Cloudmesh Raspberry PI Cluster Case

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2 Raspbery PI 5 Node Cluster Case

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This document is published in github at

- PDF: https://github.com/cloudmesh-community/case/blob/master/vonLaszewski-pi-cluster-case.pdf
- epub: https://github.com/cloudmesh-community/case/blob/master/vonLaszewski-pi-cluster-case.epub?raw=true

2.1 Abstract

We present the design of a Raspberry Pi cluster case that allows to create a cluster created form up to five Raspberry Pi's. The cluster is designed for educational purposes as part of a Cloud Engineering class taught at Indiana University. The clusters are designed to be portable and allow the integration into a *shelf* where multiple such clusters can build a bigger cluster. Hence an individual five node cluster can be taken home to support work there, but when coming to class the cluster can be plugged into the shelf to allow sharing of the Pi's among all class members. The case is designed without need of screws and can be reproduced on a laser cutter without purchasing of additional components. All design files are openly distributed.

2.2 Introduction

Raspberry PI's are inexpensive and in contrast to a compute server that cost about $15K, one can get a fully operational PI for less than $50. Despite its low cost a number of PIs are an ideal platform for developing prototype clusters to use for development of non-memory intense cluster services. Naturally it does not have the same compute or memory power as a number of $15K servers have, but to showcase some of the software services and tools needed to build more expensive clusters the PI platform is very useful. However, such a cluster does not come with a case. One could purchase multiple cases, but such cases assume external power and networking. Our goal is to create a single case that can hold up to 5 Raspberry Pi's. Furthermore, We like to be able to connect multiple such clusters to a larger cluster that is housed in a shelf or rack.

We present here our current solution for such a case and also give opportunities for further improvements to this effort which can be conducted as part of educational activities including high school, undergraduate, and graduate students that are interested in such activities. Alternatives such as virtualizing a cluster entirely in a cloud or on a user's local computer are discussed in [1] and [2].

2.3 Requirements

Next we list a number of requirements for this effort. We distinguish educational requirements and technical requirements.

2.3.1 Educational Requirements

We list a number of educational requirements that we addressed through this effort

Focus on Programming: Typically students will use a graphical user interface based tool to design such a case. However, from the beginning on we wanted to avoid such a GUI based method and expose students to programming. This is especially desirable in case students need to not only be introduced in GUI design processes, but also programming as this will lead to a more parameterized design as well as exposing students to concepts of programming.

Focus on Simplicity of the Design: Certainly it is possible to create a fairly complex design or a design inspired by art and architecture. However, in our case we wanted to focus on a simple design that could be integrated in a shelf. In future we hope that the cases can be modified and for example get artful additions to for example support efforts such as documented in [3].

Iterative Design: The activity was scheduled around the principle of an iterative design process in which first principles such as easy connectors were prototyped, before the whole case was designed.

Alternative but Integrative Design: The activity allowed for alternative designs to be explored and each student member had the opportunity to follow their own idea. Exchange of ideas in an open environment was however encouraged and improvement suggestions need to influence the design process. This is part of a strong team work approach of the activities.

Documentation: The activity has a minimal documentation requirement in which the design is documented so it can be reproduced and sufficient assembly instructions are provided. As the Laser cutting equipment use if very new, we want to make sure that enough documentation is identified and added so that it can be used for other students to reuse.

Advanced Documentation Requirements: The activity allows also for participation in advanced documentation requirements such as this document that is also influenced by [1] and [2]. As part of this requirement students have the ability to participate in writing a paper instead of an experience report. A paper focusses on how to write an academic paper, while an experience report focusses more on what a student has done. We identified that the later often leads to information that although valuable for the student to recognize, does not communicate the effort in a short an effective manner to the reader while focusing on the deliverables.

STEM Integration: Demonstrate that STEM students can meaningful contribute to activities done at the University level.

2.3.2 Technical Requirements

The following technical requirements exist

- Develop a case than can hold up to five PI's of Raspberry PI 3B or PI 3B+, a network switch that can in addition be plugged into a laptop, and a power supply to power the Pi's.
- No screws or glue needs to be used to assemble the case
- Laser cut material is to be used for the case
- The design document is openly redistributable
- The design has been fully tested and an assembly has been conducted
- Assembly instructions are provided
- A materials ordering list is provided to print either 1 or 10 cases.
- The cases be integratabtle intoa shelf that can host many of the clusters with 10 being the minimal.
- Prepare integration of a cluster with 200+ Raspberry PI's
- Compare the design to that of other cluster cases for PI's
- Have the cases be stable enough so they can be carried in a bag between home and class without breaking them.

