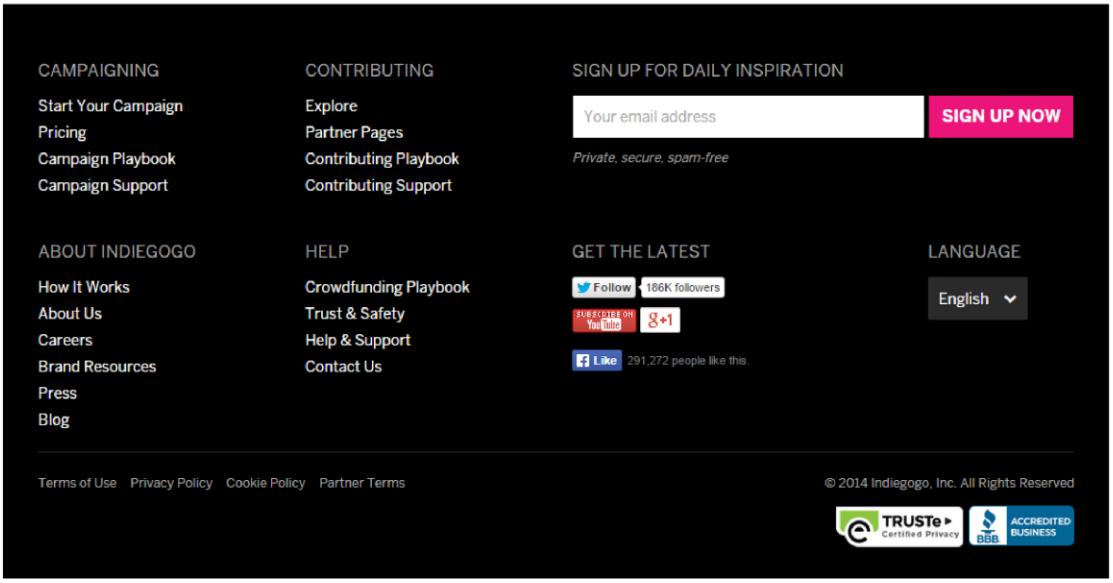
Daniel Olsen
Computer Engineer
VERIFIED

Casey Spencer
Electrical Engineer
VERIFIED

Chance Baker
Electrical Engineer

Nick Lowman
VERIFIED

Nathaniel Tyler
VERIFIED



9.8.2 FUNDERS

Project PAM

Story | Updates 0 | Comments 0 | Funders 11 | Gallery 4

sophie10130	1 month ago	$30 USD
Patricia Townsend	1 month ago	$100 USD
Anonymous	1 month ago	$250 USD
Laura Morgan	1 month ago	$25 USD
olivia.dalby92	1 month ago	$25 USD
daveo.olsen	1 month ago	$50 USD
cjlahue	1 month ago	$25 USD
gcolbourn	2 months ago	$35 USD
rmpoole	2 months ago	$100 USD

$741 USD
RAISED OF $2,500 GOAL

30% 0 time left

This campaign started on Sep 30 and closed on October 28, 2014 (11:59pm PT).

Flexible Funding

CAMPAIGN CLOSED
This campaign ended on October 28, 2014

SELECT A PERK

$5 USD

Thank You

For contributing $5.00 or more you will receive a personalized thank you email from the team and you will be immortalized as a funder on our website.

