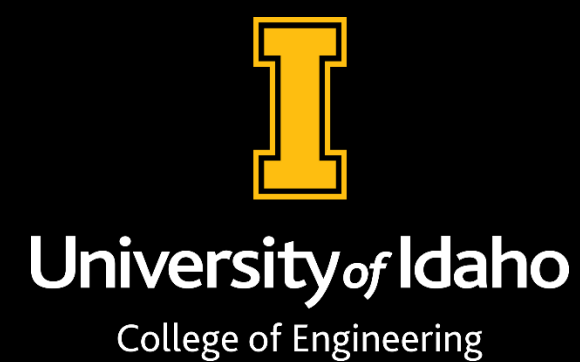


EXPO
engineering ▲ design



APOLLO MINI SLIDE SCANNER

MICHAEL CAMERINO

JEFF CRAWFORD

ARCHANA DAHAL

ISAAC RIGGS

NICHOLAS YENSEN

TEAM MEMBERS

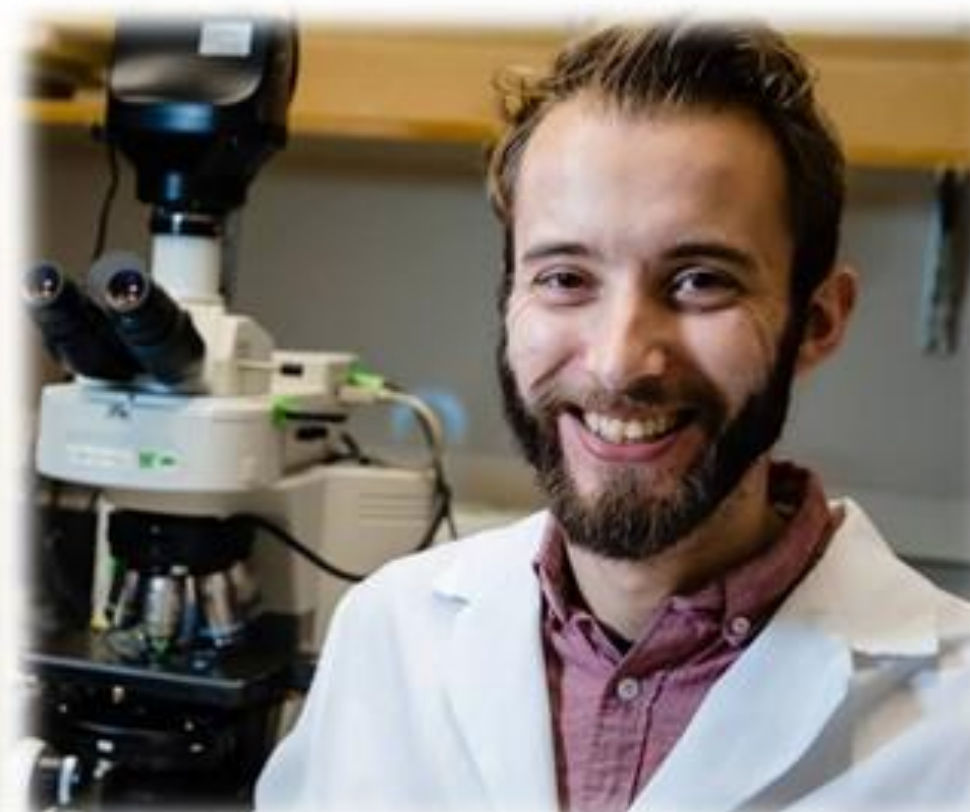
Nicholas Yensen



Archana Dahal



Jeff Crawford



Michael Camerino



Isaac Riggs

OBJECTIVE

We aim to develop a product that is an affordable, portable, and rugged microscope slide scanner to diagnose early stage cancers in developing countries where access to biomedical tools are limited.



Improved access to educational opportunities and technology is integral to economic progress in the developing world.

(Credit: World Atlas)

VALUE PROPOSITION

- World wide, there are 9.5 million cancer deaths per year, 70% are in developing countries (WHO, 2018).

Why?

- Late stage diagnoses due to little or no diagnostics available
- Limited medical expertise available locally



Kenyatta National Hospital Cancer Treatment Center
(Credit: Management Sciences for Health)

BACKGROUND

Apollo Mini Slide Scanner:

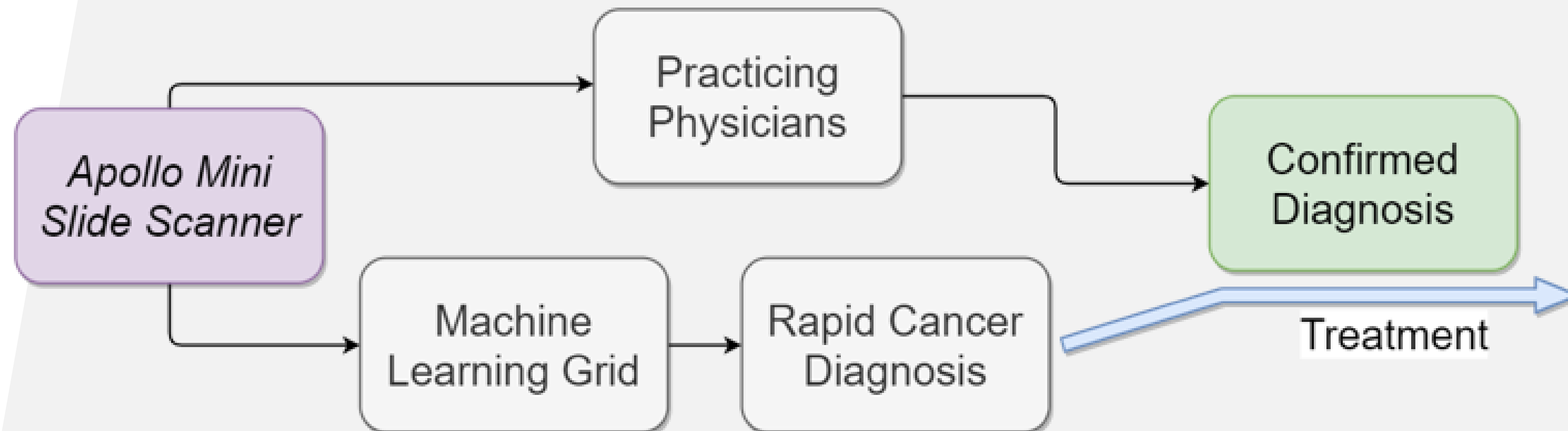
Low-cost, durable,
portable

Machine Learning Grid:

Diagnosis with 97% accuracy
Expediated start of cancer
treatment

Practicing physicians:

Confirming diagnosis made by
Machine Learning Grid



KEY REQUIREMENTS

Cost:

- **Device under \$1000**

Interface and Networking :

