

# Automatic Brain Segmentation for 3D Printing - Phase 6

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Group B1

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# Our Team

## Mechanical Engineers



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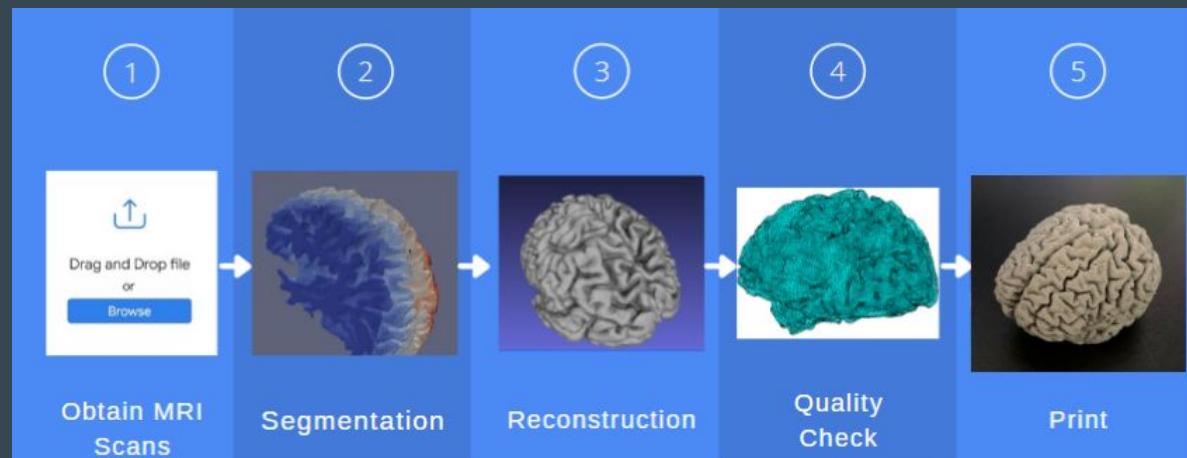
Nicolas Re  
Bernardsville, NJ

# Problem Statement

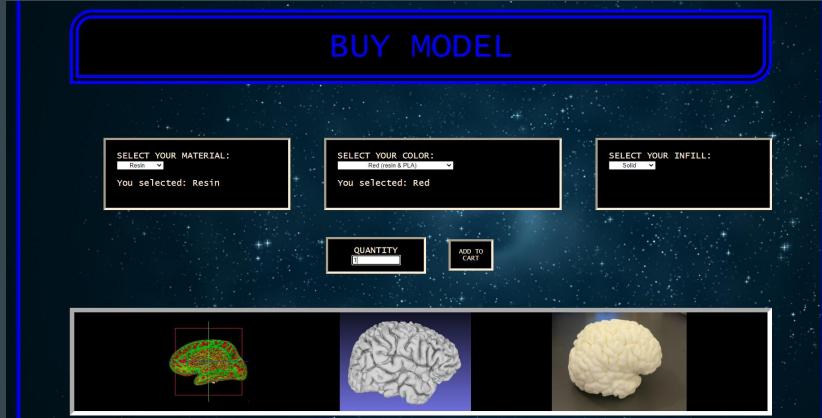
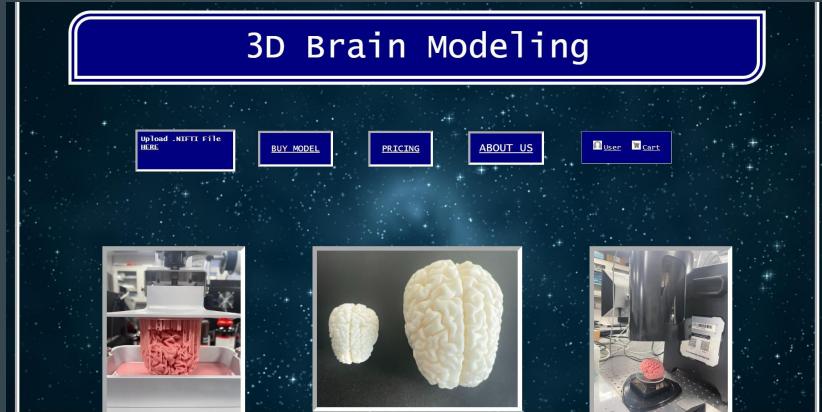
- Create a personalized brain model from an MRI scan
- Make the process from MRI scan to brain model nearly fully automatic
  - Only a single input needed from the customer
- Print 3D model to help doctor/surgeons have an accurate visual aid when explaining the patient's brain ailments or upcoming surgeries
- Create 3D models to serve as gifts/souvenirs for patients receiving brain-related treatment