0 claimed

$25 USD

Key Chains

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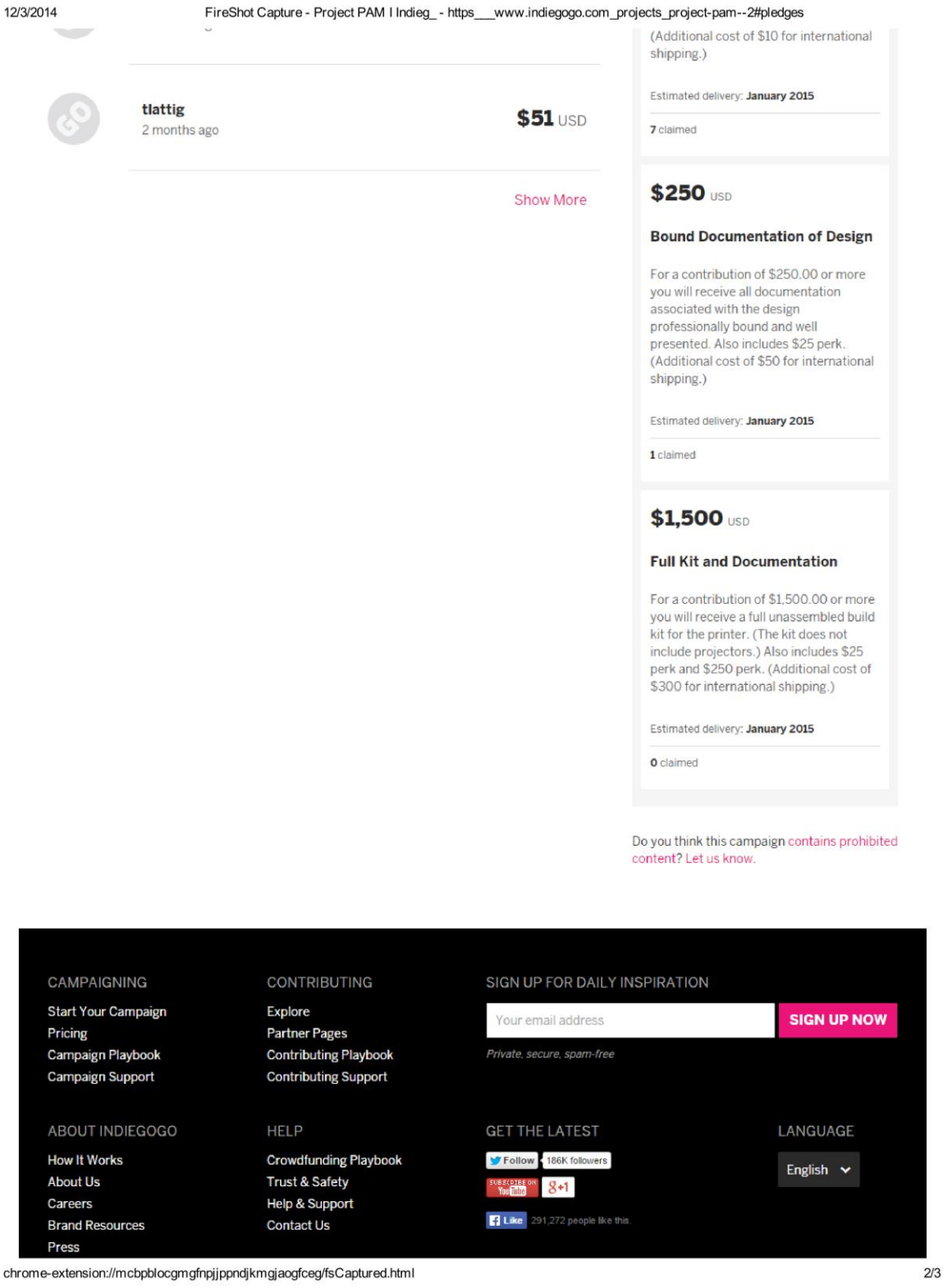
12/3/2014
FireShot Capture - Project PAM I Indieg_ - https___www.indiegogo.com_projects_project-pam--2#pledges
(Additional cost of $10 for international shipping.)
Estimated delivery: January 2015
7 claimed
tlattig
2 months ago
$51 USD
Show More
$250 USD
Bound Documentation of Design
For a contribution of $250.00 or more you will receive all documentation associated with the design professionally bound and well presented. Also includes $25 perk. (Additional cost of $50 for international shipping.)
Estimated delivery: January 2015
1 claimed
$1,500 USD
Full Kit and Documentation
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Estimated delivery: January 2015
0 claimed
Do you think this campaign contains prohibited content? Let us know.
CAMPAIGNING
Start Your Campaign
Pricing
Campaign Playbook
Campaign Support
CONTRIBUTING
Explore
Partner Pages
Contributing Playbook
Contributing Support
SIGN UP FOR DAILY INSPIRATION
Your email address
SIGN UP NOW
Private, secure, spam-free
ABOUT INDIEGOGO
How It Works
About Us
Careers
Brand Resources
Press
HELP
Crowdfunding Playbook
Trust & Safety
Help & Support
Contact Us
GET THE LATEST
Follow 186K followers
+1
Like 291,272 people like this.
LANGUAGE
English
chrome-extension://mcbpblocgmgfnpjjppndjkmgjaogfceg/fsCaptured.html
2/3

9.8.3 GALLERY

Project PAM

Story | Updates 0 | Comments 0 | Funders 11 | Gallery 4

Video Gallery

Image Gallery

$741 USD
RAISED OF $2,500 GOAL

30% 0 time left

This campaign started on Sep 30 and closed on October 28, 2014 (11:59pm PT).

Flexible Funding

CAMPAIGN CLOSED
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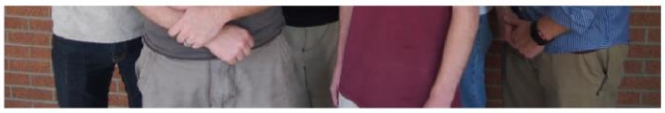

(Additional cost of $10 for international shipping.)

Estimated delivery: **January 2015**

7 claimed

$250 USD

Bound Documentation of Design

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1 claimed

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Estimated delivery: **January 2015**

0 claimed

Do you think this campaign contains prohibited content? Let us know.

CAMPAIGNING

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Pricing
Campaign Playbook
Campaign Support

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Partner Pages
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Contributing Support

SIGN UP FOR DAILY INSPIRATION

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Private, secure, spam-free

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Brand Resources
Press

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Crowdfunding Playbook
Trust & Safety
Help & Support
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Follow 186K followers

SUBSCRIBE ON YouTube +1

Like 291,272 people like this.

LANGUAGE

English

9.9 SOCIAL MEDIA PAGES

9.9.1 TWITTER PAGE

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Have an account? Log in

Project PAM

TWEETS 58 | FOLLOWING 34 | FOLLOWERS 16 | FAVORITES 5

Follow

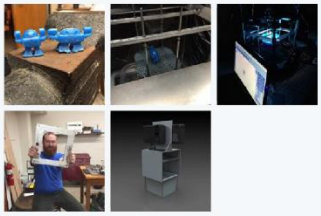
Project PAM
@ProjectPAM

The world's first open source hardware DLP 3D printer

Carbondale, IL

projectpam.github.io

6 Photos and videos



Tweets | Tweets & replies | Photos & videos

Project PAM @ProjectPAM · Nov 27

First two prints. First one on the right (we had a aspect ratio problem) second one on left. Already looking better!

