

# Applying the Iterative Development Process: The Creation of Fractal Emergence

Christopher R. H. Hanusa  
Eric Vergo

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# Who are we?

## Christopher Hanusa

- Mathematician
- Mathematics Educator
- Artist & Jewelry Designer

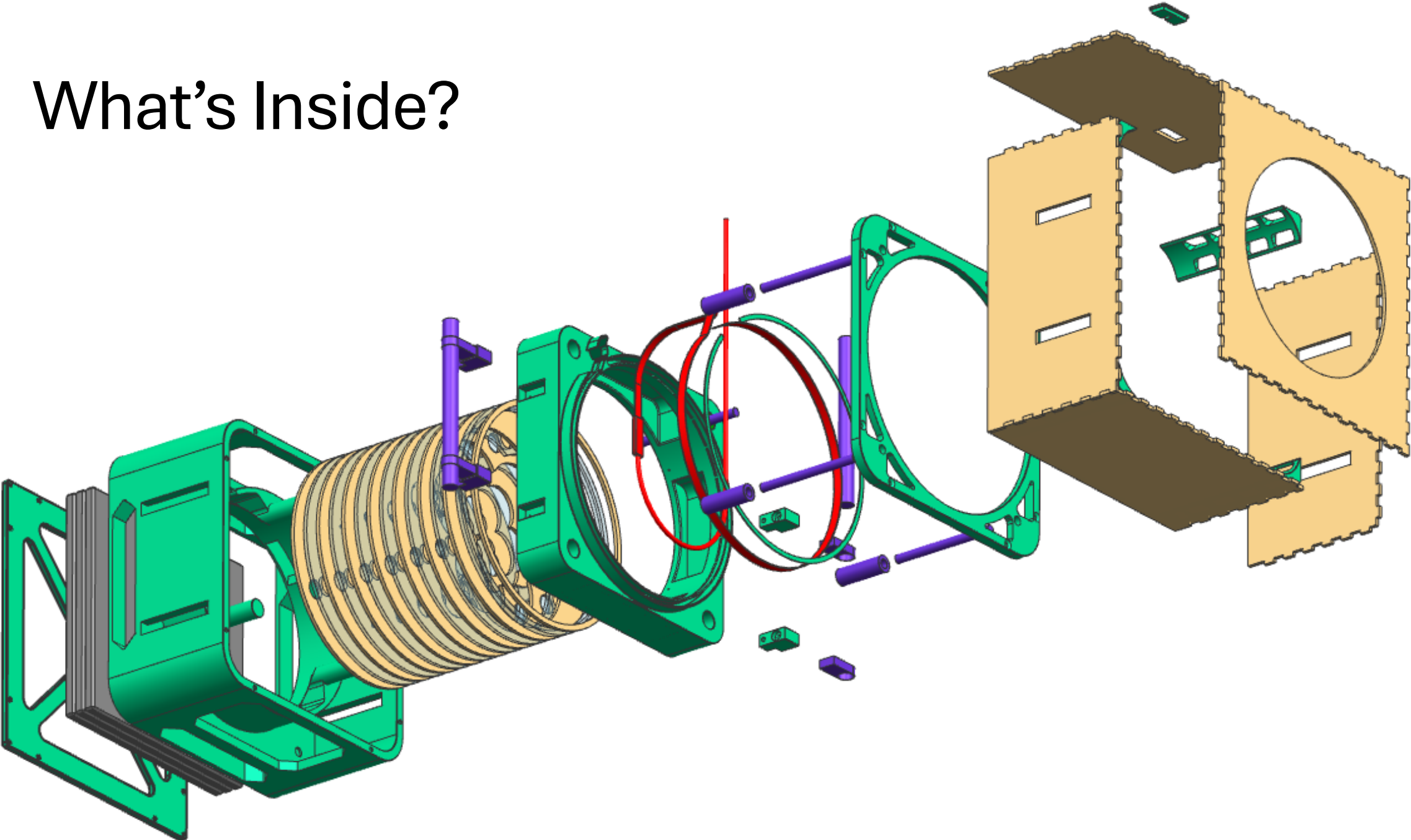


## Eric Vergo

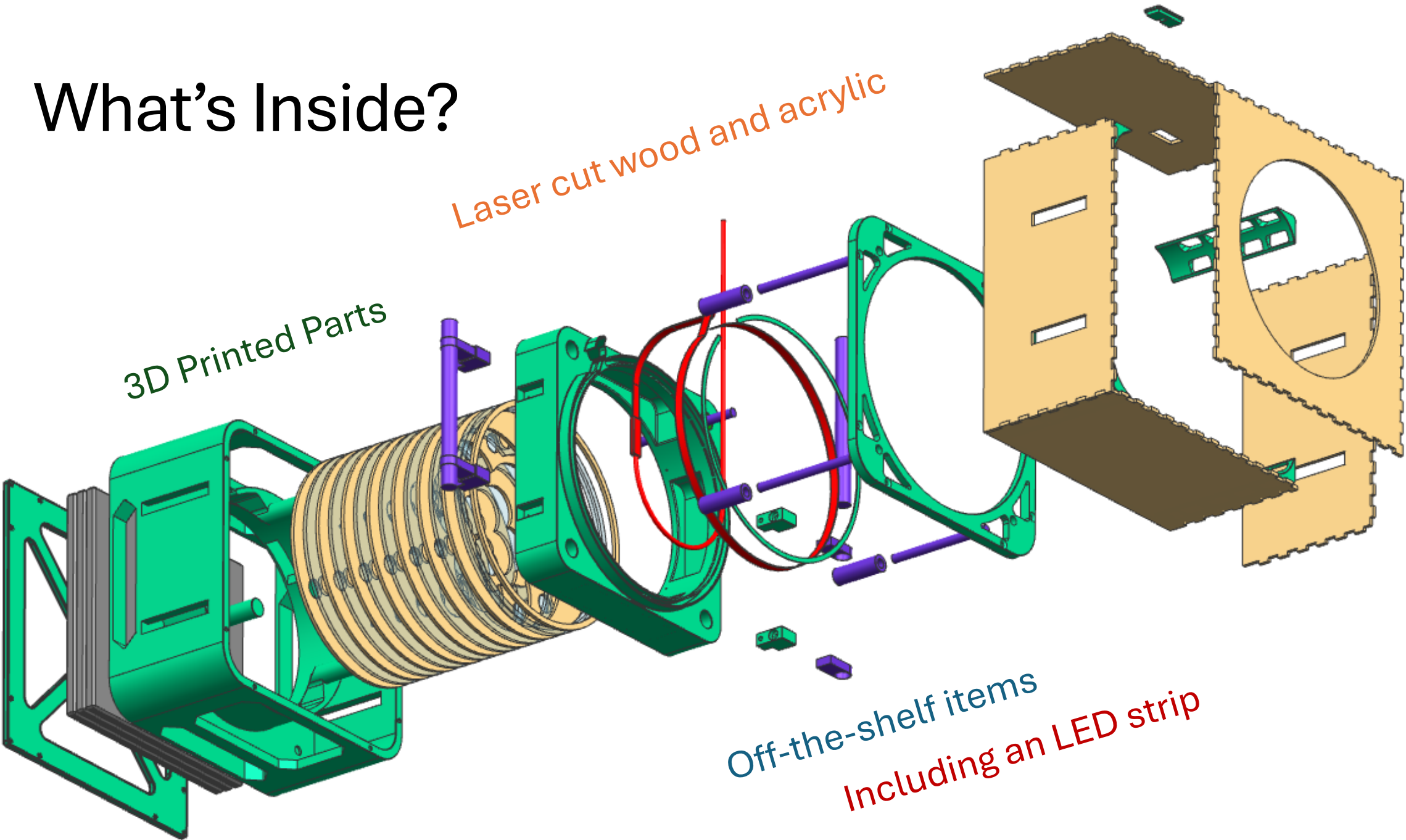
- Math Graduate Student
- Former Apple Engineer
- Puzzle Connoisseur