# Final Beta Prototype Design

1. Our UI design
  - a. Within UI is code to execute process
2. Freesurfer Software
3. Meshlab Software
4. Meshmixer Software
5. Printer



# UI



- First page of UI allows customers to upload their MRI and access the rest of the page
- The “Buy Model” page allows the user to select the material, color, infill type, and quantity for their 3D models

# UI

The Pricing page displays two tables. The first table, titled "PRICING OPTIONS", shows the cost per print for three materials: PLA, RESIN, and MULTI. The second table, titled "MONTHLY SUBSCRIPTION OPTIONS", shows the number of models included and the cost for Bronze, Silver, and Gold levels, along with material options.

MATERIAL	COST PER PRINT
PLA	\$X
RESIN	\$X
MULTI	\$X

Type	# OF Models	MATERIAL OPTIONS	COST
Bronze	5	PLA	X
Silver	10	PLA & RESIN	X
Gold	15	PLA, RESIN & MULTI	X

- The pricing page informs the user on the pricing for the different types of materials offered, and offers a subscription plan for the option of bulk purchasing

The Create Account page features a form for entering user information. It includes fields for "User Email" and "User Password", a checkbox for agreeing to the terms of service, and a "Create Account" button. Below the form, there are links for "Sign In With Google" and "Do you have an account? [Sign In](#)".

CREATE ACCOUNT

User Email: \_\_\_\_\_  
User Password: \_\_\_\_\_

I agree to the terms of services  
[Create Account](#)

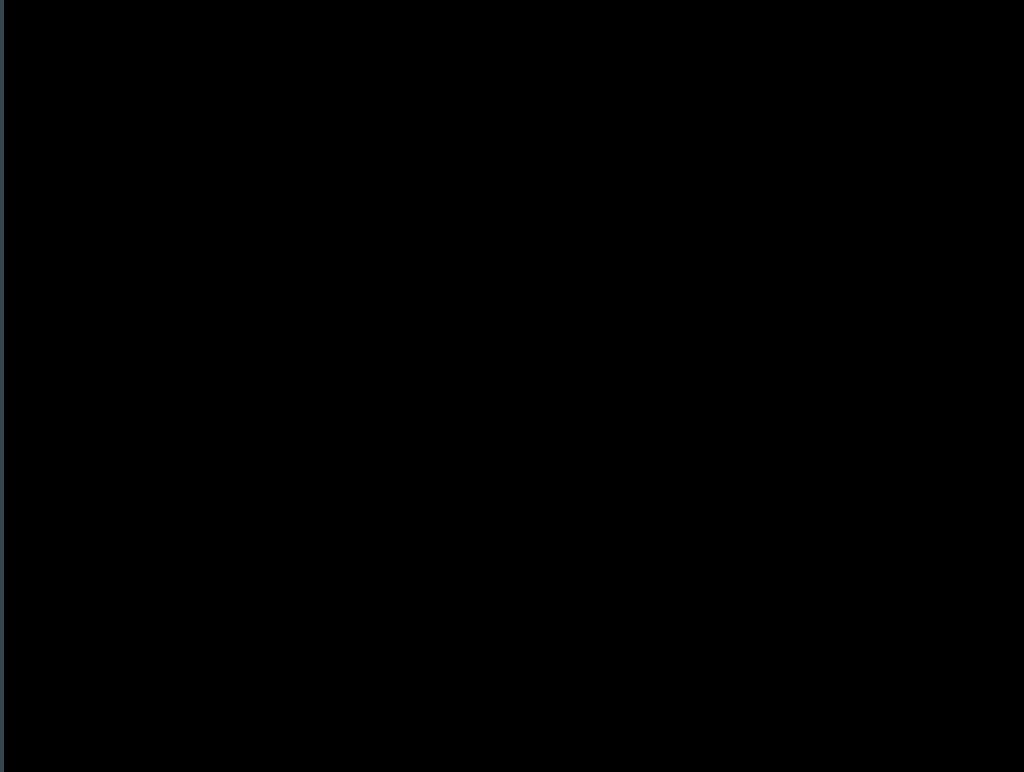
OR

[Sign In With Google](#)