View more photos and videos

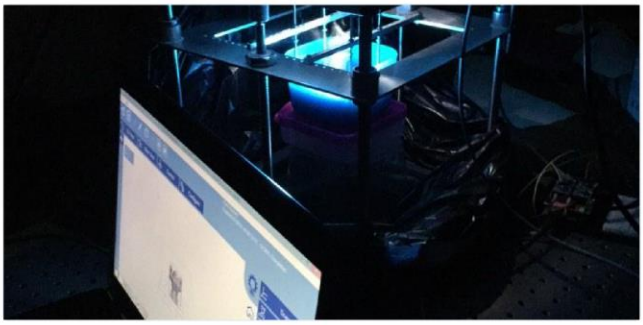
Project PAM @ProjectPAM · Nov 27

First print done!

View more photos and videos

Project PAM @ProjectPAM · Nov 27

Our first test print in progress!



View more photos and videos

Project PAM @ProjectPAM · Nov 13

Top chassis plate machined!

View more photos and videos

Project PAM @ProjectPAM · Oct 30

Help make it happen for NASA Rover Challenge, SIUC Design Team on @indiegogo igg.me/p/988827/twtr/…

View summary

Project PAM @ProjectPAM · Oct 28

SIU students create open source 3-D printer - dailyegyptian.com/?p=115679

1

There's less than 12 hours left for Project PAM on @indiegogo igg.me/p/952142/twtr/…

View summary

Project PAM @ProjectPAM · Oct 26

Cool Crowdfunding: October 26, 2014: wp.me/p22K2I-1ToP via @make

1

View summary

Project PAM retweeted

ISTCoalition @ISTCoalition · Oct 16

Engineering students at @SIUC use crowdfunding for #3Dprinter cc: @ProjectPam via @WSIURadio ow.ly/CSIOa

1 1

Project PAM @ProjectPAM · Oct 8

Hey @MattStultz. Help make it happen for Project PAM - The World's First Open Source DLP 3D Printer on @indiegogo igg.me/p/952142/twtr/…

1

View summary

Project PAM retweeted

Crowd Funding @fundmycampaign · Oct 7

Help make it happen for Project PAM on @indiegogo igg.me/p/952142/twtr/…

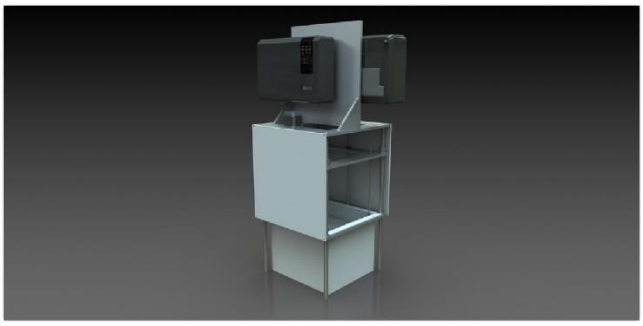
1 1

View summary

Project PAM retweeted

3D Print .com @3DPrintBoard · Oct 2

Project PAM - College Students Look to Create an Entirely Open Source DLP 3D Printer - 3dprint.com/17504/project-…



3 3

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Project PAM retweeted

3D Printing Industry @3dprintindustry · Oct 2

Engineering students want to crowd fund their fully open sourced DLP #3Dprinterhttp://bit.ly/1vbnks9 via @3dprintindustry @ProjectPAM

3 1

Project PAM retweeted

MakerJuice @MakerJuice · Oct 1

Check out Project PAM, an open source DLP printer by students at Southern Illinois University Carbondale: indiegogo.com/projects/proje…

1 2 View summary

Project PAM retweeted

Semi-Utilitronic @SemiU_co_uk · Oct 3

Awesome large-build-volume OSHW DLP printer - Help make it happen for Project PAM igg.me/p/project-pam-… #indiegogo via @indiegogo

1 1 View summary

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1

Project PAM @ProjectPAM · Oct 1

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View conversation

Project PAM followed All Tech Considered, LulzBot, you3Dit and 11 others

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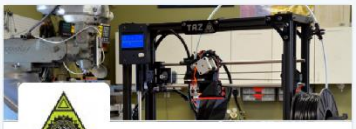
NPR's exploration of technology and digital culture, on-air and online.



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LulzBot

@lulzbot3D

LulzBot Libre / Open Source Hardware 3D printers, parts, and filaments are designed, manufactured, and sold by Aleph Objects, Inc.

Project PAM @ProjectPAM · Sep 30

Help fund Project PAM on @indiegogo igg.me/p/952142/twtr/…

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Project PAM @ProjectPAM · Sep 18

Project PAM Promo
youtu.be/zL18pSLKOzU?a

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Project PAM @ProjectPAM · Sep 16

The first render of Project PAM.
youtube.com/watch?v=nInJxA…

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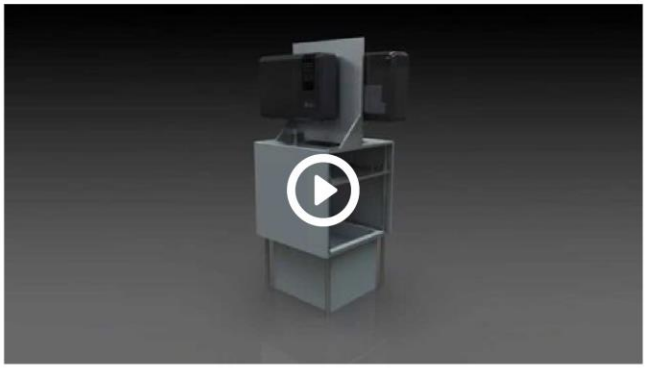

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ABOUT

The world's first open source hardware DLP 3D printer

http://projectpam.github.io/

PHOTOS

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Project PAM
November 27

First two prints. First one on the right (we had a aspect ratio problem) second one on left. Already looking better! http://t.co/Pw7pDZBLkB

Project PAM (@ProjectPAM) posted a photo on Twitter
pic.twitter.com
Get the whole picture - and other photos from Project PAM

Like · Comment · @ProjectPAM on Twitter · Share

Justin Steele, Kathy Olsen and Josh Cozart like this.