# What's Inside?



# What's Inside?



3D Printed Parts

Laser cut wood and acrylic

Off-the-shelf items  
Including an LED strip

# Iterative Development Process

- Originally from software engineering.
  - Standard practice in hardware eng, art, and design
- Iterate a cycle of **design**, **build**, and **test**.  
Refine some aspect at each step.

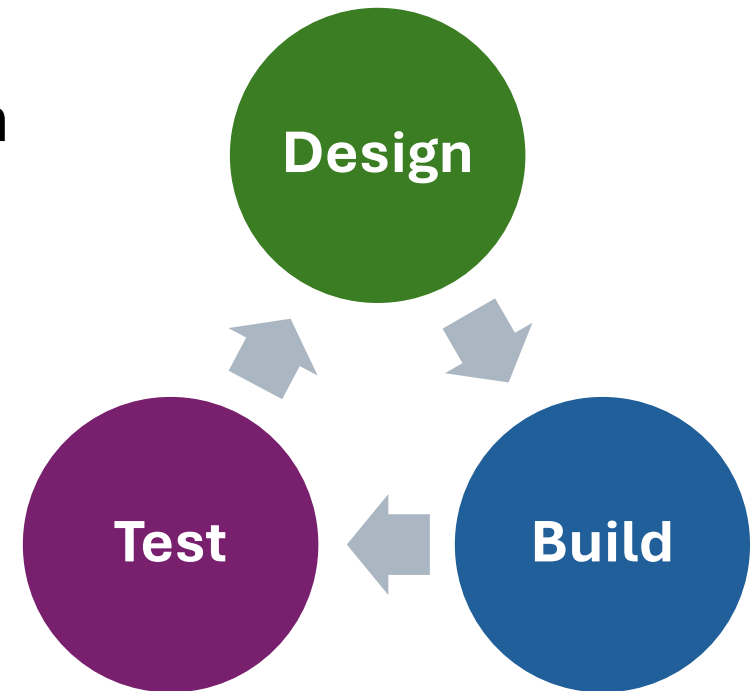
**Design:** Mathematica, NX (3D CAD software)  
Export files for manufacturing.

**Build:** A physical prototype (3D print, laser cut)

**Test:** Simulate user experience and anticipate audience reactions.

*Identify improvements and update the design.*

- Useful for me to have a definition for this process.



# Guiding Principles

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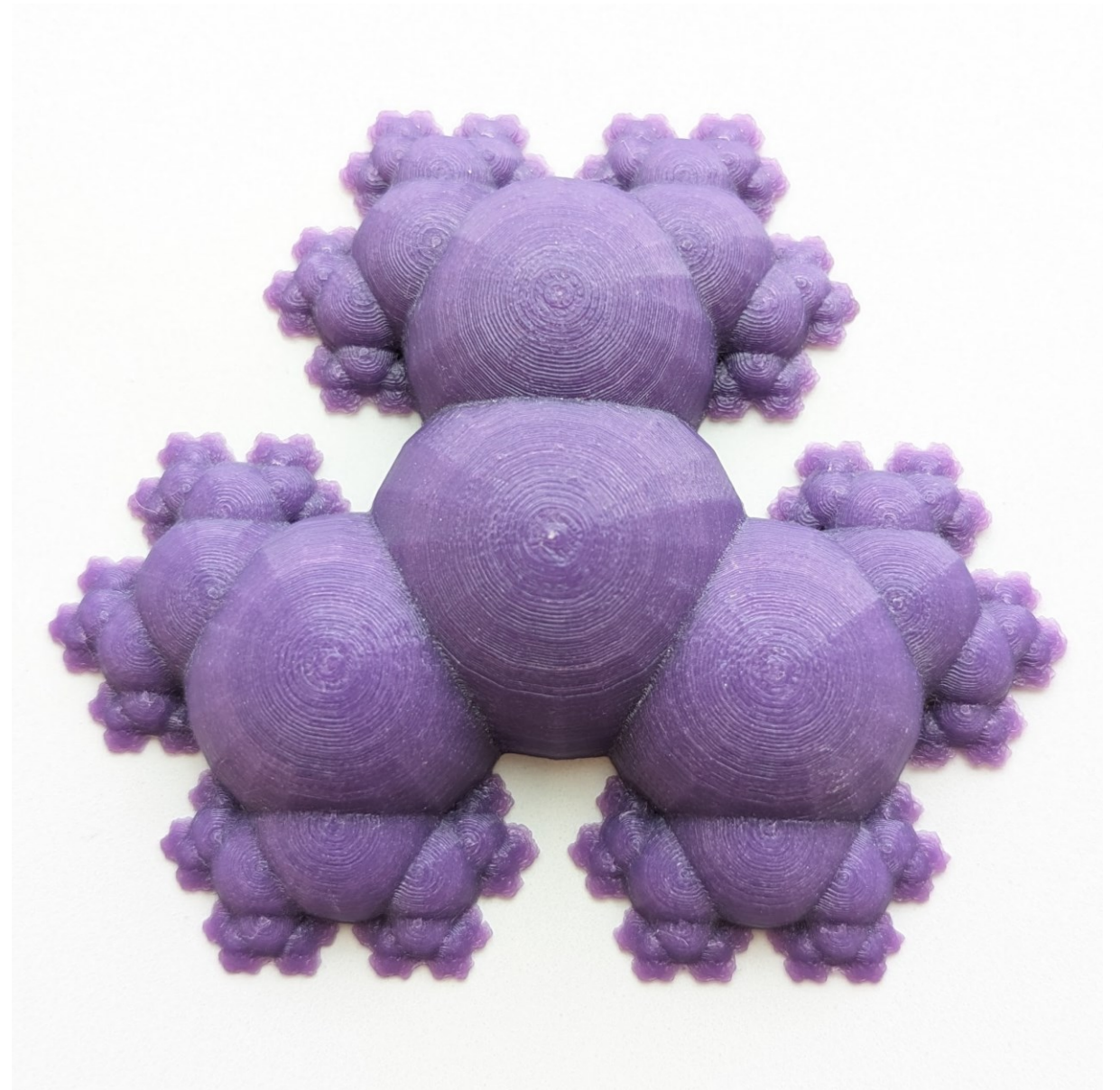
**The final piece should be  
engaging,  
aesthetically pleasing,  
and well-crafted.**