- Bluetooth 4.1 compliant
- Interface device via Apollo phone app

Storage and Battery:

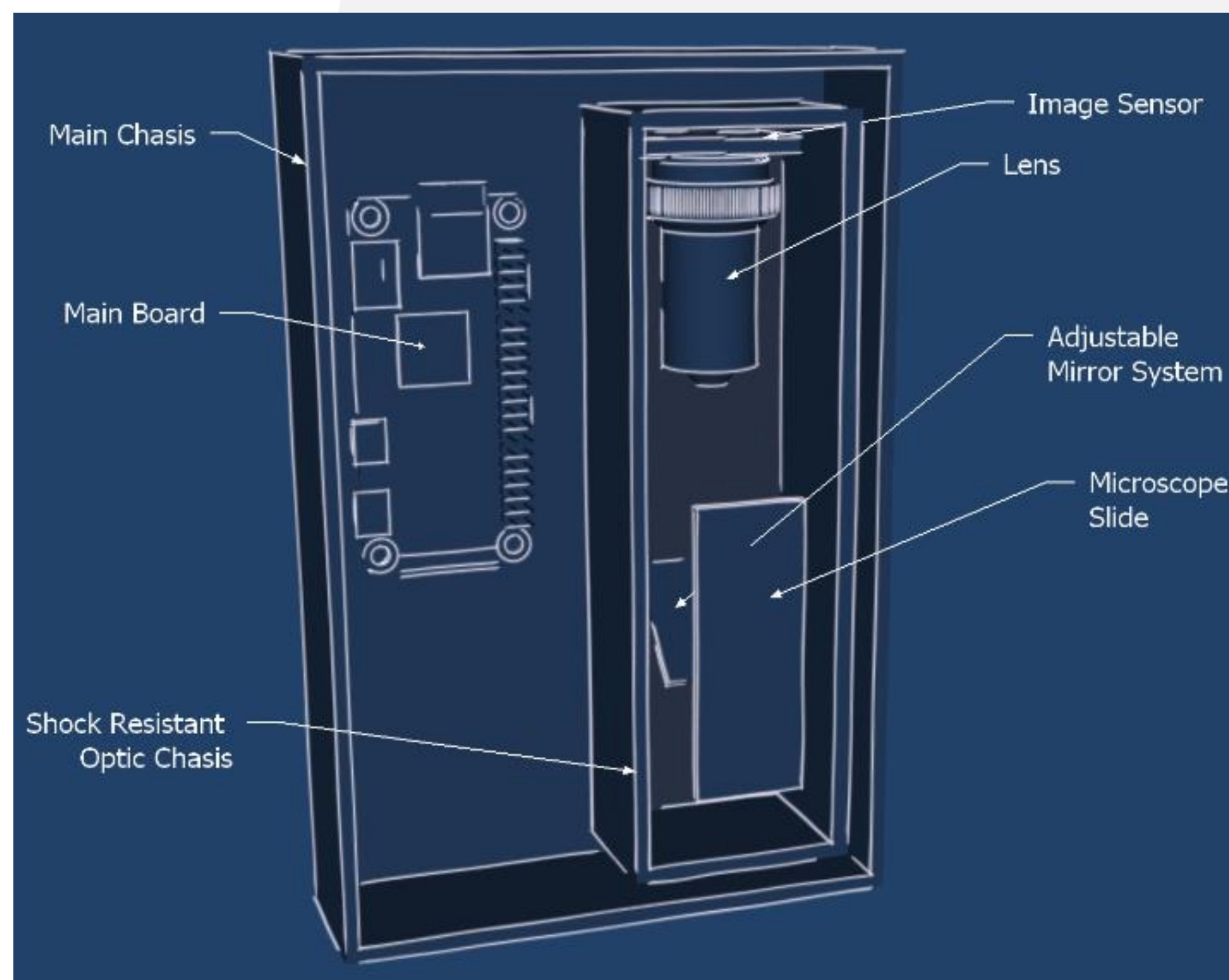
- Utilization of phone memory storage
- 8000 cycles per charge

Optics and Camera:

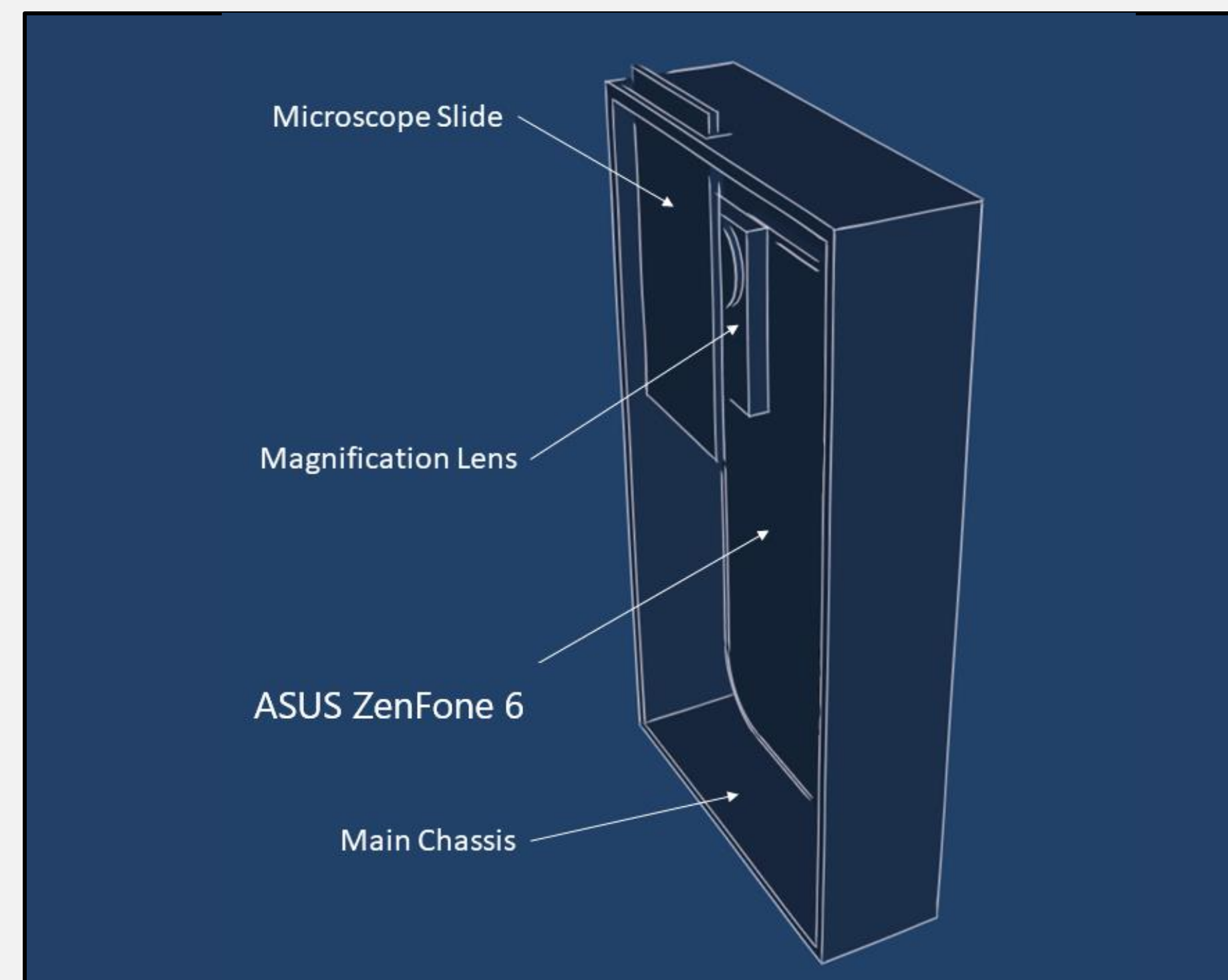
- **20x effective zoom**
- **0.25 - 0.5 μm /pixel resolution**
- **Large format imaging capability (up to 1cm²)**
- 30 minute image acquisition time limit
- Auto-focus