2.4 Design of the Case

Based on these requirements we designing a Raspberry PI Case for five PI's out of laser cut sheets with the goals of keeping the design as simple as possible, using few parts as to minimize production costs, allowing for easy assembly without screws or glue, while making it structurally sound. Furthermore, we allow reproducibility through an open source design.

Two major innovations were included into the design to address the requirement of not using screws and glue:

1. a peg and slot system to easily lock in perpendicularly
2. an interlock system based on cutouts and rectangular wholes so the pieces fit nicely.

Due to the iterative design process including the programmatic design plans, build, test, and analyze phase and its iteration The final design was refined over time addressing issues that were discovered during the actual assembly.

Although our design does not require it, we recommend to put some strong rubber bands around the case before transporting it between home and school as preventive measurement. Cushioning the case during the transport in the bag for example with cloth material is not needed, but is recommended just in case.

2.5 Manufacturing Facilities

Our design is general enough so that it fits common laser cutters. We used two different cutters, both from Trotech. This includes the Speedy 360 and the Speedy 400. The Speedy 360 has a 813x508mm bed while the 400 has a 1000x610mm bed. Acrylic material on these laser cutters can be cut up to 6mm. To ensure that the material will fit into the laser cutter, ordered acrylic sheets are limited to the dimensions of the bed minus a quarter inch. The laser cutter has an influence on our layout of the design. If you have laser cutters with a different bed size, please make appropriate modifications of the layout of the parts for the case.

2.5.1 Material

The laser cut parts utilize 3mm cut-to-size acrylic. Although thicker material would be more stable, it is not as suitable as its weight is more and it is also more expensive. Thus a decision has been made to stick with the 3mm as it is lighter during the transport. It can be purchased for ex ample from

- https://www.tapplastics.com/product/plastics/cut_to_size_plastic.

The acrylic material may either be cast or extruded. Choosing cast acrylic will give a higher quality in color and engraving but it is also more expensive. A single case will need the following dimensions:

- 21 3/16in x 15in

or in cm rounded up to the next cm

- 54cm x 39 cm

The cost for a single cluster would be based on material choices:

- Extruded Acrylic (Clear): $11.16
- Cast Acrylic (Clear): $16.41
- Cast Acrylic (Transparent Colors): $18.81

This is considerable cheaper than buying cases individually as they typically are sold for about $10 a Pi but do not include the encasement for the power and network equipment.

To build 10 cases that fit on the larger Trotech laser cutter we need to order the following while using extruded acrylic:

⚠ Student will provide concreate order information

2.6 SCAD Files

The design of the cases were conducted in SCAD.

SCAD [4] is a program that can creating 3D CAD models. It is freely available for the common operating systems. The special aspect about SCAD is that it is based on a programming language to develop the model instead of a Graphics interface. This allows a programmatic creation of the model and modification through its programming language rather than a drag and drop interface.

The CAD files for the case are shard in SCAD and SVG format in the following location

- https://github.com/cloudmesh-community/case/tree/master/design/scad

We have two designs. One with a locking mechanism the other without.

To produce a physical copy of our prototypes, we could not simply use the file in it's SCAD format. To ready the design for laser cutting, we first have to export the file as a SVG. Once this is done, the file can be edited in a graphic design program, such as Adobe Illustrator [5] or Inkscape [6]. Edits required to prepare the design include the removal of the interior fill color of the case components and adjustment of the edges for cutting. The laser cutter is preset to cut along red lines with a low thickness. For the prototypes, we used a 0.03 point thickness.

⚠ At this time the description of how to identify a reference point for scaling is not yet complete. This can be completed in one of two ways.

1. Keep the SCAD files as they are, but make sure that a concrete description be added which feature can be used for scaling and how.
2. add a 1x1 cm or 1x1 inch square to the design which serves as reference point.

To avoid complex instructions the solution 2 seems overall easier.

The design must also be correctly scaled to the right size. So far, we have achieved the correct scaling by finding a feature within the design and find the correct scale factor by measuring it. We are currently considering the possibility of using the size of the rectangle the case fits into; this should speed up the process, since the dimensions can be viewed in Illustrator by clicking on the artboard tab on the right vertical tool bar and selecting the artboard settings button. The correct scale factor can be calculated by dividing the desired length by the length of the artboard. Then select all objects and scale them by the calculated factor. Once this is done, the artboard must be scaled up as well.

Once all editing is done, the design can be cut. This can be done by selecting the print option in the graphic design program and clicking on settings, in Adobe Illustrator, this can be found in the lower left corner of the main print window. If the laser cutter is not selected as the printer, it will need to be selected. The dimensions in the print settings will also need to be adjusted if they are smaller than the size of the design; in Illustrator, the size can be changed under preferences, which is located directly beneath the printer selection. The settings window can now be closed and the *print* button on the main print window can be selected. This will send the file to the laser cutter as a job.