We applied iterative development in parallel to:  
**the artwork** and **the housing**

# Iterative Development: **The artwork, v.0**

## **v.0 - The inspiration**

- A 3D print from 2017





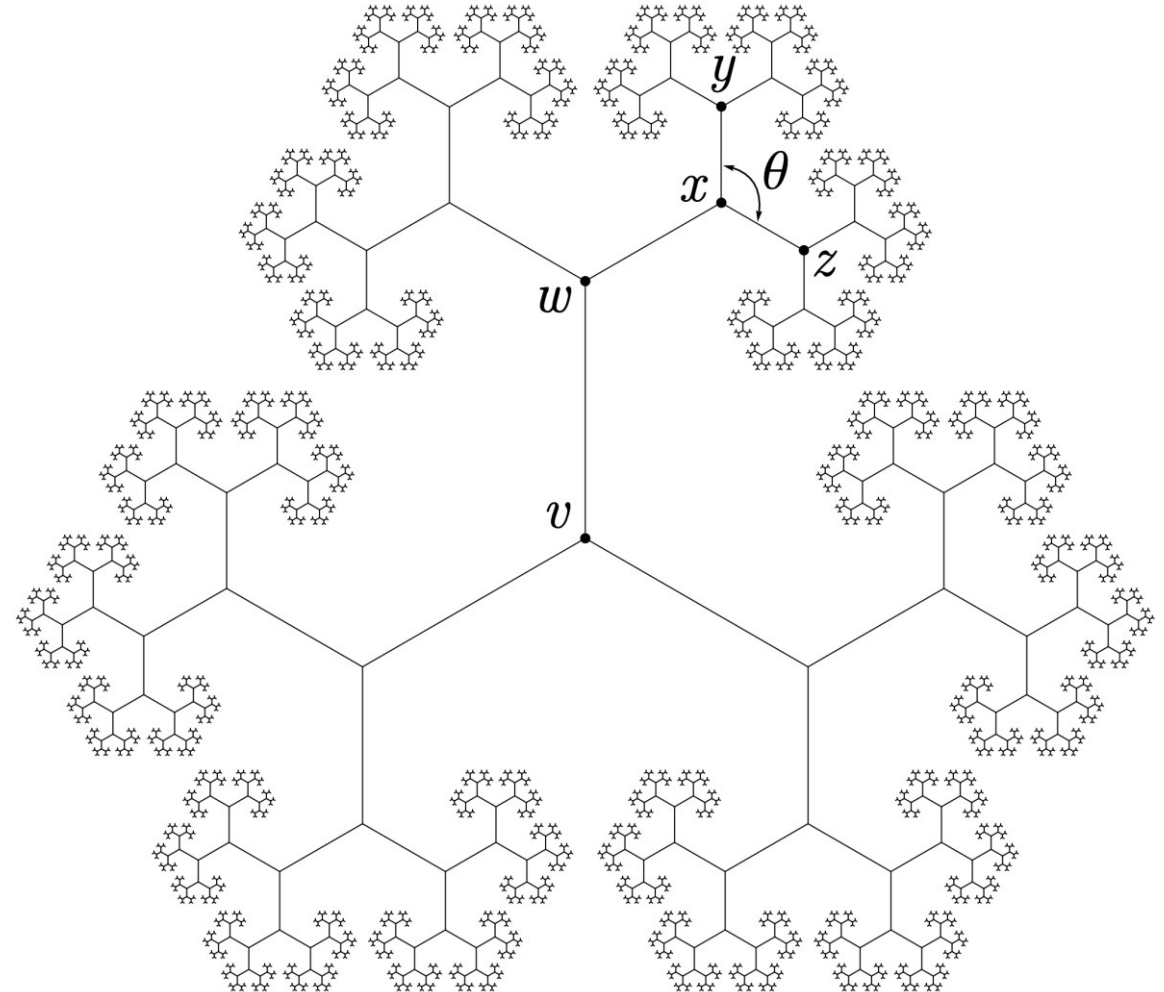
# Iterative Development: **The artwork, v.0**

## **v.0 - The inspiration**

- A 3D print from 2017

## **Infinite trivalent tree $T$**

- infinite graph
- Every vertex has degree 3
- Symmetric and self-similar embedding



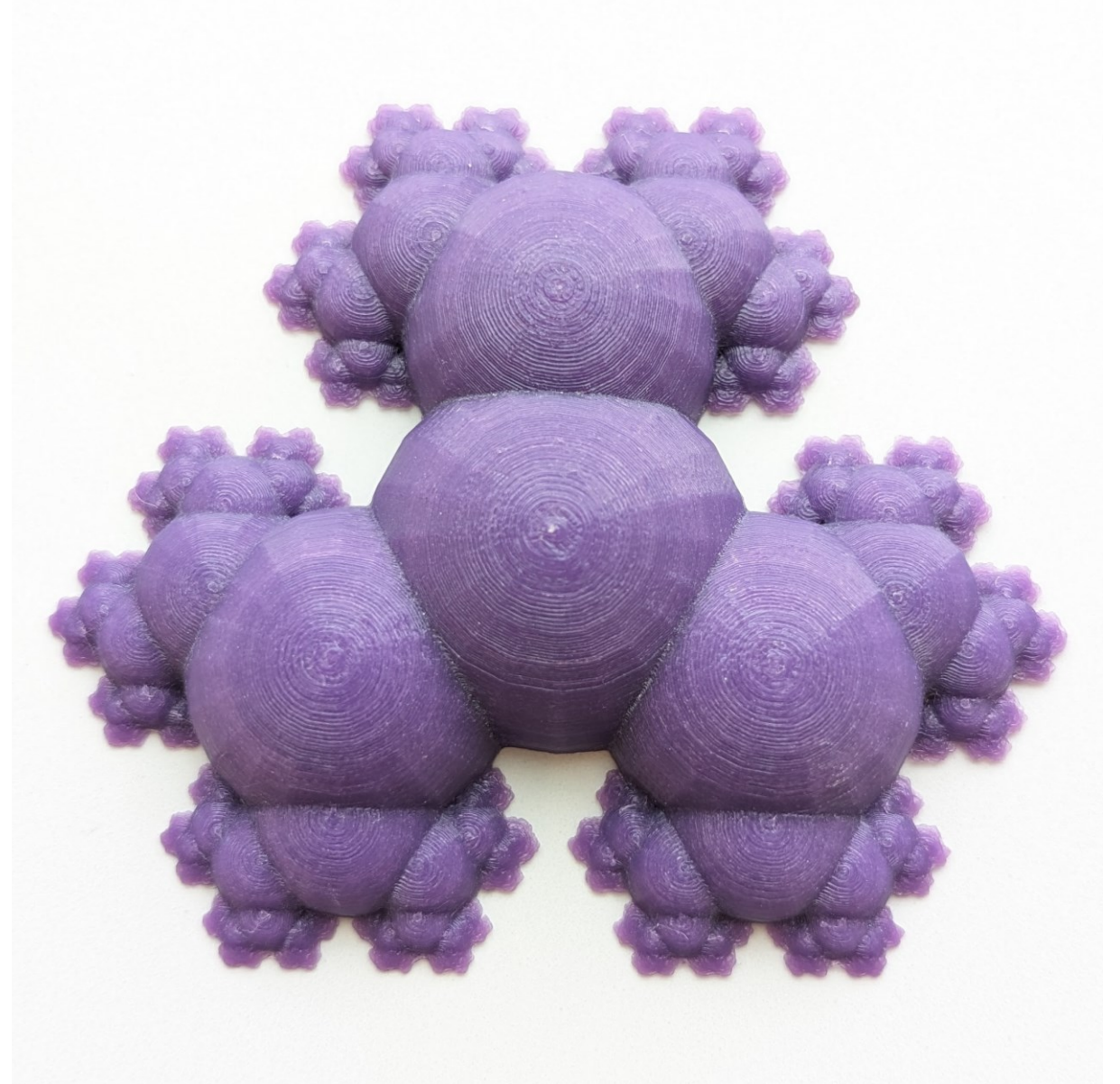
# Iterative Development: **The artwork, v.0**