Do you have an account? [Sign In](#)

- This page allows the user to create an account so that they can be notified of the model progress/status

# UI Demonstration



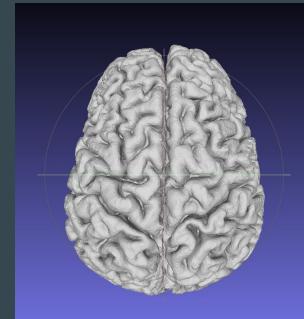
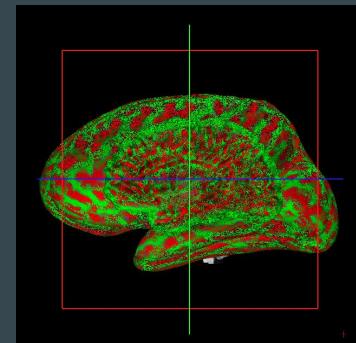
# FreeSurfer

- Commands used to upload NIFTI files into Freesurfer
- Recon-all command used to perform segmentation process
- Last group of commands to convert file into .stl for the rest of the pipeline/printing
- Boolean union used to unify both hemispheres of the brain

```
----- freesurfer-linux-ubuntu18 x86_64-dev-20211020-b964143 -----
Setting up environment for FreeSurfer/FSL-FAST (and FSL)
FREESURFER_HOME  /usr/local/freesurfer/7-dev
FSFAST_HOME      /usr/local/freesurfer/7-dev/fsfast
FSF_OUTPUT_FORMAT nii.gz
SUBJECTS_DIR     /usr/local/freesurfer/7-dev/subjects
MNI_DIR          /usr/local/freesurfer/7-dev/mni
nathan@LAPTOP-FF9FC75L:~$ cd /usr/local/freesurfer/7-dev/subjects
nathan@LAPTOP-FF9FC75L:/usr/local/freesurfer/7-dev/subjects$ 
nathan@LAPTOP-FF9FC75L:/usr/local/freesurfer/7-dev/subjects$ sudo cp -r <Path to File> /usr/local/freesurfer/7-dev/subjects
```

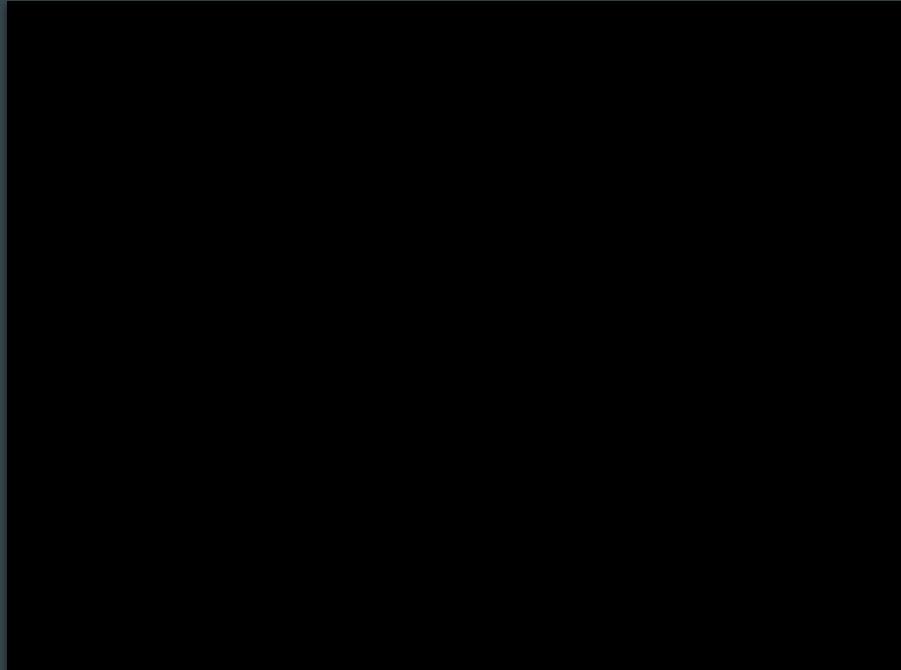
```
recon-all -s subj01 -i subj1_anat.nii -all
```

```
nathan@LAPTOP-FF9FC75L:~$ cd /usr/local/freesurfer/7-dev/subjects
nathan@LAPTOP-FF9FC75L:/usr/local/freesurfer/7-dev/subjects$ mris_convert /usr/local/freesurfer/7-dev/subjects/NIFTI01/surf/rh.pial rh.stl
Saving rh.stl as a surface
nathan@LAPTOP-FF9FC75L:/usr/local/freesurfer/7-dev/subjects$ mris_convert /usr/local/freesurfer/7-dev/subjects/NIFTI01/surf/lh.pial lh.stl
Saving lh.stl as a surface
```