CONCEPT DEVELOPMENT

DESIGN COMPARISON



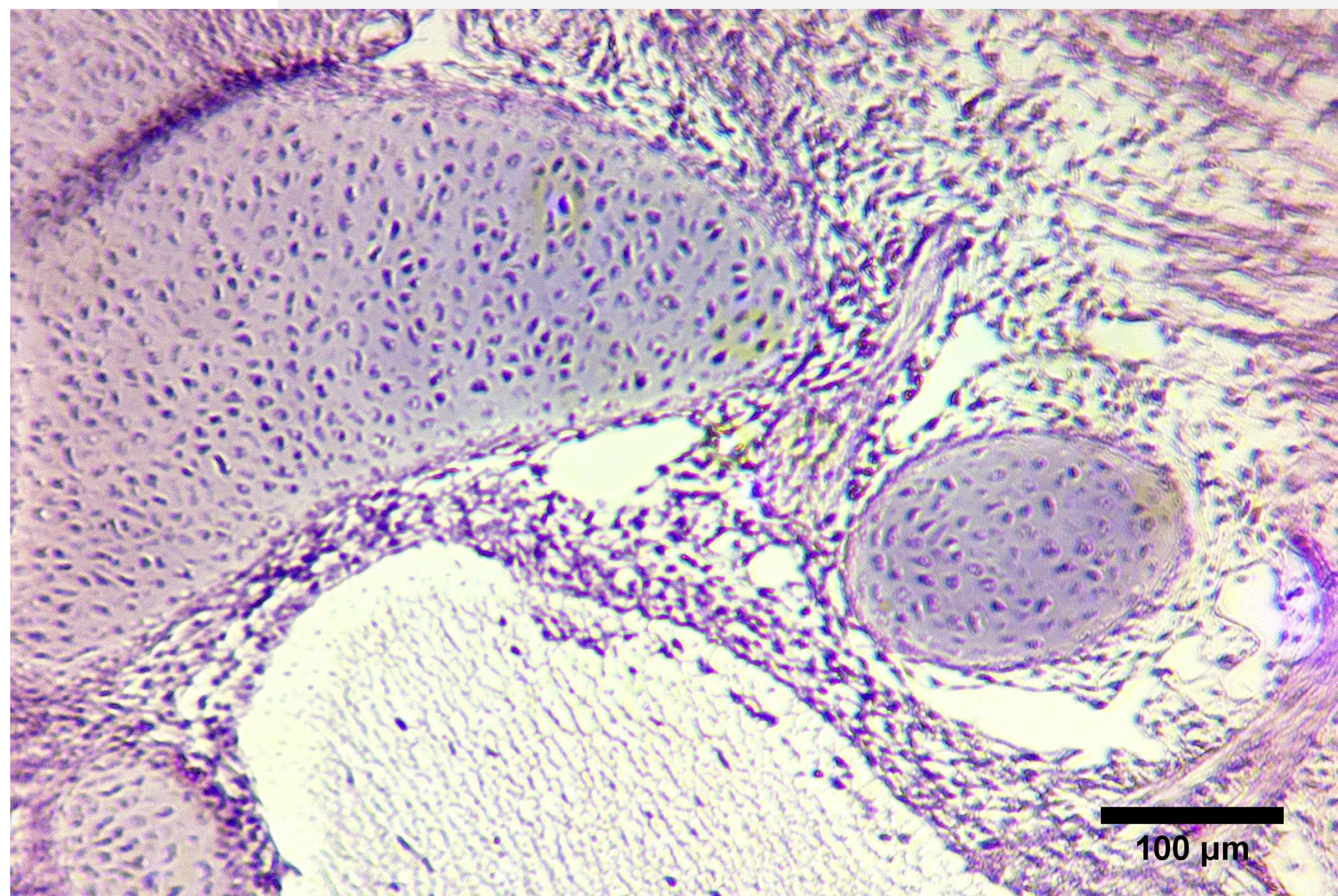
Design A:
Standalone Device Concept



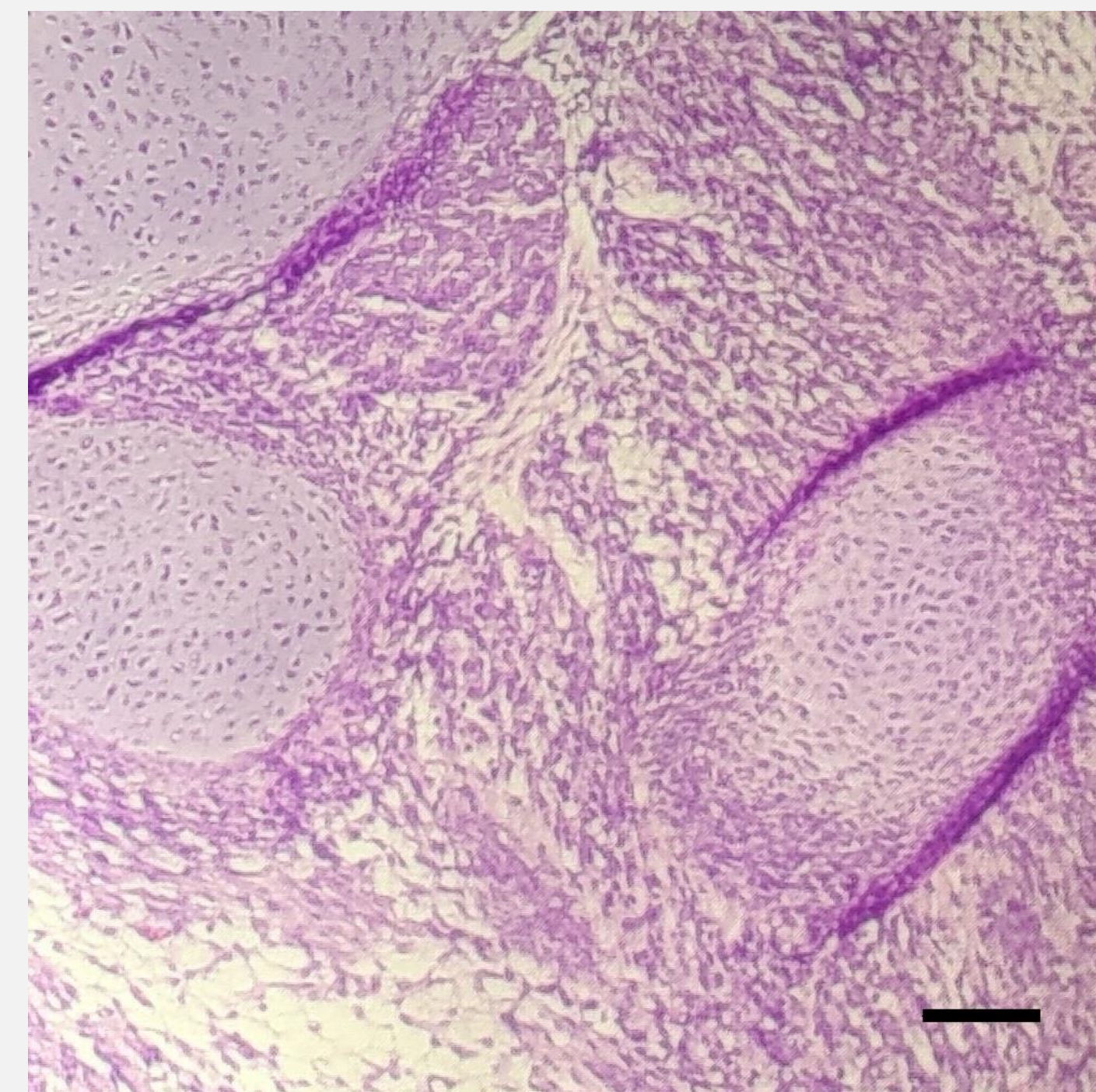
Design B:
Integrated Phone Concept

CONCEPT DEVELOPMENT

IMAGE QUALITY COMPARISON



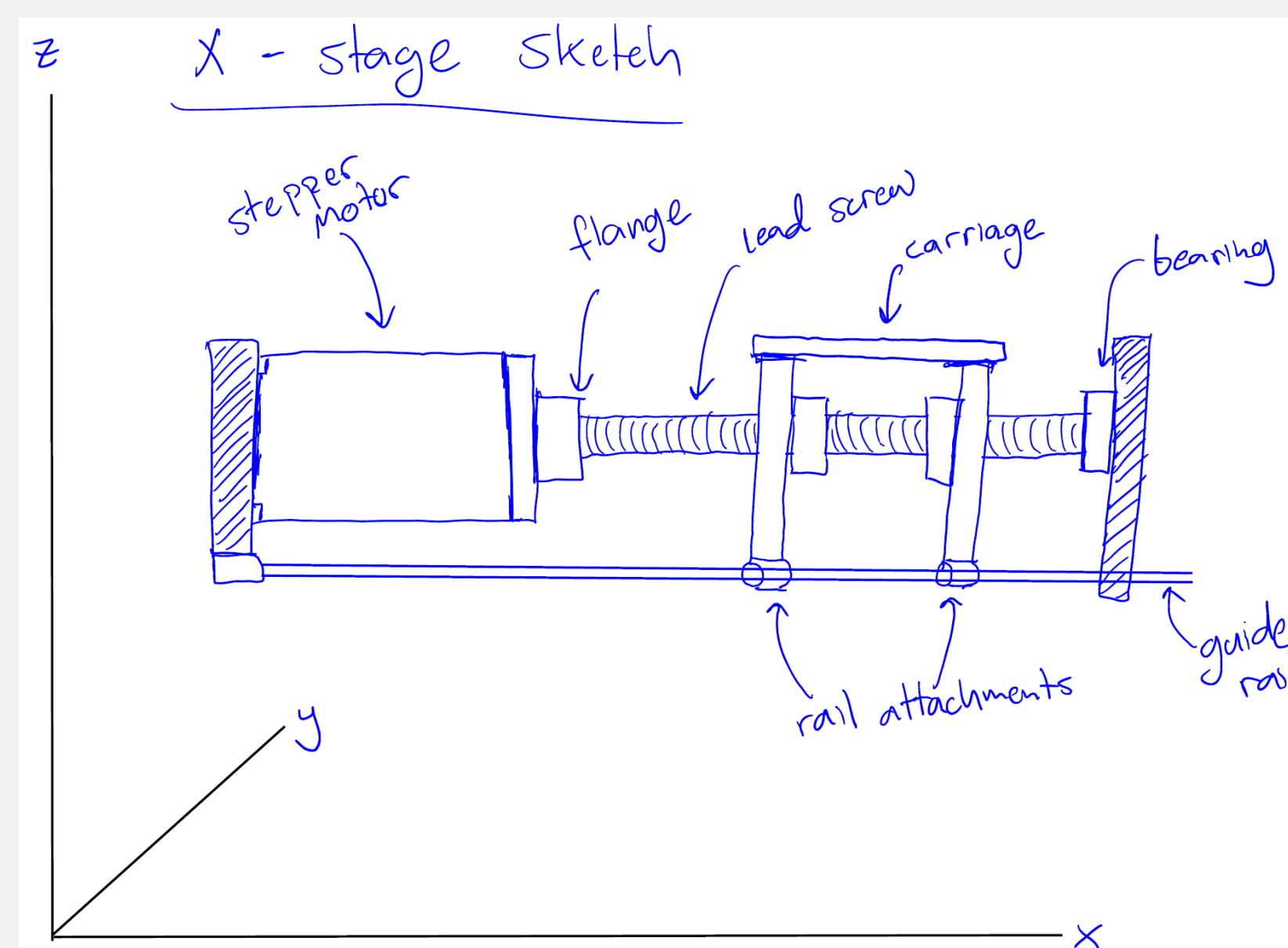
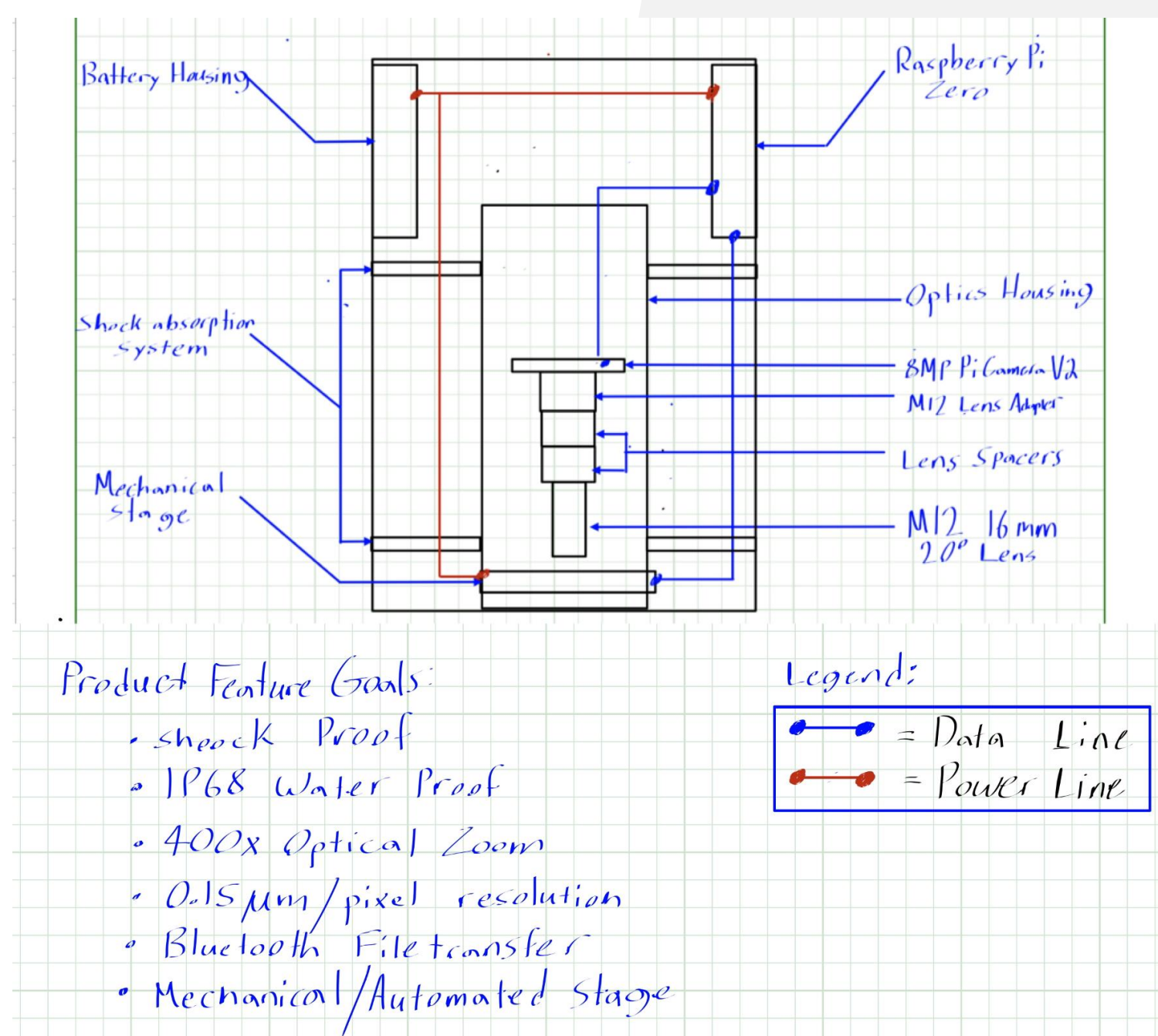
Design-A:
0.35 $\mu\text{m}/\text{px}$