## **v.0 - The inspiration**

- A 3D print from 2017

## **Infinite trivalent tree $T$**

- infinite graph
- Every vertex has degree 3
- Symmetric and self-similar embedding
- How to recreate through layers of laser-cut wood?



# Iterative Development: **The artwork, v.1**

## **v.1 - Faithful Representation**

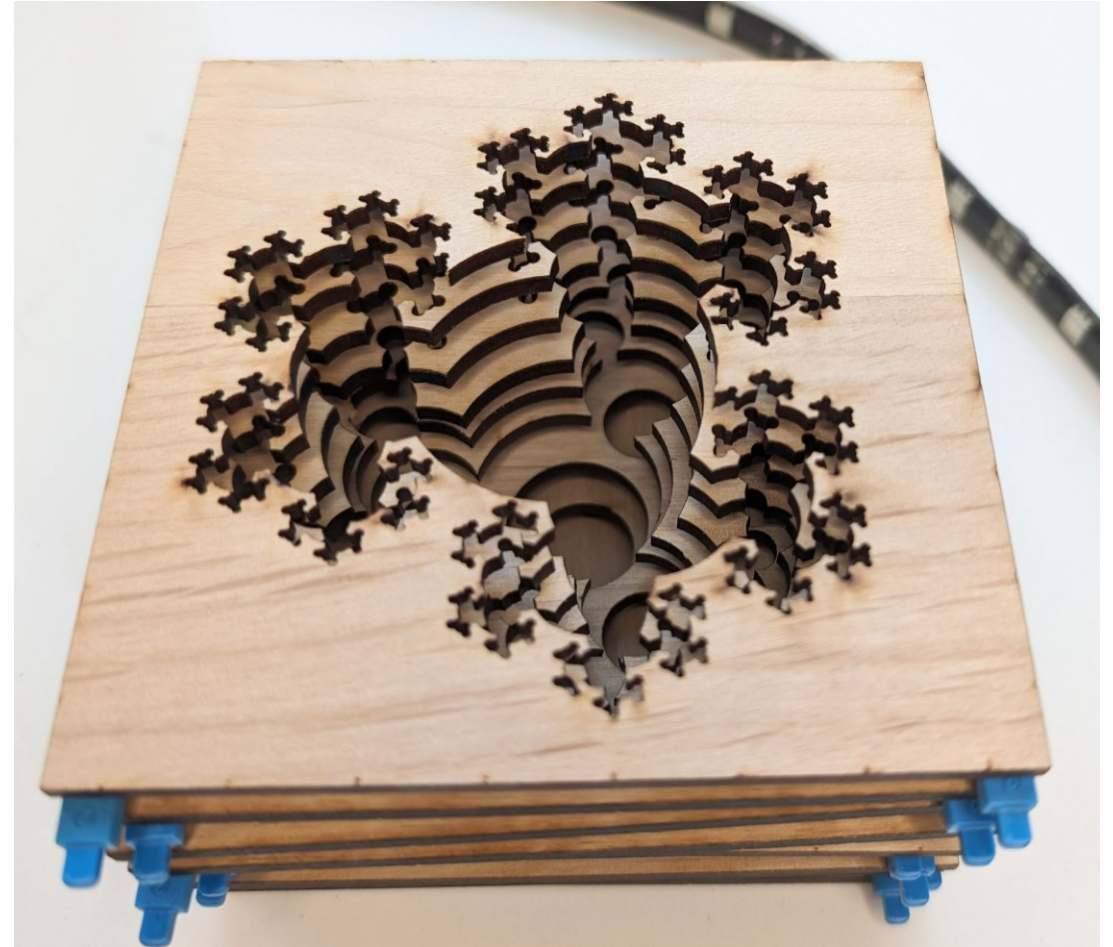
- Slice the model
- One slice per iteration