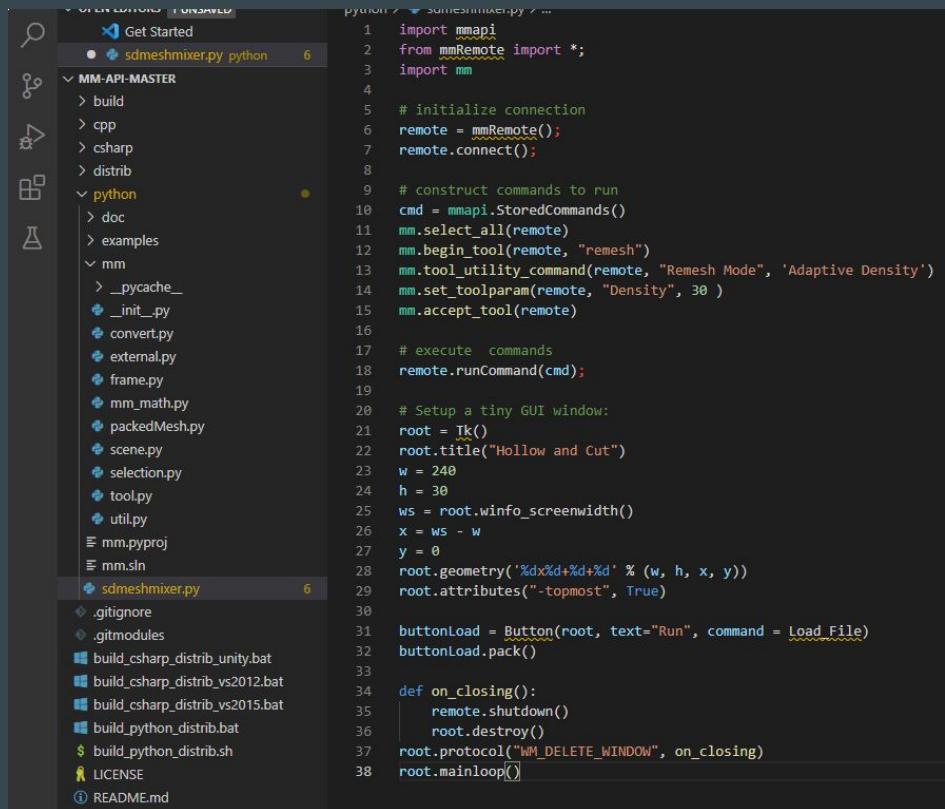
# Meshlab

- Final commands used
  - Flatten Visible Layers - Fix layers that were segmented incorrectly
  - Quadric Edge Collapse Decimation - Fix holes and inconsistencies
  - HC Laplacian Smoothing - Smooth the model
- Python script
  - Program provides easy way to alter script