2.6.1 Assembly Instructions

Once the case has been printed it needs to be assembled as follows. Our assembly instructions include one instructions to showcase the assembly of the case alone with pictures, and the other one with all electronic components included. Additional images are included in the Appendix.

⚠ TBD include assembly instruction images (use nice background, e.g. white or black)

2.6.2 Final Product

The final case without components is shown in fig. 1.

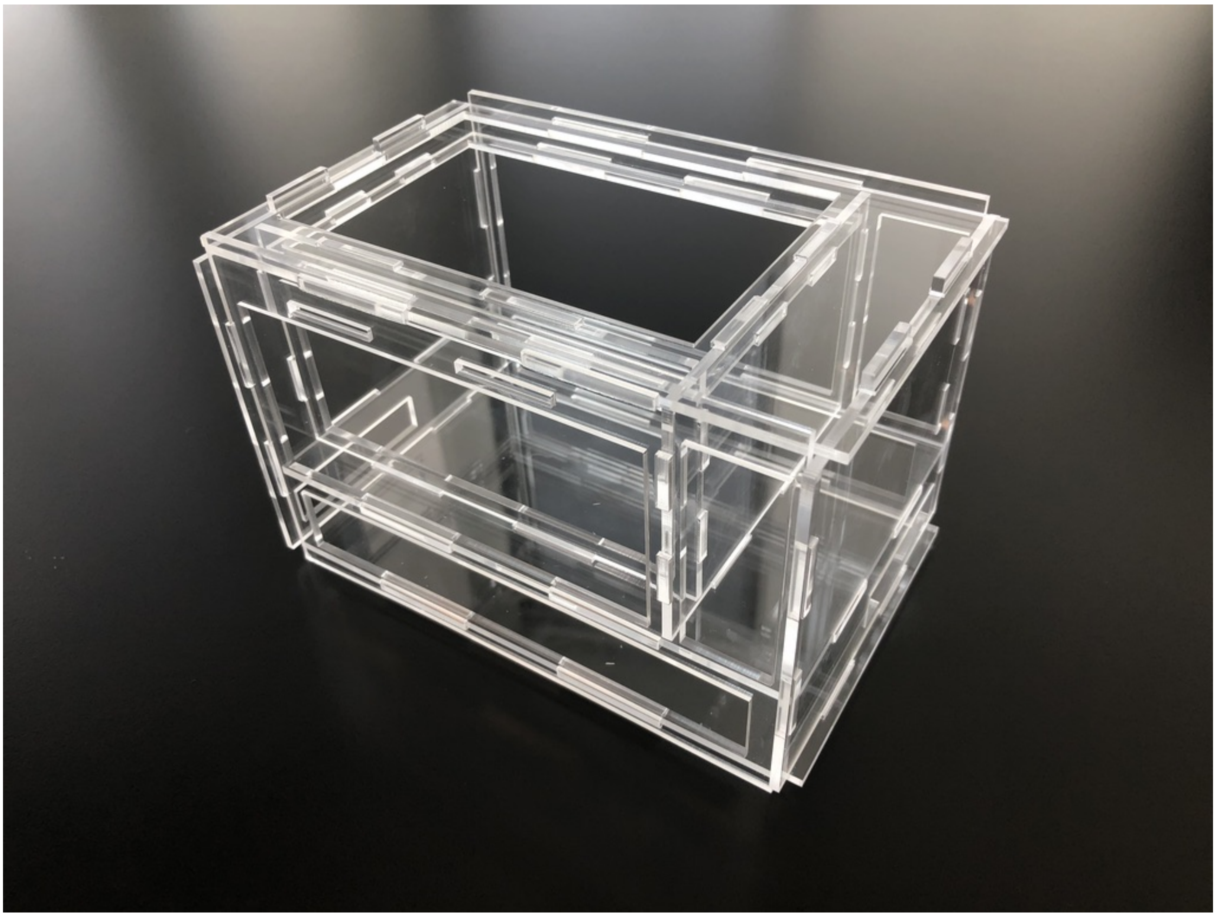


Figure 1: Case

The final product looks as shown in fig. 2. Cables are not added in this image.

Figure 2: Case

If cables are added the case looks as depicted in fig. 3.