# Iterative Development: **The artwork, v.1.5**

## **v.1 - Faithful Representation**

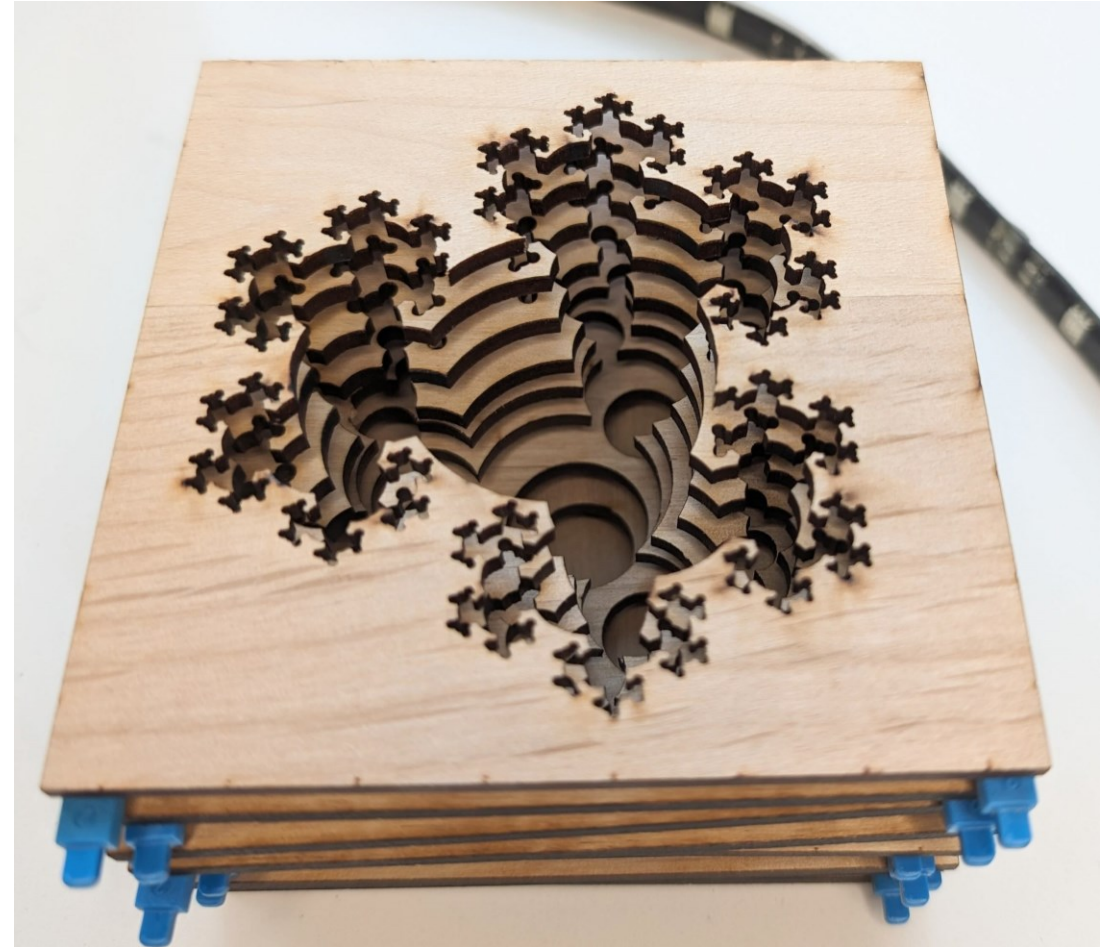
- Slice the model
- One slice per iteration
- **Space the layers to add light**



# Iterative Development: **The artwork, v.1.5**

## **v.1 - Faithful Representation**

- Slice the model
- One slice per iteration
- **Space the layers to add light**
- Add more light with LEDs
- Is this the best representation?



# Iterative Development: **The artwork, v.2**

## **v.1 - Faithful Representation**

Fractal iterations increase upward  
Centers of disks at the same  
position in all levels.

### **Concerns Identified**



The final piece should be  
**engaging,**  
**aesthetically pleasing,**  
**and well-crafted.**

Concerns about the **aesthetics:**

- How much wood is being illuminated?

Concerns about the **well-craftedness:**

- The cut-outs are brittle.

# Iterative Development: **The artwork, v.2**

## **v.1 - Faithful Representation**

Fractal iterations increase upward

Centers of disks at the same position in all levels.

### **Concerns Identified**

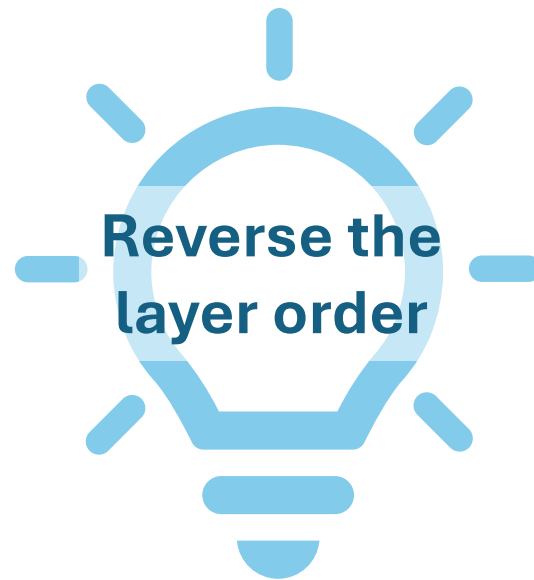


## **v.2 – Dual Representation**

Fractal iterations increase downward

Iterations nest inside each other; disks contract to expose more of the detail.

### **Concerns Addressed**

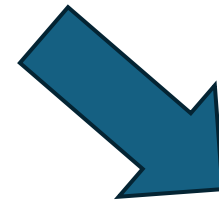
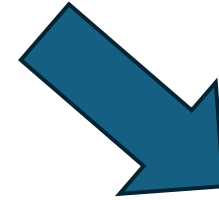


We added acrylic between the layers for consistency.

# Iterative Development: **The artwork, v.3-5**

## Design small changes to hone the artwork

- Change the shape of the artwork
- Test other amounts of spacing, colors
- Adapt the orientation for symmetry
- Top layer has no support holes.