Design-B:
0.65 $\mu\text{m}/\text{px}$

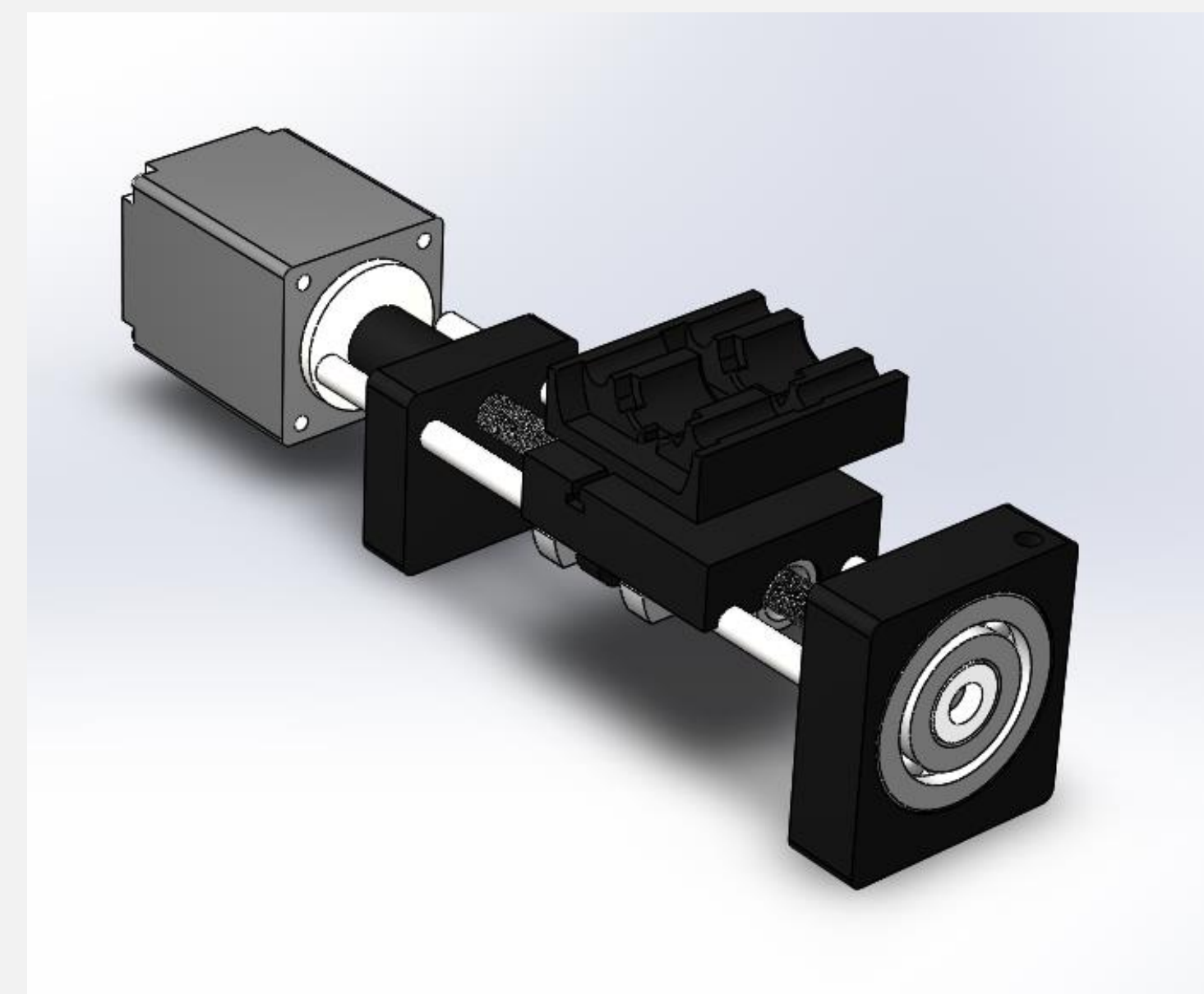
CONCEPT DEVELOPMENT

DESIGN-A DEVELOPMENT



X-Stage Early Design

(Jan. 21st)