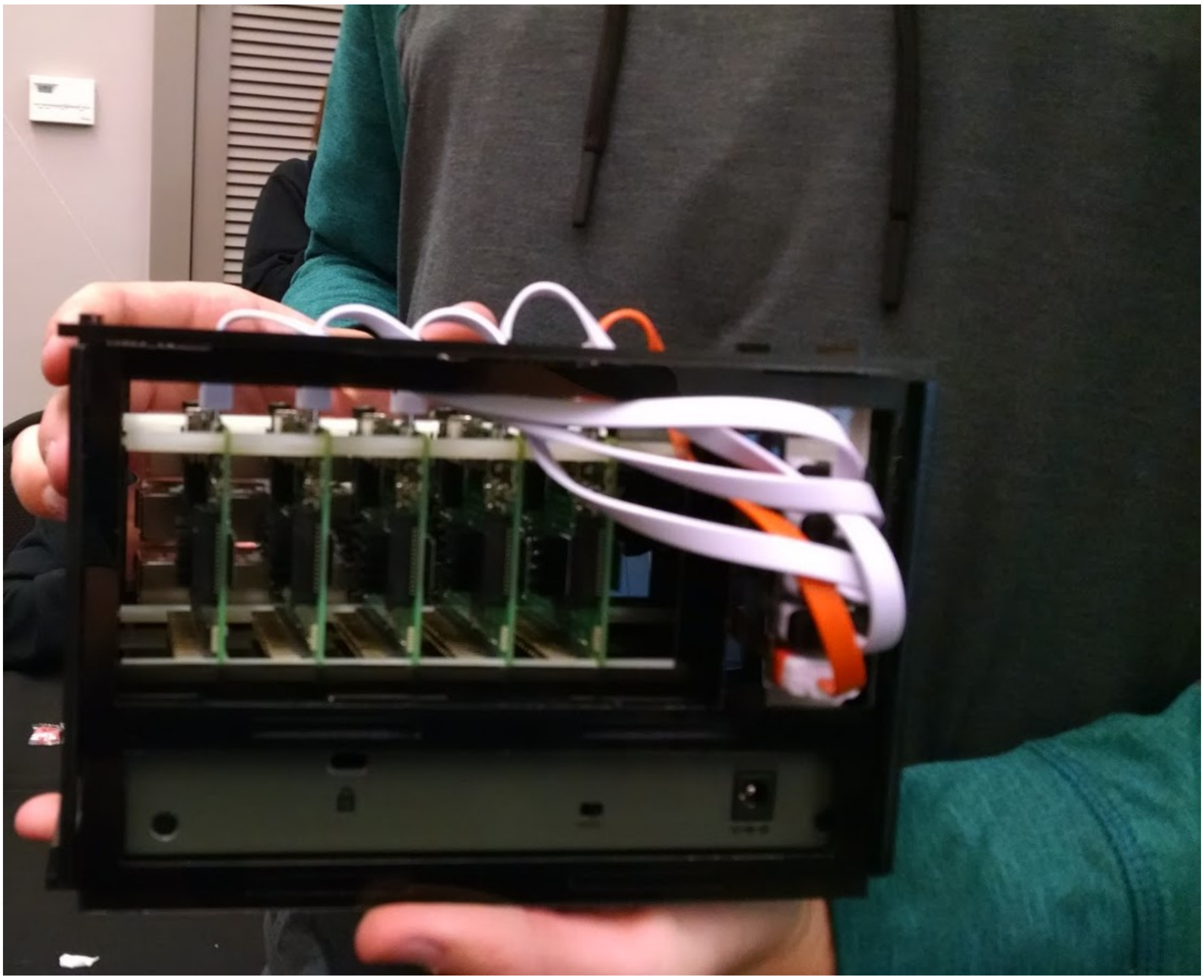


Figure 3: Prototype 3

2.7 Community Outreach

As part of this activity, we exhibited the Cluster at a local maker fare called Makevention [7]. During that exhibit we got a lot of interest in the Pi cluster activities and the Cloud Computing course [1] taught at Indiana University. An event picture is shown in fig. 4.

Figure 4: Case

2.8 Future work

Future Design Activities include the following activities. We are looking for students that would like to take on these tasks and contribute to this document.

Cluster Shelf or Rack: To accommodate larger clusters in the class setting a shelf is proposed in which we *place* the miniclusters while attaching it through a power distribution bar and a large network switch to integrate the individual clusters into the larger cluster. Furthermore we want to create a product in a box called *Cloudmesh Pi Cluster* that we can give to students so they can assemble such a cluster themselves, or order the parts directly from us and we ship the parts and the cluster case to them.

Product Box: It is useful to be able to distribute such a cluster as a Kit, either distributed by us or others. For this we need to design a shipping box that includes all parts of a five node cluster including an online instruction manual and an artful product label.