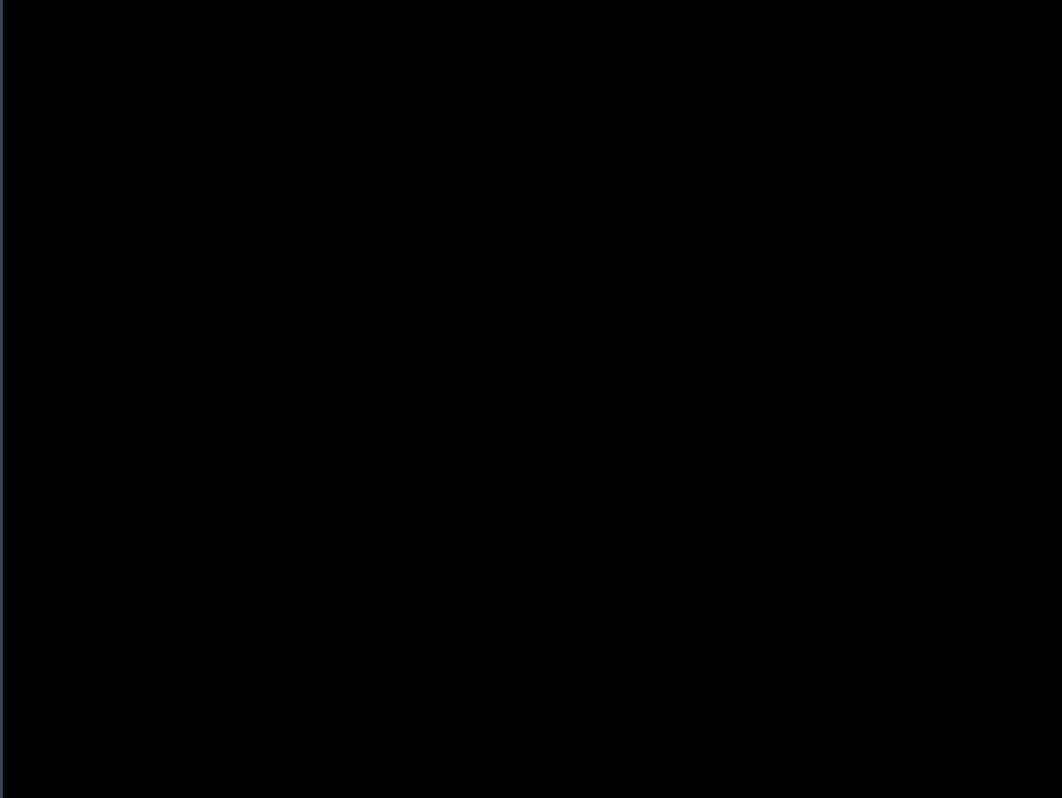
# Meshmixer

- Meshmixer API used to remotely control Meshmixer
  - mm.select\_all
  - mm.begin\_tool
  - mm.tool\_utility\_command
  - mm.set\_toolparam
  - remote.runCommand
- Meshmixer commands used
  - Remesh
  - Adaptive Density
  - Mesh Density



```
python > * sdmeshmixer.py > ...
1 import mmapi
2 from mmRemote import *
3 import mm
4
5 # initialize connection
6 remote = mmRemote();
7 remote.connect();
8
9 # construct commands to run
10 cmd = mmapi.StoredCommands()
11 mm.select_all(remote)
12 mm.begin_tool(remote, "remesh")
13 mm.tool_utility_command(remote, "Remesh Mode", 'Adaptive Density')
14 mm.set_toolparam(remote, "Density", 30 )
15 mm.accept_tool(remote)
16
17 # execute commands
18 remote.runCommand(cmd);
19
20 # Setup a tiny GUI window:
21 root = Tk()
22 root.title("Hollow and Cut")
23 w = 240
24 h = 30
25 ws = root.winfo_screenwidth()
26 x = ws - w
27 y = 0
28 root.geometry('%dx%d+%d+%d' % (w, h, x, y))
29 root.attributes("-topmost", True)
30
31 buttonLoad = Button(root, text="Run", command = Load_File)
32 buttonLoad.pack()
33
34 def on_closing():
35     remote.shutdown()
36     root.destroy()
37 root.protocol("WM_DELETE_WINDOW", on_closing)
38 root.mainloop()
```

# Meshmixer - Output Comparison

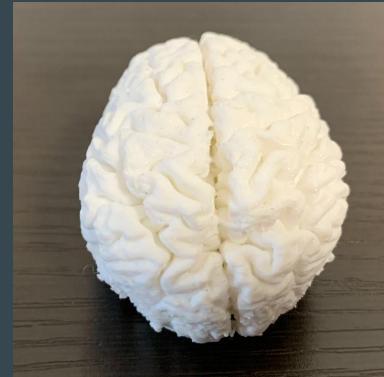
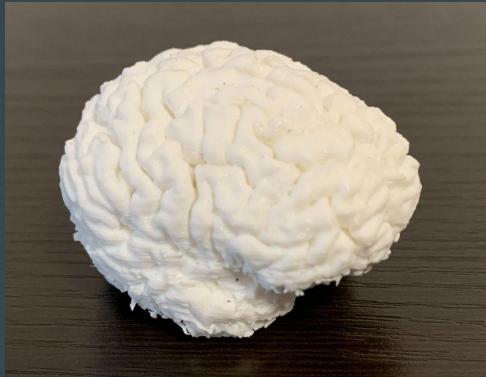