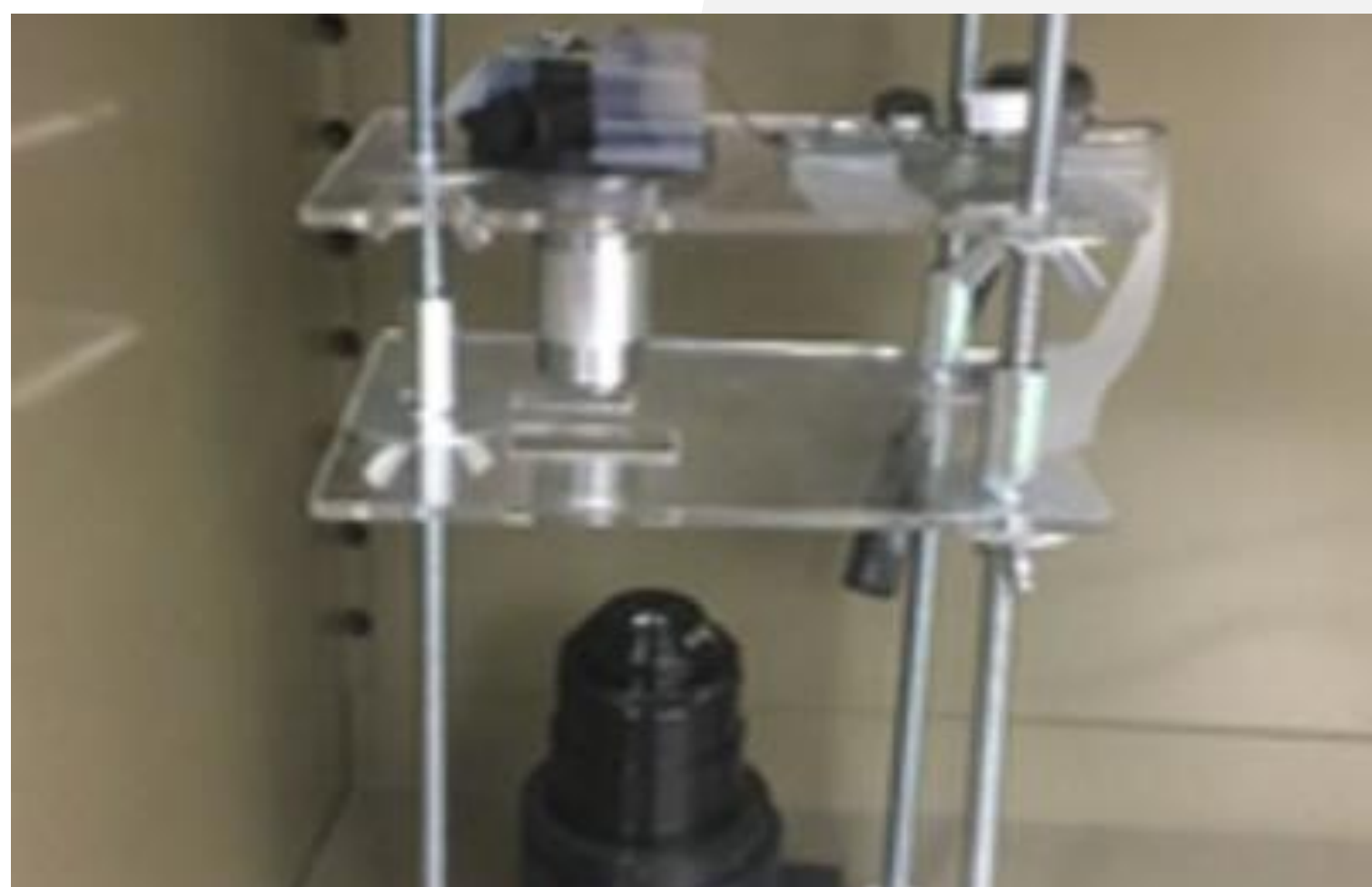


X-Stage Early CAD Model

(Mar. 31st)