Bitscope Rack: We have also access to a 19 inch rack based on:

- 19 inch rack for 40 nodes via bitscope, https://www.festi.info/boxes.py/Rack19Box

We like to create a rack that contains 5 such clusters holding all together 200 Raspberry Pis.

40 node case: We like to design a 40 node case in 19 inch rack format from laser cut material

Dense joints: we could design a future case with tighter joints in mind such as projected by the following program that creates basic boxes based on any dimension provided by the user.

- https://www.festi.info/boxes.py/

2.9 Partners

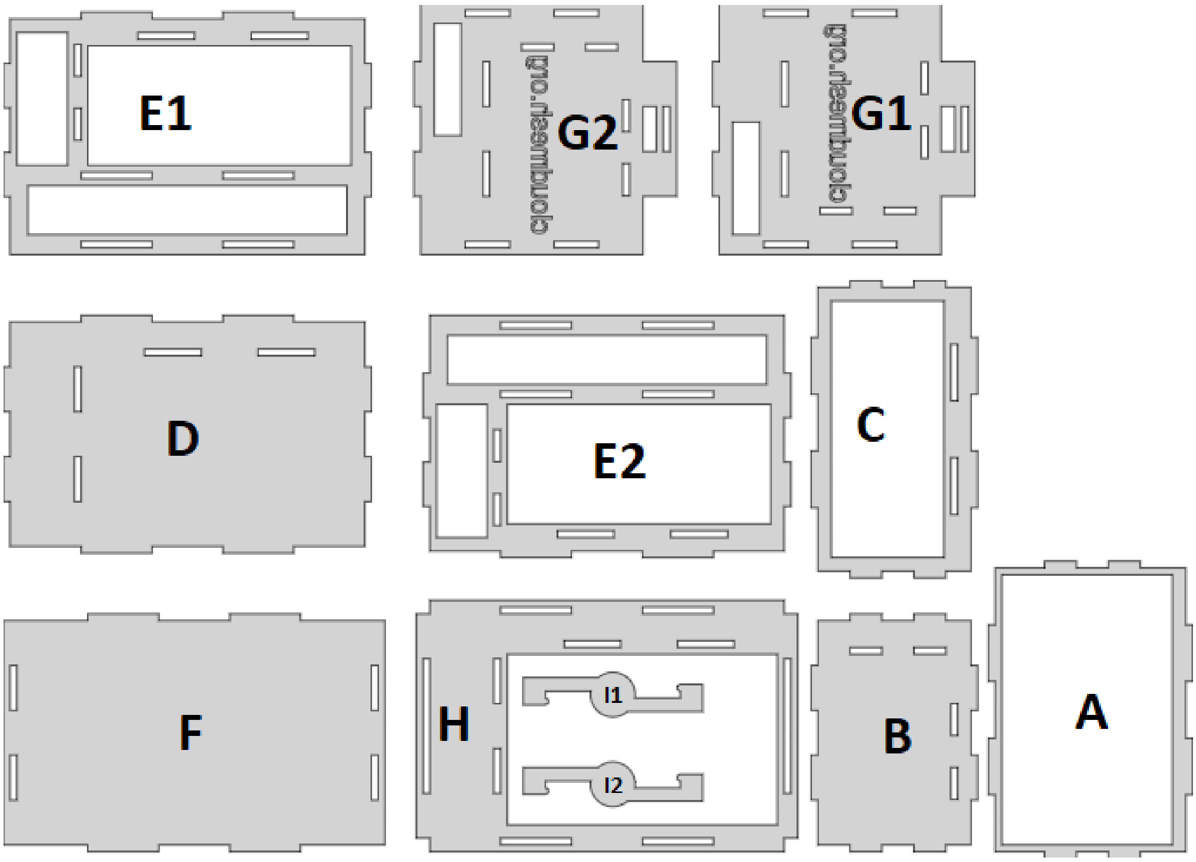
This internship was conducted in partnership with the Academy of Science and Entrepreneurship [8] is a public high school located in Bloomington, Indiana, and part of the Monroe County Community School Corporation. Unlike other public high schools in Monroe County, the Academy focuses almost exclusively on high-quality project-based learning. Classes are often co-taught and subject matter integrated into one course. For example, sophomore English and World History are combined into the Global Perspectives course taken by all sophomore students and taught by two instructors.

The Academy strongly emphasizes authentic projects and *real world* skills; therefore, student internships are strongly encouraged for all upperclassmen. Each career exploration internship must be at least forty hours in length, and students are required to complete a series of reflections, in addition to receiving an evaluation by the internship host. Internships may be completed during the school year and/or over summer break. The Academy is also an early college high school and has a strong partnership with Bloomington Ivy Tech, where students may take up to five free dual credit classes. It is through all of these experiences that Academy graduates are uniquely prepared for post-secondary success. Additional information can be found at the school web site:.