# Printing - First Iteration



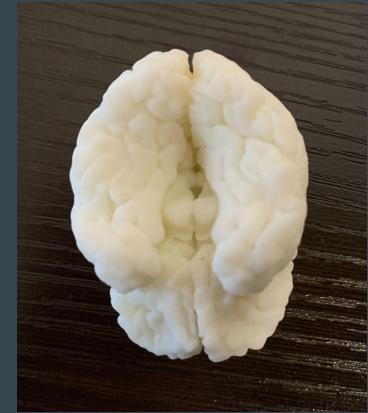
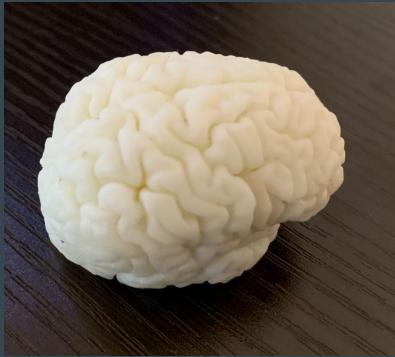
- First print was done in PLA
- Proved feasibility of process
- Lacking in quality and durability
- Underside of brain has minimal detail
- 1:4 ratio

# Printing - Different MRI



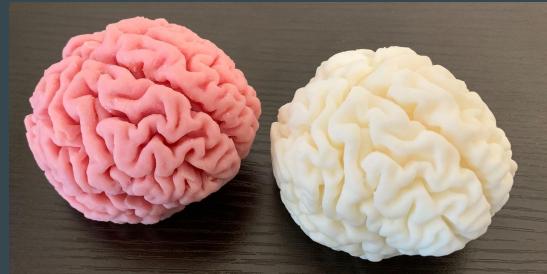
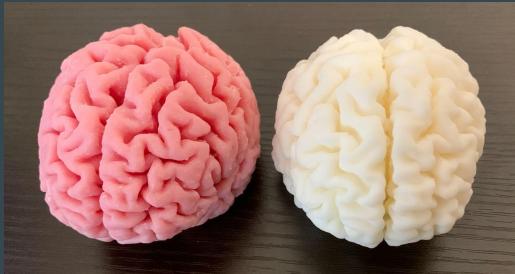
- A different MRI was run through the process
- A print was successfully generated in a white PLA
- The top had decent quality but the sides began to lose detail
- Bottom of print was unacceptable

# Printing - Material Switch



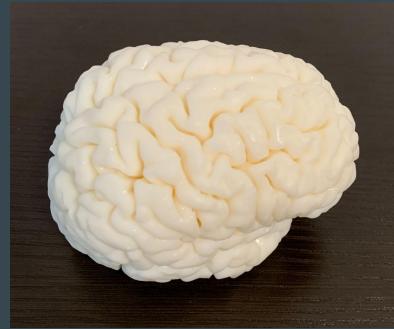
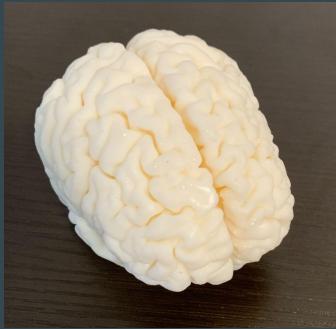
- First print with resin material
- Quality was much higher
- Print time and cost were beneficial
- Team was leaning towards resin being main material

# Printing - Process Evaluation



- The pink brain on the left is a print without the smoothing and repair steps
- Right white brain is a finalized model
- The right is much smoother and has better detail
- Biggest difference is noticed by looking at underside
- Shows importance of later steps of pipeline
- Both prints were 1:2

# Printing - Resin Further Testing



- Another MRI scan was run through pipeline and printed in resin
- Again team was happy with the print quality
- The weight is significantly higher than the PLA models
- Pipeline seems to handle various MRIs easily