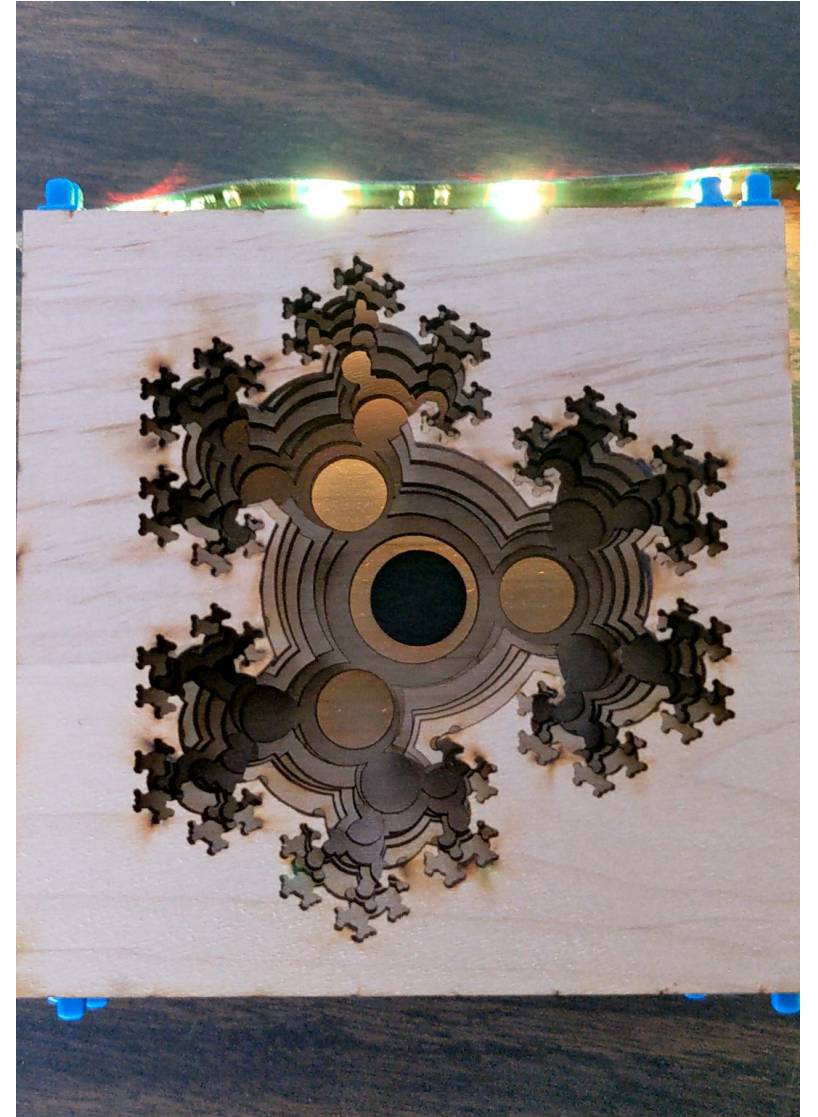
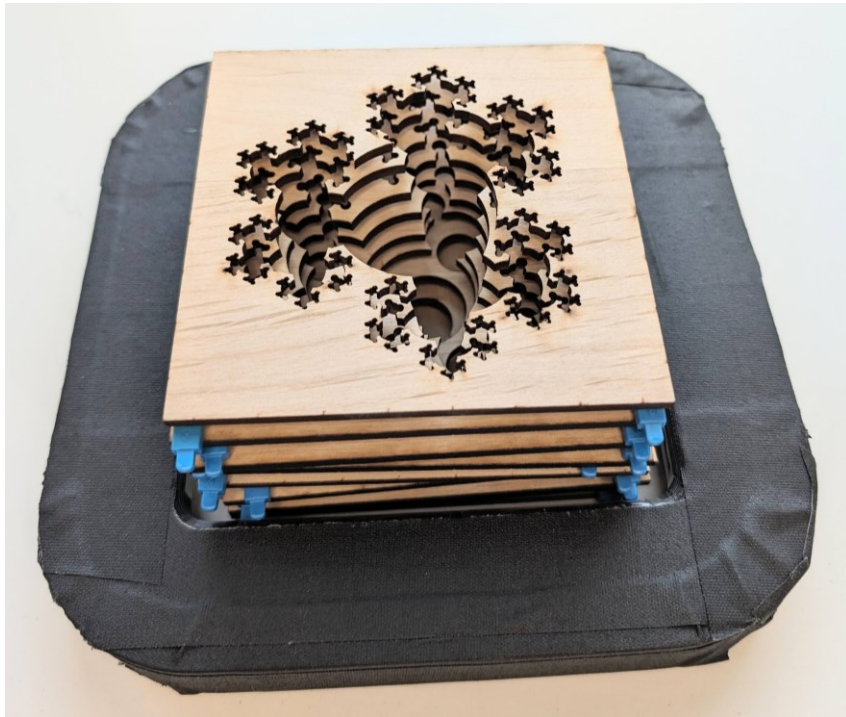


(Principles: Aesthetics & well-designed)



# Iterative Development: **The Housing, v.1**

- LED strip provided the (digital) spark
- **Concern: The lighting is not consistent**
- **Solution: Build a carriage**



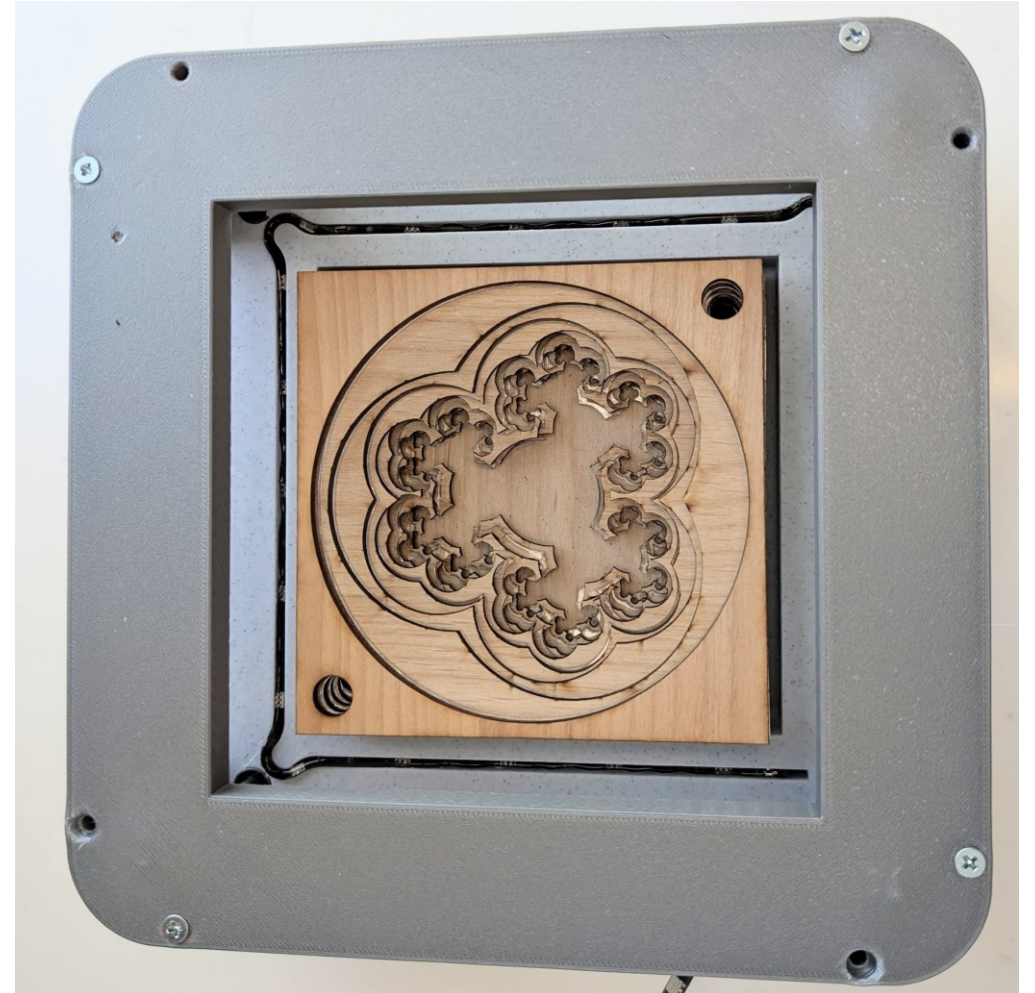
# Iterative Development: **The Housing, v.2**

**Rough form** comes into view

- 3D print a frame
- Mount carriage on linear bearings
- Track for LED lights

**Now what?**

- Looks unpolished
- Art is small.