Project PAM
November 27

First print done! http://t.co/XbheCV0kD0

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Jean Powers and Kathy Olsen like this.

Project PAM
November 27

Our first test print in progress! http://t.co/E1weWiCOXf

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pic.twitter.com
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Project PAM
November 13

Top chassis plate machined! http://t.co/xpFmlo2FT6

Project PAM (@ProjectPAM) posted a photo on Twitter
pic.twitter.com
Get the whole picture - and other photos from Project PAM

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Project PAM
October 30

Help make it happen for NASA Rover Challenge, SIUC Design Team on @indiegogo http://t.co/pbma90Is1p

NASA Rover Challenge, SIUC Design Team
igg.me
An off road vehicle built by engineering students to compete in a NASA's rover challenge.

Like · Comment · @ProjectPAM on Twitter · Share

Project PAM
October 28

SIU students create open source 3-D printer - http://t.co/Y34G9PX5Yi

SIU students create open source 3-D printer - The Daily Egyptian
dailyegyptian.com
Imagine being able to create an object out of thin air. Whether it is a new car, shoes or cell phone, a group of SIU students are working on

Like · Comment · @ProjectPAM on Twitter · Share

Project PAM
October 28

There's less than 12 hours left for Project PAM on @indiegogo http://t.co/3obojpMzAV

Project PAM
igg.me
The world's first open source hardware DLP 3D printer.

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Project PAM
October 26

Cool Crowdfunding: October 26, 2014: http://t.co/0CEgzJmwCS via @make

Cool Crowdfunding: October 26, 2014
wp.me
Project PAM, an open source DLP based 3D printer View on Indiegogo MeU Open Source wearable display View on Indiegogo Nanobeam View on Kickstartter ibox nano 3D printer View on Kickstartter Electri...

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Project PAM
October 8

Hey @MattStultz. Help make it happen for Project PAM - The World's First Open Source DLP 3D Printer on @indiegogo http://t.co/xSLiOMwNBr

Project PAM
igg.me
The world's first open source hardware DLP 3D printer.

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Project PAM
October 2

Project PAM – College Students Look to Create an Entirely Open Source DLP 3D Printer http://t.co/GCkAGrHjyF

Project PAM – College Students Look to Create an Entirely Open Source DLP 3D Printer
3dprint.com
Open source has contributed to 3D printing in such a tremendous way. Without the open sourcing of many desktop 3D printers several years

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Project PAM
October 2

Help The Open Sourced DLP 3D Printer called Project Pam on Indiegogo? http://t.co/MzmuKy9oMc via @3dprintindustry

Open Source DLP 3D Printer Project Pam - 3D Printing Industry
3dprintingindustry.com
A team of engineering students from Southern Illinois University Carbondale need help completing their fully open sourced DLP 3D printer and so turned to crowdfunding.

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Project PAM
October 1

Thanks for the shout-out @MakerJuice! We'll be ordering a lot of resin for prints out of that gigantic #9Lvat!

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Project PAM
September 30

Help fund Project PAM on @indiegogo http://t.co/3obojpMzAV

Project PAM
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The world's first open source hardware DLP 3D printer.

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Project PAM
September 18

Project PAM Promo http://t.co/e15sI3PoZe

Project PAM Promo
youtu.be

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Project PAM
September 16

The first render of Project PAM.
https://t.co/M0u0XQQbEe

Project PAM: First Render
youtube.com
The first render of Project PAM.

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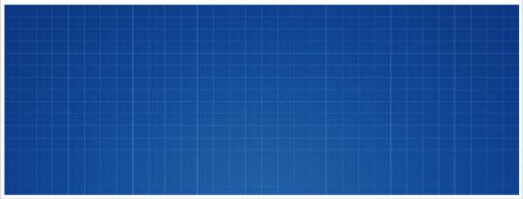
Project PAM changed their cover photo.
September 16



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Project PAM changed their profile picture.
September 5

9.10 ARTICLES PROJECT PAM WAS FEATURED IN

Webpage Screenshot

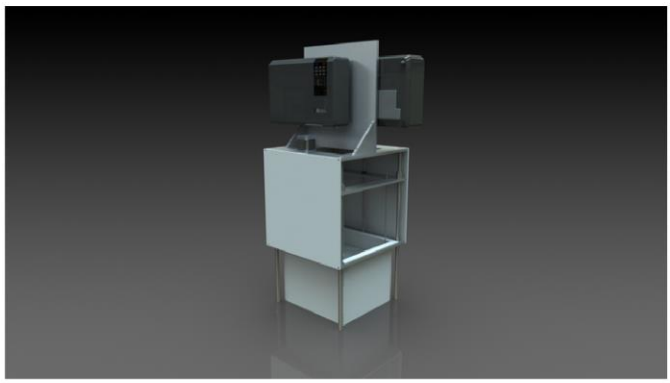
NEXT STORY
With This 3D Printed Brain, I Thee Wed – Neuroscientist Gives His Bride His Brain

PREVIOUS STORY
voxeljet Acquires 3D Printed Movie Prop Maker Propshop (Model Makers) Limited

Project PAM – College Students Look to Create an Entirely Open Source DLP 3D Printer

BY EDDIE KRASSENSTEIN · OCTOBER 2, 2014

Open source has contributed to 3D printing in such a tremendous way. Without the open sourcing of many desktop 3D printers several years ago, the space would not be nearly as advanced as it currently is. Open source allows for brilliant people to take brilliant ideas and products, and then develop them further through the implementation of their own ideas. Open sourcing is not for companies looking to make huge profits, although it definitely still remains possible. Open sourcing is meant for those individuals who believe that the ideology behind technology should be for the greater good of mankind, not for the profits on certain individuals. We have seen many companies originate as part of an open source movement, only then to slowly migrate into closing off the rights to their designs, through the filing of patents and other means.