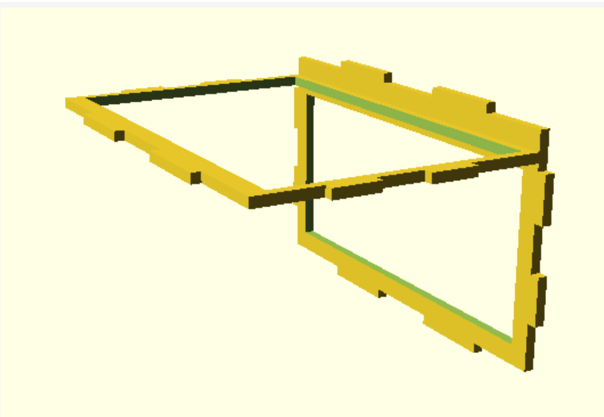
This project served also as prototype to identify opportunities for local high schools to participate in educational activities at the University, which it successfully demonstrated.

2.10 Assembly Instructions

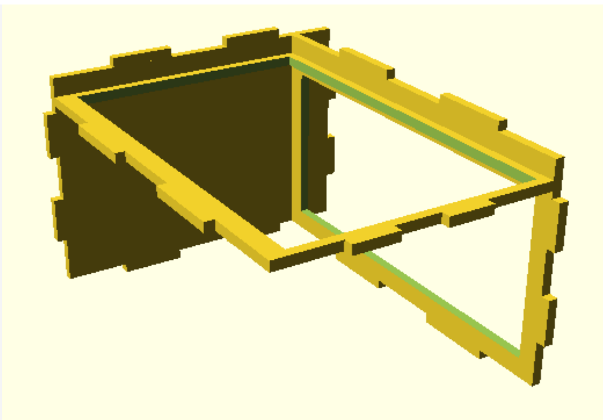
2.10.1 Case A - With lock



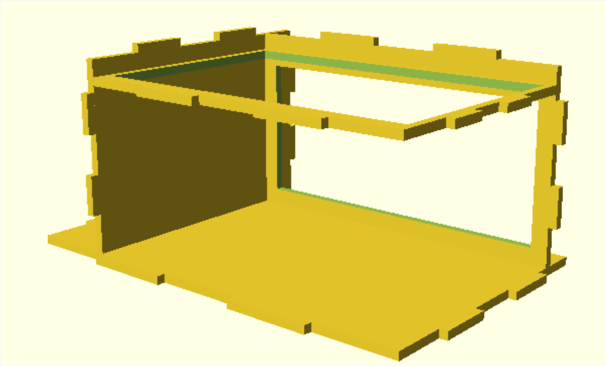
Piece Layout



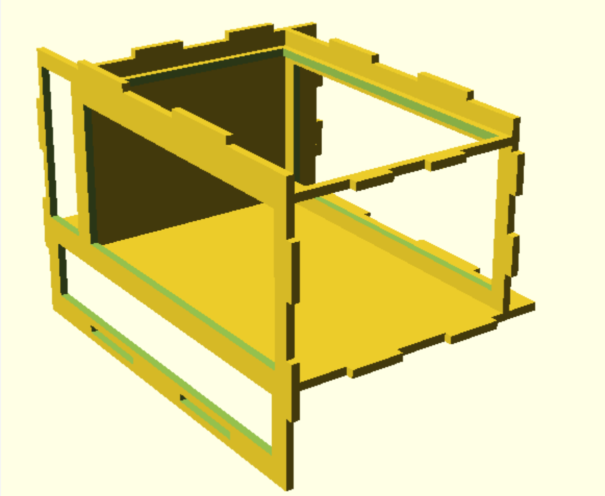
Add A and C



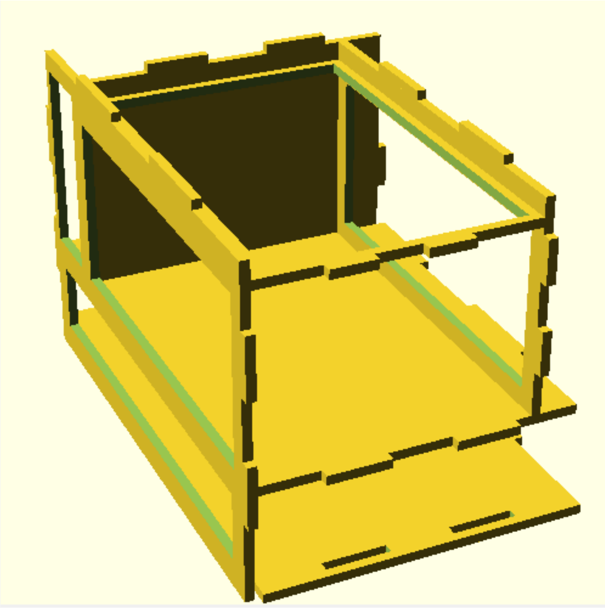
Add B



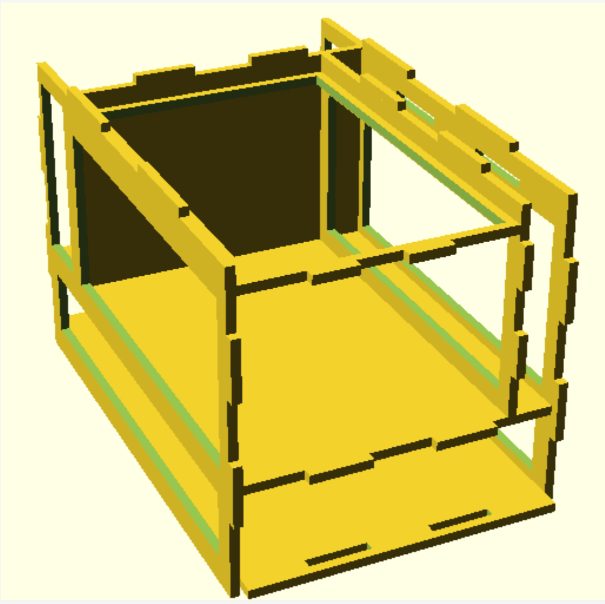