# Printing - Two Material & Lattice Infill



- Two images of the brain on the left were experimental two-material prints
  - Translucent PLA was used to represent grey matter, pink PLA represented white matter
  - Print did not come out great, hard to see distinction between the two materials
  - 1:2 ratio
- The brain in the two photos on the right was a lattice infill test (1:4 ratio)
  - Print time was quicker and model was very light
  - Sufficient for strictly outer detail observing
  - Another testament of the poor underside print quality from PLA material

# Moving Forward

- Continue to look into different materials
  - Qualities that replicate those of the brain
  - More transparent to see inside
- Optimize the automatic process to make it smoother
- Test MRI scan with abnormality to see how results are displayed



# Key Insights & Lessons Learned

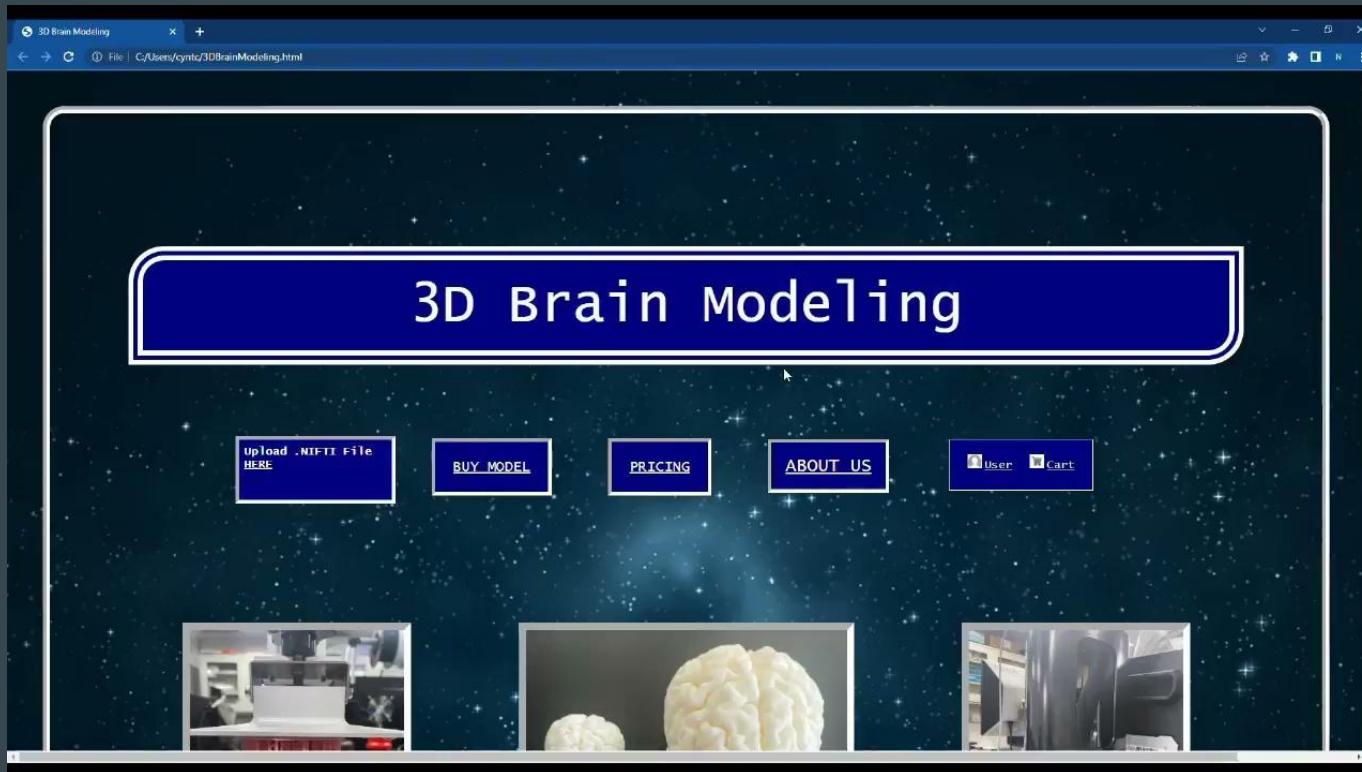
- Coding
- Importance of doing thorough research
  - Allows for full comprehension of product
  - Promotes new ideas
  - Prevents roadblocks for future plan
- Full process from idea to beta prototype
  - Idea, research, alpha prototype, testing, beta prototype



# Thank You!



# Additional Slides- Beta Prototype Demonstration



# Innovation Expo Table