A team of undergraduate students at Southern Illinois University (SIU) Carbondale sees open source as a way to expand the use of 3D printing to those all around the world. They set out to create what they say is the "world's first open source hardware DLP 3d printer". Whether this claim is true or not is debatable, but that's not the important part here.

Project PAM, as the group of students calls it, stands for 'Photoresin Additive Manufacturing', and it started out as a senior design project. Unfortunately for the students, the SIU Engineering Department would not provide them with the funding needed in order to create a working prototype. Because of this, they have elected to launch an Indiegogo campaign in order to raise the $2,500 needed to go forward with this project. If they are successful in gathering the funding needed, they will use it to create a prototype which showcases a hardware configuration that will hopefully prove their design works. Any funds left over will go towards hopefully creating a student makerspace at SIU.

CATEGORIES

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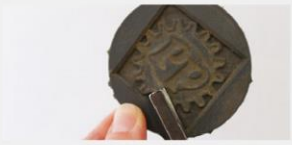
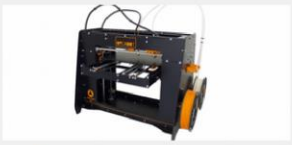
MORE ARTICLES



Proto-Pasta Announces Stainless Steel and Magnetic Iron PLA Filament for 3D Printing



Prodim International Unveils its Large Build Volume Orcabot XXL 3D Printer

Maker's Tool Works Unveils Their New MendelMax 3 3D Printer Kit

voxeljet Introduces New Phenolic-Direct-Binding 3D Printing Method

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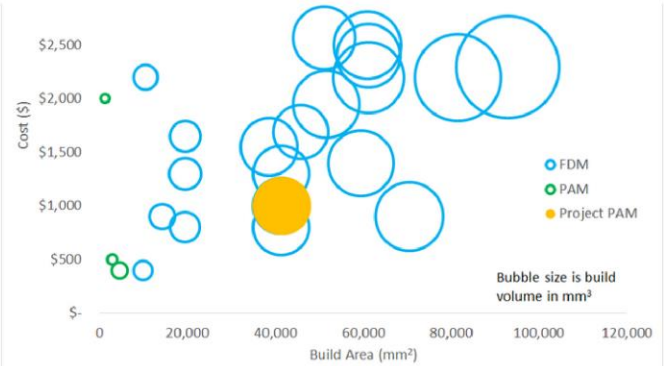
To search type and hit enter



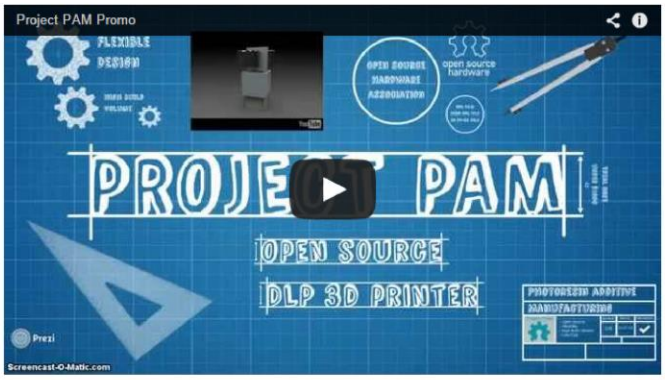
There are several tiered levels for backers to choose, ranging from $5 for a 'thank you' note, to $25 for a key chain, $250 for the complete documentation on how to create the printer from scratch, all the way up to $1500 for the full kit and documentation. The full kit will include everything needed to assemble the printer, except for the DLP projector which will need to be purchased separately from another vendor.

If all goes as planned, the team hopes to be able to create this 3D printer, release the documentation for free, and let others build upon it, to make it the best possible DLP 3D printer available. As for the open sourcing, the licenses that Project PAM uses are as follows:

- Hardware: CERN OHL v1.2
- Software: GNU GPL 3.0
- Documentation: CC BY-SA 4.0

Unlike most DLP 3D printers on the market today, Project PAM's 3D printer features a relatively large build volume of 9 liters. To build the printer without the kit, most parts can be sourced from Amazon, Adafruit or other industrial supply stores. $2,500 is not a lot of money to raise, so hopefully they are able to achieve this goal. It will be nice to see a truly open source DLP 3D printer out there that hackers and makers can continue to modify and improve upon. This may just be the start of something revolutionary.

What do you think? Have you supported this project? Discuss in the Project PAM forum thread on 3DPB.com. Check out the Project PAM video below:



Tags: dlp 3d printer, indiegogo, open source, open source 3d printer, sla, stereolithography

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9.10.2 3D PRINTING INDUSTRY

Webpage Screenshot

3D PRINTING INDUSTRY

Help The Open Sourced DLP 3D Printer called Project Pam on Indiegogo?

BY SCOTT J GRUNEWALD ON THU, OCTOBER 2, 2014 · 3D PRINTERS, 3D PRINTING, CROWD FUNDING, EDUCATION, VIDEOS 1 COMMENT

A team of engineering students from Southern Illinois University Carbondale need help completing their fully open sourced DLP 3D printer for their senior design project, so they have turned to the crowdfunding community on Indiegogo to help them out.