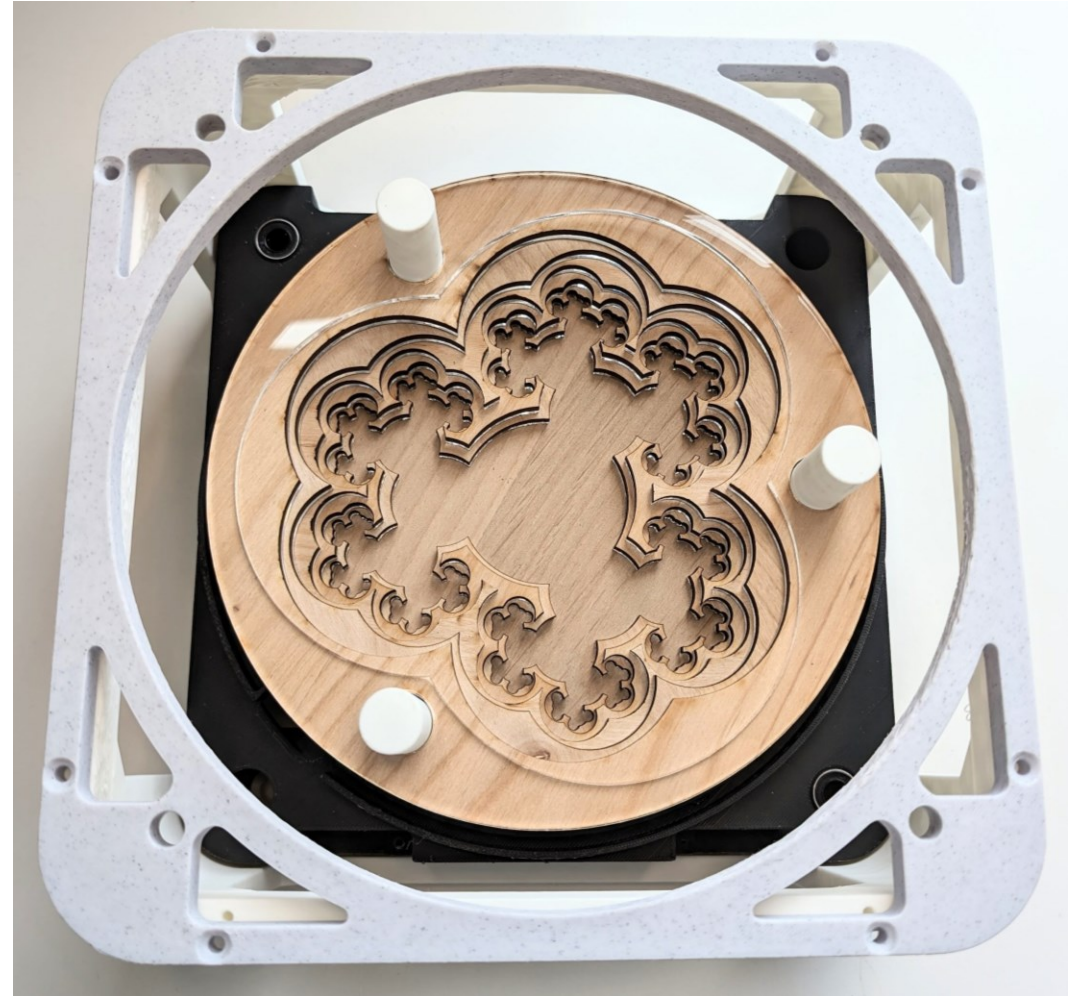
# Iterative Development: **The Housing, v.3**

## Time to design BIG improvements:

- Lighting consistency → circular art
- Increase size of art (machine limits!)
- Art base incorporates pillars
- Extra-tall pillars for experimentation
- Handles
- Planning for wood housing

## Results of testing:

- Only one layer of wood/acrylic
- Attaching Handles awkward!
- LED concerns: path / fragile



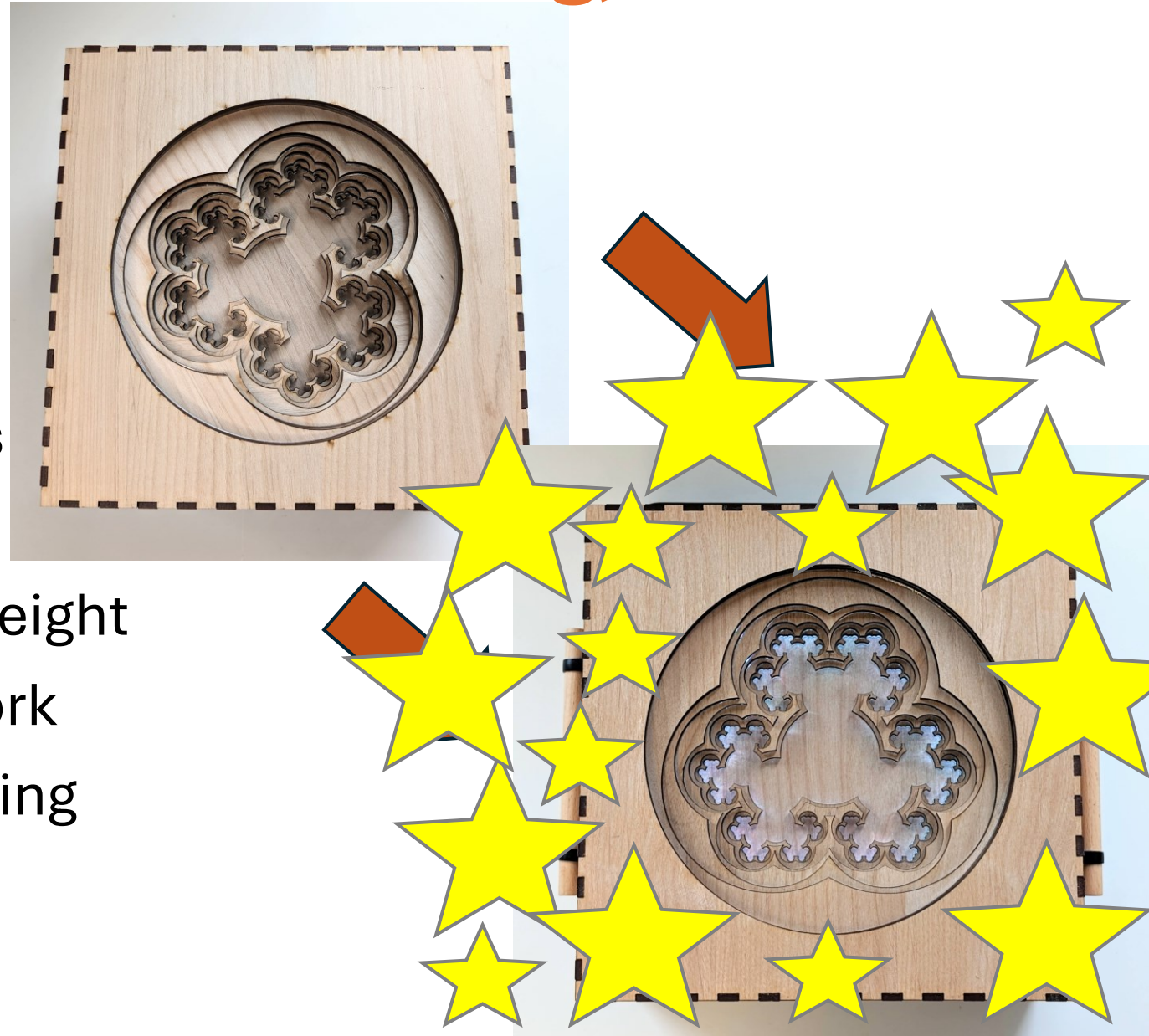
# Iterative Development: **The Housing, v.4-5**

We fixed those in Version 4.