Add D



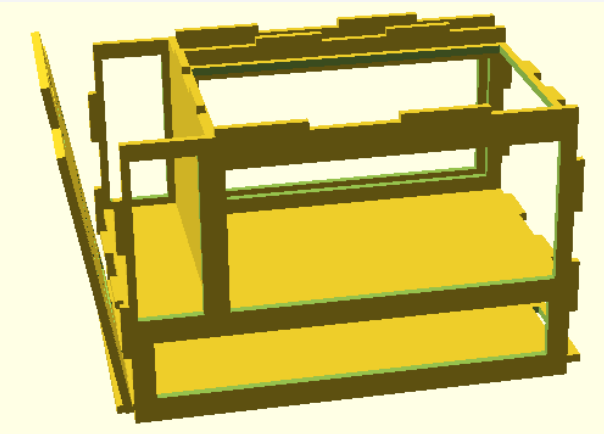
Add E2



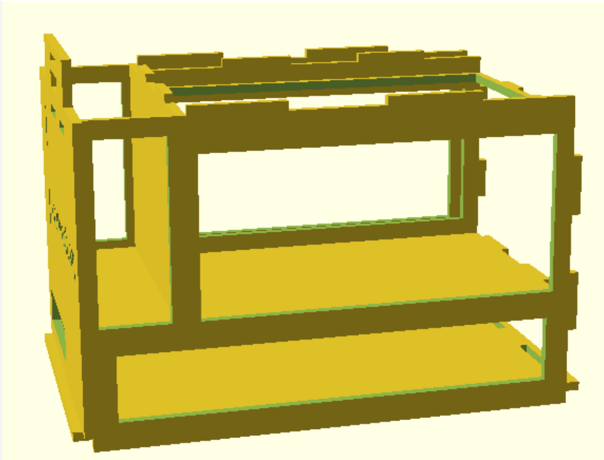
Add F



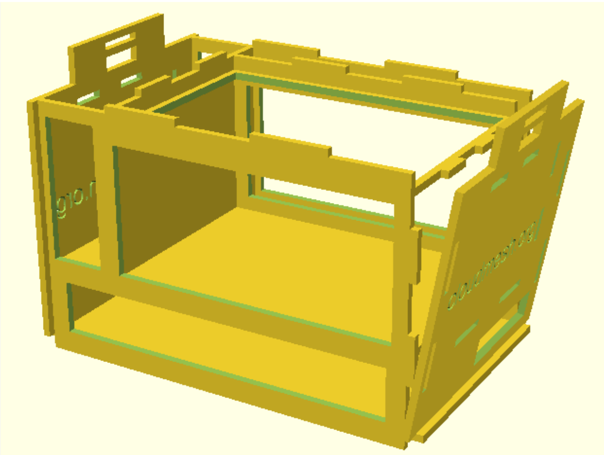
Add E1



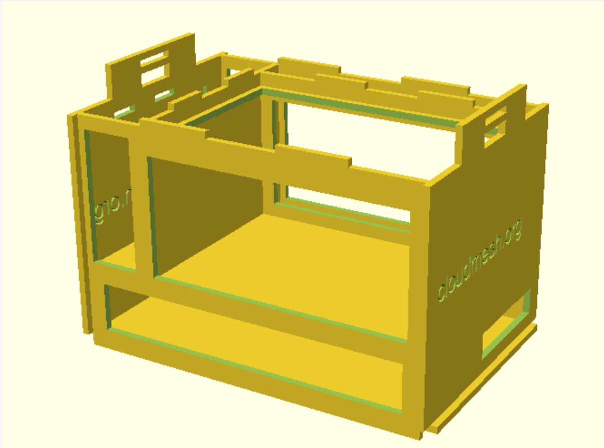
Add G1



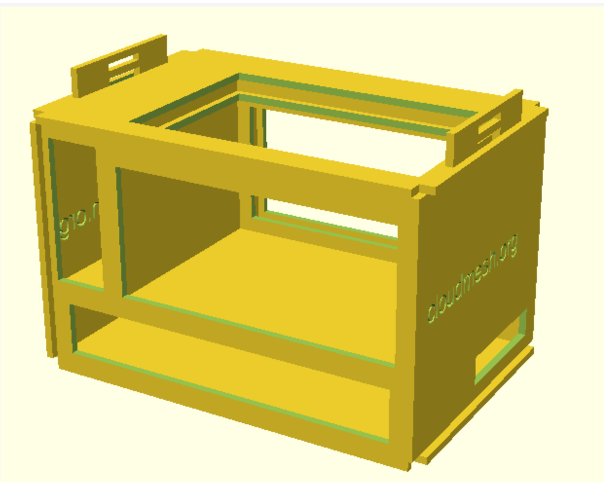
Lock G1



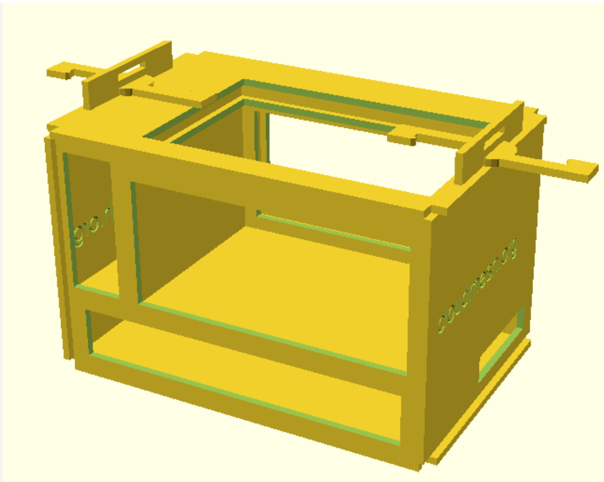
Add G2



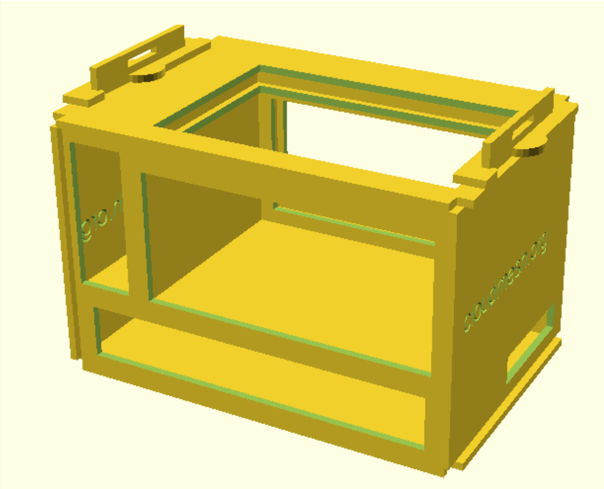
Lock G2



Add H



Add L1 L2



Twist L1 L2

2.11 Links

- Other cases are at https://github.com/cloudmesh-community/book/blob/master/chapters/pi/case.md
- Website for OpenSCAD http://www.openscad.org/index.html
- Presentation: https://docs.google.com/presentation/d/1CSdbXzB3QMpkFJ3mvA80TYrvF13VuKiJK-m96QDGw_I
- Images are included in the file are available at https://github.com/cloudmesh-community/case/blob/master/appendix.md

References

[1] G. von Laszewski, *Engineering cloud computing*. Bloomington, IN: Indiana University, 2018 [Online]. Available: https://github.com/cloudmesh-community/book/blob/master/vonLaszewski-cloud.epub?raw=true

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