Project PAM – Photoresin Additive Manufacturing – is a high resolution DLP 3D printer that will contain about $1000 worth of readily available parts that can easily be sourced. When the students who are trying to build it discovered that their SIU Engineering department funding wouldn't cover the total cost of the prototype development, they needed to get creative. To fill the gap in funding, they are hoping to raise $2500 on Indiegogo so they can successfully build and test their prototype.

The final prototype kit will include everything that backers need to build a complete DLP 3D printer with the exception of the projectors. That means it will contain the chassis, linear motion parts, the resin vat, electronics and a complete enclosure. Backing the campaign for the full kit will cost about $1,500. You can also back the campaign for $250 and receive a professionally bound copy of all of the documentation of the project and the build. $25 get's you a 3D printed keychain, and $5 will get you the standard "thank you" email.

Here is their Indiegogo campaign video:

EXECUTIVE INTERVIEW SERIES

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Bre Pettis is CEO of Makerbot, the Brooklyn based 3D printer manufacturer that brought the...

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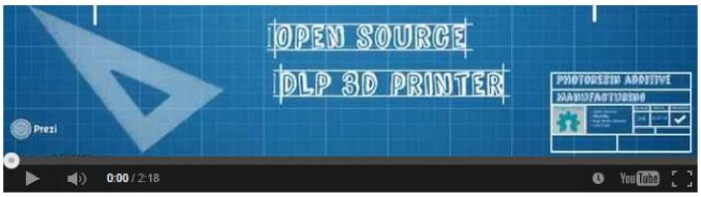
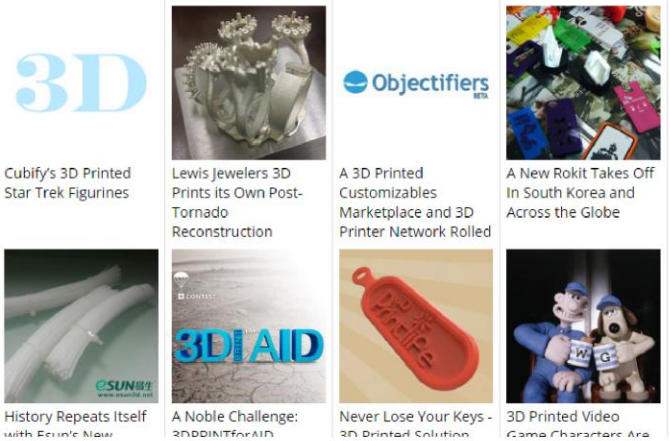


This is certainly an unconventional crowdfunding campaign, as the supporters are actually paying more for the final product than they would by just using the open source documentation. Of course there will be no open source documentation if the students don't manage to finish their senior project. So they are essentially asking backers to support them because they want to make it fully open source, so other people don't have to support them. While that may sound like a bum deal, backers could look at it as investing in the open source movement, because that is essentially what they are doing.

The students have committed to making everything completely open source and not hiding anything behind a patent. And if they do end up with any extra funds from the campaign, it will be donated to creating a new student makerspace within the SIU Engineering department, so as a backer you will also be supporting a new generation of makers.

You can find out more about Project PAM on the students Indiegogo page, or check them out over on their GitHub page, where the project is being fully documented. And if you're curious about what the 3D printer will look like, here is a very brief video of the final computer render:

Recommended articles:



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15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

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Fri, November 28, 2014

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Getting Smarter with Things3D

ABOUT THE AUTHOR

Scott J Grunewald

Scott J Grunewald often writes about comics, pop culture, technology and social issues and has a keen interest in what happens when the needs of commerce, art and science inevitably intersect. He also likes writing about bacon. This isn't the greatest bio in the world. This is just a tribute.

Visit Authors Website →

1 Comment 3D Printing Industry Login

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Jeffrey Burdick · 2 months ago

Thank you very much for covering our project. We're very excited others find supporting our project worth mentioning.

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ALSO ON 3D PRINTING INDUSTRY WHAT'S THIS?

Proto-pasta Announces Addition of Two New Metallic PLA Filaments

1 comment · 16 hours ago

michael — It would be awesome if Proto-Pasta would do a little testing and publish the mechanical properties of the new ...

For 3D Printed Ceramics Designer Alice Le Biez, Materials Matter

1 comment · 6 days ago

3D Printer Filament — What we need is to get these printer down in price, then we can talk about going mainstream with ...

New Modular Positioning Axis for Inventors Launched on KS

1 comment · 14 days ago

bonooobong — although it looks promising I think it might be overpriced... 150$ for a single axis movement without the ...

Making Crystal Warhammer 40,000 Terrain using a 3D Printed Mold

2 comments · 15 days ago

Jason Spiller — Cool. Wonder how long it takes GW to consider suing the guy (even though the models are generic).

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3D Printing Industry (3DPI) is a global media company providing a dedicated resource for anyone interested in 3D printing — a technology field that is growing quickly in relevance and application across industrial and consumer sectors. The mission of 3DPI is to report on and create original content about the latest developments in 3D printing to keep our large and growing audience abreast of technology

3DPI works with a dedicated team of writers with experience and a keen interest in this technology field technology. Their remit is to provide reliable news, interviews and insight about the latest trends in 3D printing across the board, including the pioneering home users, the maker community and industrialists.