CONCEPT DEVELOPMENT

DESIGN-A PROTOTYPING



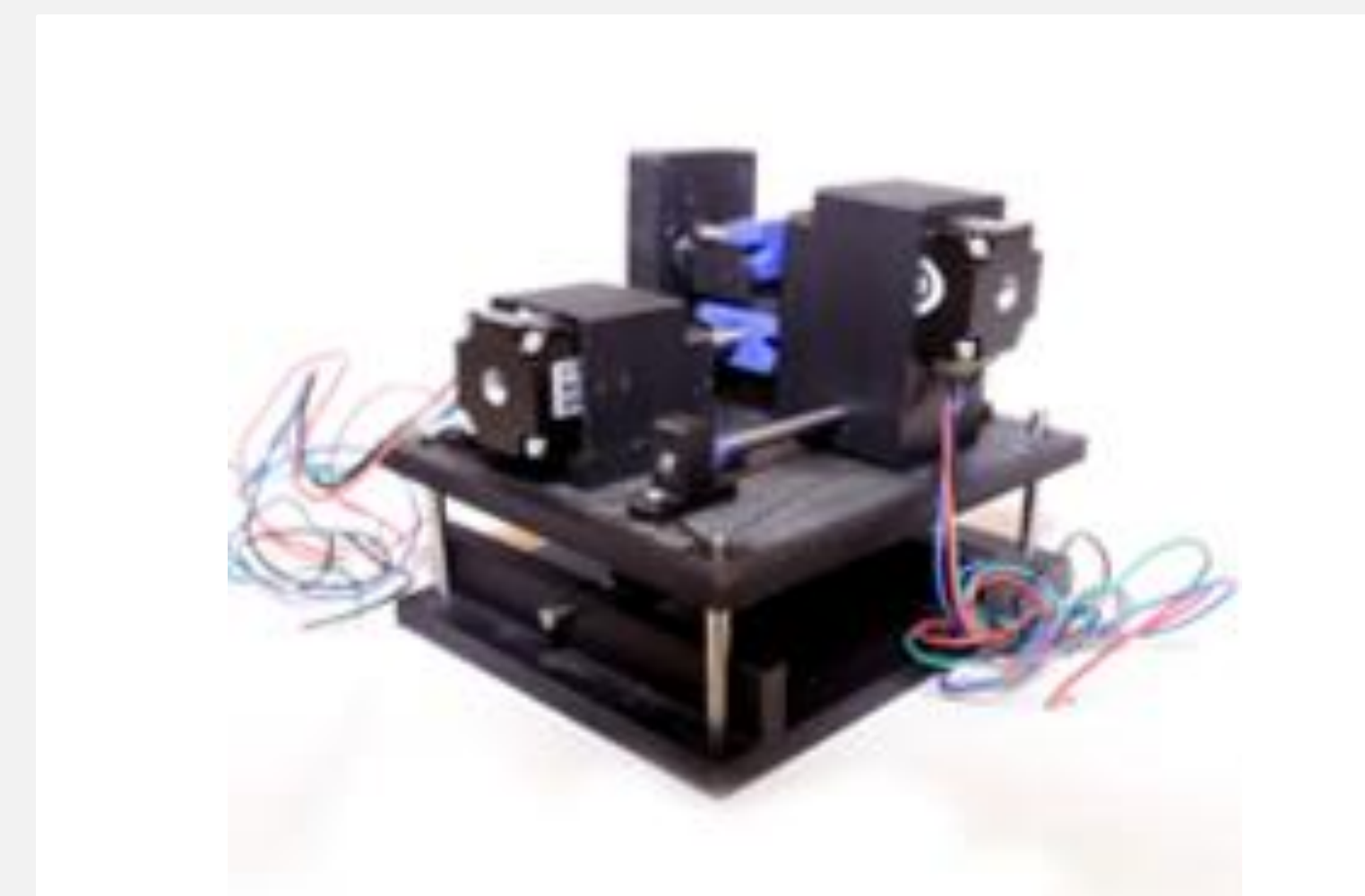
Optics Calibration Prototype

(Sept. 17th)



Initial Y-Stage Build

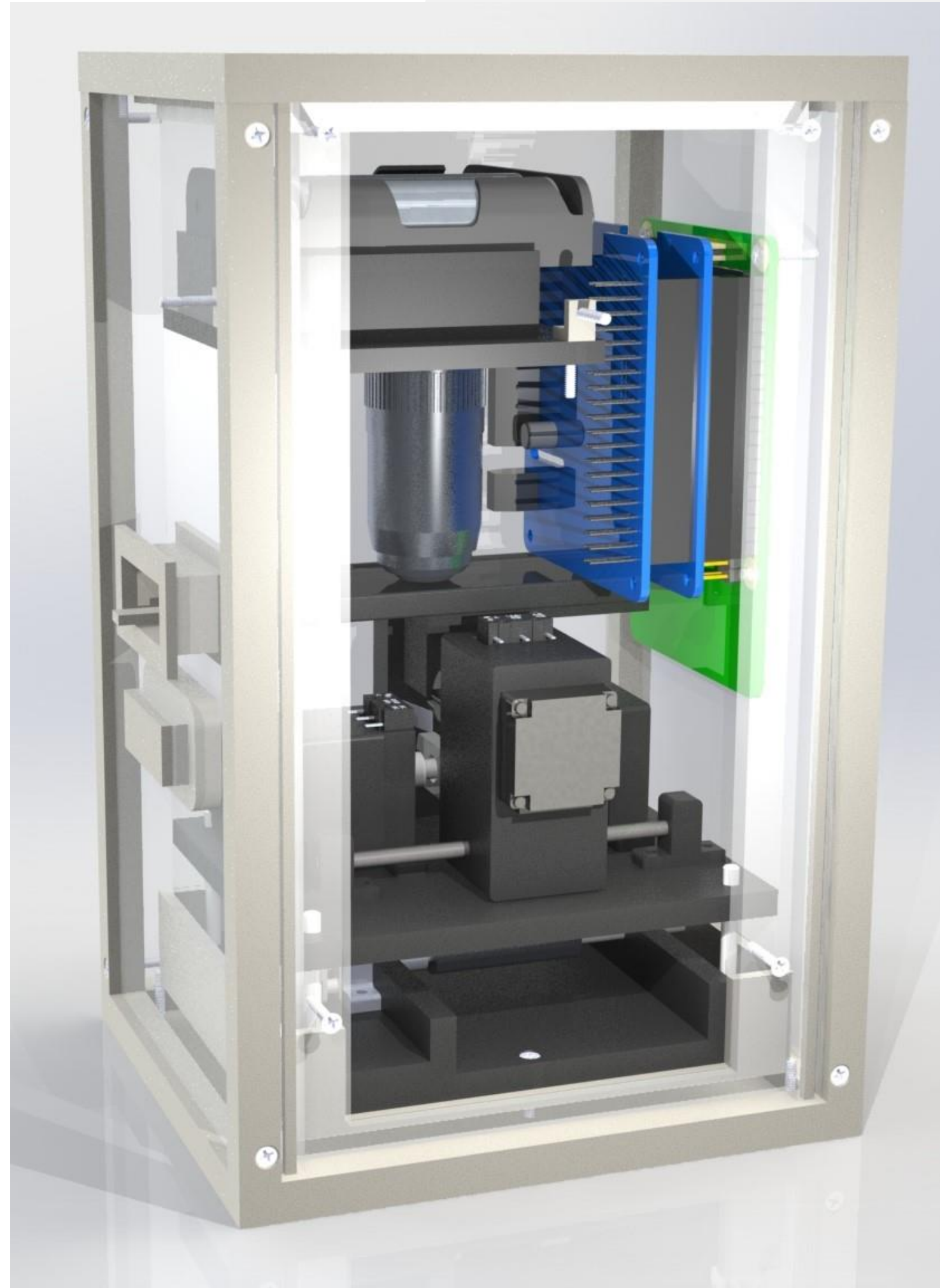
(Feb. 22nd)