*We experienced distractions.*

## **Time to Nitpick!**

- Not smooth – Oil the bearings
- Faded color – Add varnish
- Easy to move – Add tiles for weight
- Not symmetric – Rotate artwork
- Handle gaps – Redesign housing
- Scraping table – Add felt feet

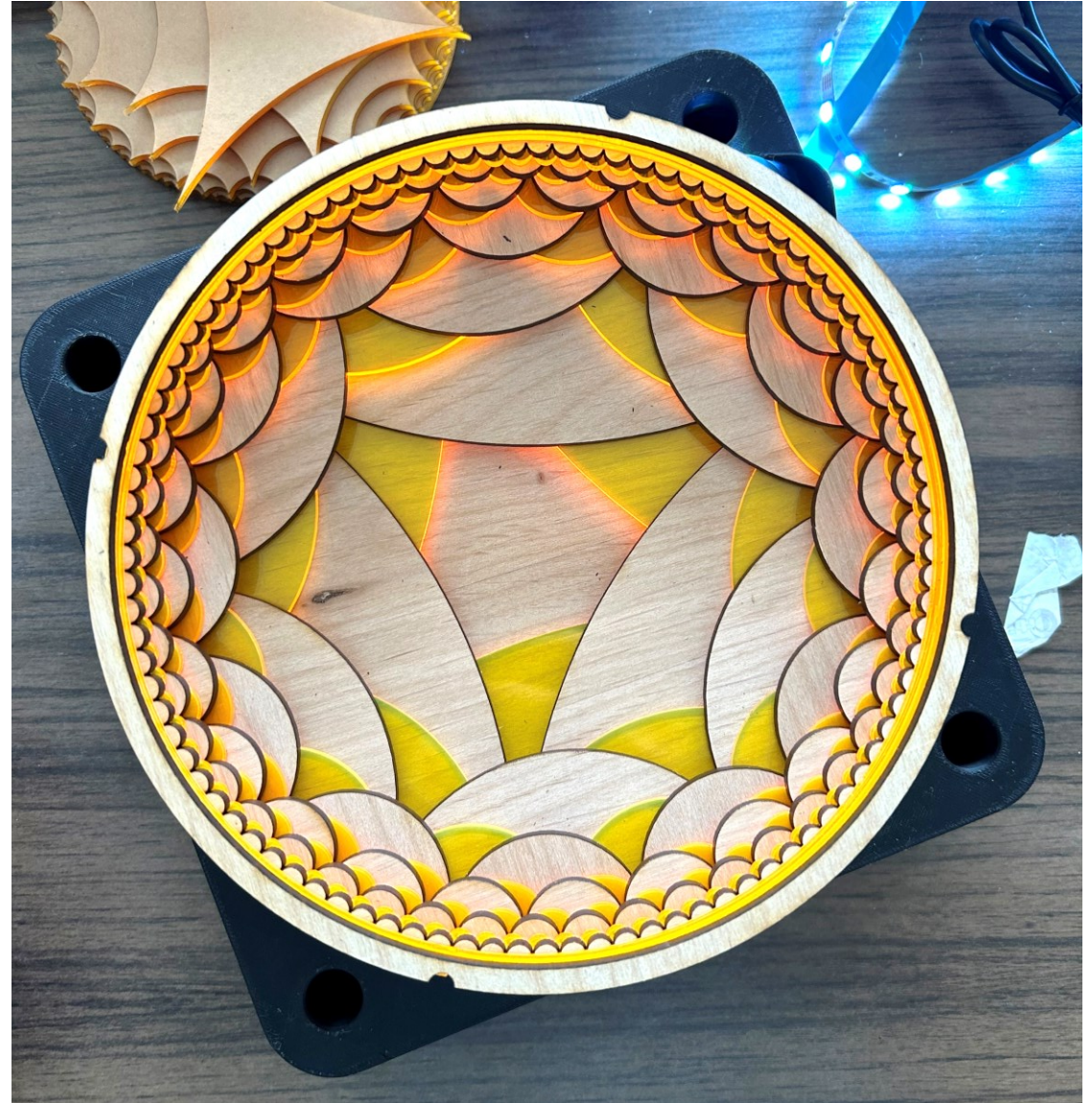


# The Box as a Platform

- Artwork can be swapped out.

## Hyperbolic Emergence

- In the 2024 Bridges exhibit
- Honing never truly complete.
- The supports needed updating



# Takeaways

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- Iterative development process was helpful in making mathematical art.
  - We took the time to evaluate prototypes
  - Closer and closer to the ideal form
- **Aesthetic** and **Mechanical** evolved similarly from Guiding Principles
  - Start w/ Rough Construction
  - Large Improvements Quickly
  - Hone the Final Details
- This is an *artwork of the moment*, relying on technology of today.
  - **Efficiency**: Design software, 3D printers, laser cutters
  - **Access**: Online marketplaces for off-the-shelf components

# What's Next?

- Different / Mixed materials
- One-way mirrors
- Overlaps: shadows
- **Open Question:**  
How to visualize combinatorics?
- **Wish list:** Rotate the art as carriage moves up and down

# Call for Mathematical Art

Submit your artwork to the inaugural  
**Mathematical Art Digital Exhibition  
at Queens College**

- Images / Photos / Videos  
connected to college-level mathematics
- To be shown on video displays and online

To submit & more info: [math.qc.cuny.edu/made](http://math.qc.cuny.edu/made)

First round submission deadline: **August 10**







**THANK YOU!**

I AM: **CHRISTOPHER HANUSA**

**My artwork:** [christopherhanusa.com](http://christopherhanusa.com)

**My mathwork:** [qc.edu/~chanusa](http://qc.edu/~chanusa)

**Email:** [chanusa@qc.cuny.edu](mailto:chanusa@qc.cuny.edu)

**Socials:** [@mathzorro](#) / [@hanusadesign](#)

**Eric Vergo:** [eric.vergo@gmail.com](mailto:eric.vergo@gmail.com)

**Hanusa Design**  
MATHEMATICAL JEWELRY



In the 2024 Bridges Math+Fashion show

**Mathematical Art  
Digital Exhibition  
at Queens College**