3DPI provides a compelling blend of articles, blog posts and opinions, as well as videos and images across all platforms through our

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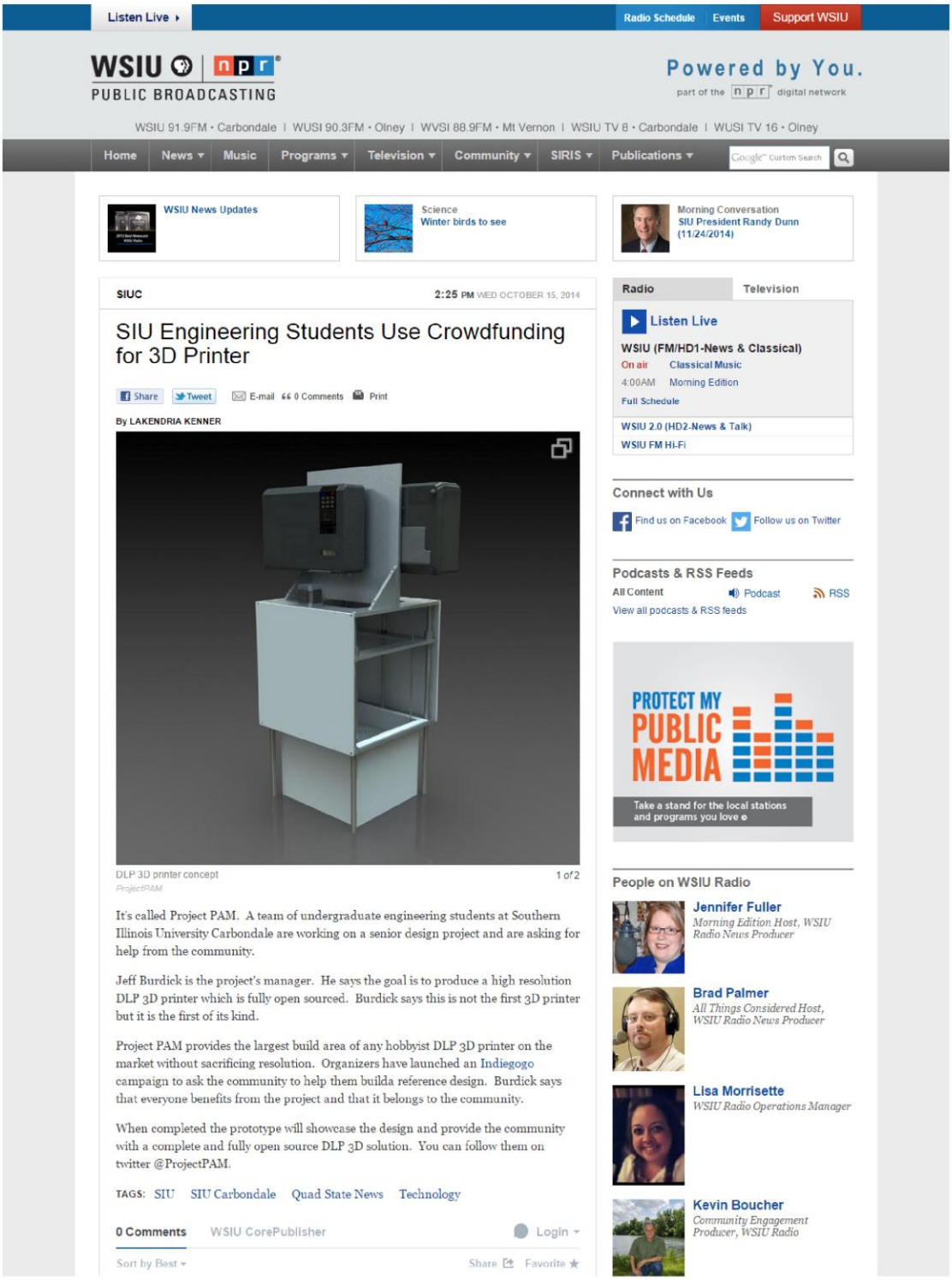

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Science
Winter birds to see

Morning Conversation
SIU President Randy Dunn (11/24/2014)

SIUC 2:25 PM WED OCTOBER 15, 2014

SIU Engineering Students Use Crowdfunding for 3D Printer

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By LAKENDRIA KENNER

DLP 3D printer concept 1 of 2
ProjectPAM

It's called Project PAM. A team of undergraduate engineering students at Southern Illinois University Carbondale are working on a senior design project and are asking for help from the community.

Jeff Burdick is the project's manager. He says the goal is to produce a high resolution DLP 3D printer which is fully open sourced. Burdick says this is not the first 3D printer but it is the first of its kind.

Project PAM provides the largest build area of any hobbyist DLP 3D printer on the market without sacrificing resolution. Organizers have launched an Indiegogo campaign to ask the community to help them builda reference design. Burdick says that everyone benefits from the project and that it belongs to the community.

When completed the prototype will showcase the design and provide the community with a complete and fully open source DLP 3D solution. You can follow them on twitter @ProjectPAM.

TAGS: SIU | SIU Carbondale | Quad State News | Technology

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Lisa Morrisette
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9.10.4 MAKE MAGAZINE

Cool Crowdfunding: October 26, 2014

By Caleb Kraft Posted October 26th, 2014 8:01 am Category Crowdfunding View Comments

Project PAM, an open source DLP based 3D printer

View on Indiegogo

MeU Open Source wearable display

9.11 USER MANUAL

9.11.1 PRINTING INSTRUCTIONS

Released under CC-SA
Version 0.1 2014-12-02

1 Pick a vat, build table, and build table ties based on build dimensions, leaving room for supports
2 Hang the build table and level with height gage
3 Set Z axis home based on desired X and Y dimensions
  3.1 Turn on projector
  3.2 Set rule on build table
  3.3 Adjust Z axis, zoom, and focus until projection is to desired dimensions
  3.4 Reset the Arduino so this position is zeroed
4 Position vat
  4.1 Move down from home dimensions to the bottom-most position of travel
  4.2 Set vat height, ensuring it does not interfere with the build table and provides enough Z axis travel for build
  4.3 Home the Z axis
5 Focus projector
  5.1 Place a piece of paper on the build table
  5.2 Project small text onto paper
  5.3 Adjust focus until text is clear
  5.4 Clear the build table
  5.5 Cover the lens on the projector
6 Adjust build aspect ratio
  6.1 Load a 20 mm test cube in software and project a layer which shows the extents of the build
  6.2 Place a rule on the build table and ensure the projection is 20 mm square
  6.3 Adjust the build dimensions until the build dimensions are correct
    6.3.1 The following formula is useful:
6.3.1.1 measured dimension / 20 mm * current build dimension
    6.3.2 It is useful to do this with one axis and adjust the other using the aspect ratio of the projector.
    6.3.3 If entropy creeps in and the numbers on the calculator get rather large decimal values, round to an integer and use the aspect ratio to set the other axis, then repeat the process
    6.3.4 Iterate this process until the dimensions look good

7 Fill the vat
  7.1 Measure the distance between the floor of the vat and the top of the build table
    7.1.1 The depth extension of a caliper is good for this
  7.2 Remove the vat
  7.3 Switch to non-curing light (red light, usually) and ensure the lens of the projector is covered
  7.4 Fill the vat to the depth measured
    7.4.1 Using the same depth extension of the caliper is good for this
  7.5 Place the vat in the machine
8 Level and Refine Z home position
  8.1 Do small Z moves and adjust the build table ties until the surface of the resin and the build table are parallel and the build table is just below the resin
  8.2 If there were large Z moves involved remove the vat and cover it, refocus the projector, and ensure the build dimensions are correct
9 Load model, move it 2 mm off the bottom of the build volume, and add a few supports to the bottom
10 Slice
11 Build
12 Enjoi

9.12 FLASHING GRBL

1. Download the Grbl source code.
   - https://github.com/grbl/grbl/archive/master.zip
   - Once downloaded, unzip it and you'll have a folder called grbl-master or something similar.
   - (On Arduino IDE < 1.0.6 or < 1.5.6) Re-name the folder to Grbl. You have to do this, because the Arduino IDE does not like the - hyphen in their library names.
2. Make sure are using the most recent version of the Arduino IDE (last tested on v1.05).
   - NOTE: For pre-v1.05 Arduino IDE users, you may need to manually add Grbl's source code into your Arduino libraries, so that it will appear in the Import Library... menu. Google the internet for how to do this, and once installed, skip to step 4.
3. Load Grbl into the Arduino IDE as a Library.
   - Launch the Arduino IDE.
   - Click the Sketch drop-down menu, navigate to Import Library..., and click Add Library....
   - Select the Grbl folder when asked to select a zip or folder for the library you'd like to add.

- It may take a few seconds for the Arduino IDE to import it.

4. Create a Grbl sketch in the Arduino IDE.
   - Start a new sketch, if one isn't already up on the screen.
   - Click the Sketch drop-down menu, navigate to Import Library..., and click the new menu option Grbl at the bottom of the list.
   - A long list of #include<>'s used by Grbl will be added to the sketch. Ensure (edit if necessary) that "system.h" is at or near the top of the list of includes. At this point, *don't add anything else! No void, no loop, nothing!*
5. Compile and upload Grbl to your Arduino.
   - Connect your Arduino Uno to your computer.
   - Make sure your board is set to the Arduino Uno in the Tool->Board menu and the serial port is selected correctly in Tool->Serial Port.
   - Click the Upload, and Grbl should compile and flash to your Arduino! (Flashing with a programmer also works by using the Upload Using Programmer menu command.

9.12.1 CONFIGURING GRBL

1. First, connect to Grbl using the serial terminal of your choice. Set the baud rate to **115200** as 8-N-1 (8-bits, no parity, and 1-stop bit.)
2. Once connected you should get the Grbl-prompt, which looks like this:
   - Grbl 0.9g ['$' for help]
3. Type **$** and press enter to have Grbl print a help message. You should not see any local echo of the $ and enter. Grbl should respond with:

$$ (view Grbl settings)

$# (view # parameters)

$G (view parser state)

$I (view build info)

$N (view startup blocks)

$x=value (save Grbl setting)

$Nx=line (save startup block)

$C (check gcode mode)

$X (kill alarm lock)

$H (run homing cycle)

~ (cycle start)

! (feed hold)

? (current status)

ctrl-x (reset Grbl)

4. We need to set the steps per millimeter variable equal to the pitch of your lead screw. **Type $$** to list variables

$100 = 314.961 (x, step/mm)

$101 = 314.961 (y, step/mm)

$102 = 314.961 (z, step/mm)

$110 =635.000 (x max rate, mm/min)

$111 = 635.000 (y max rate, mm/min)

$112 = 635.000 (z max rate, mm/min)

$120 = 50.000 (x accel, mm/sec^2)

$121 = 50.000 (y accel, mm/sec^2)

$122 = 50.000 (z accel, mm/sec^2)

5. Setting variables for your system
   - **Type $100** = (pitch of lead screw) to set the x motors variable
   - **Type $101** = (pitch of lead screw) to set the y motors variable
   - **Type $120** = 5 setting x motors acceleration to 5mm/sec^2 allowing the motor to accelerate during the move, rather than starting at the maximum velocity
   - **Type $121** = 5 setting y motors acceleration to 5mm/sec^2
6. Next you will need to adjust the maximum velocity of the motors, depending on the pitch of the lead screw you will need a faster or slower maximum velocity in order to prevent miss-stepping and losing track of the positioning. Our system works fine at 250mm/min, adjust accordingly
   - **Type $110** = (x motor velocity)
   - **Type $111** = (y motor velocity)