Final Stage Prototype

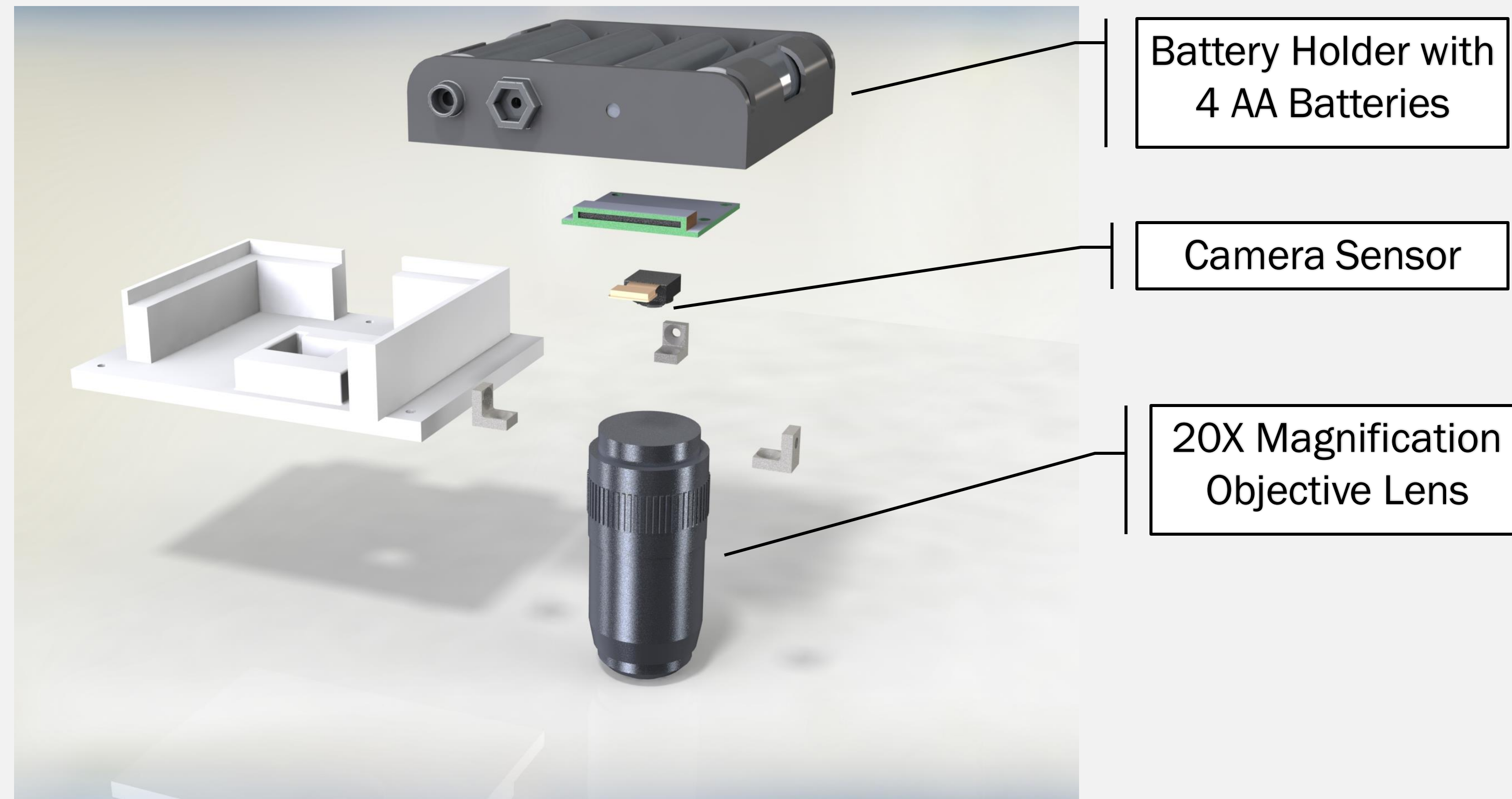
(Apr. 25th)

FINAL DESIGN



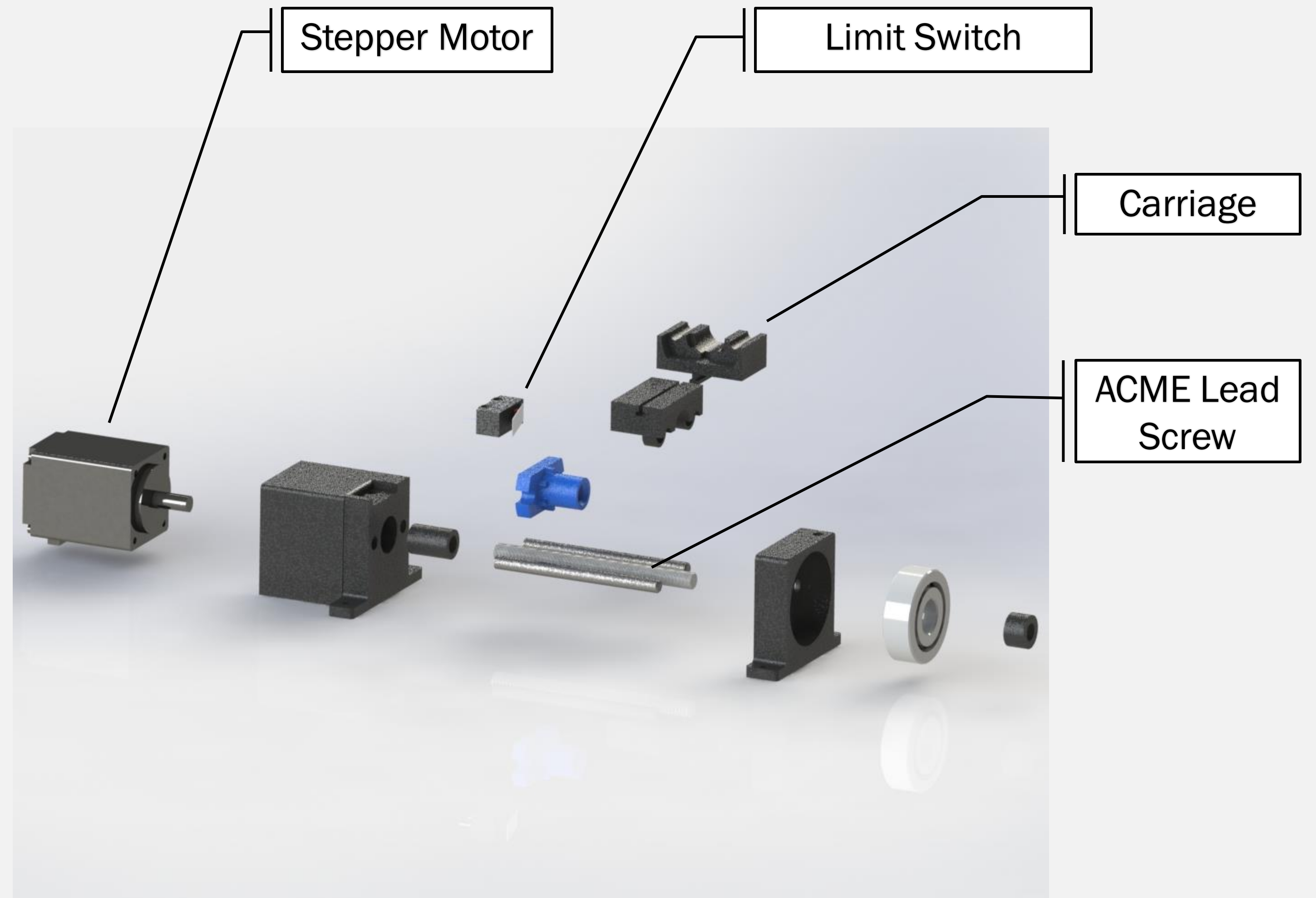
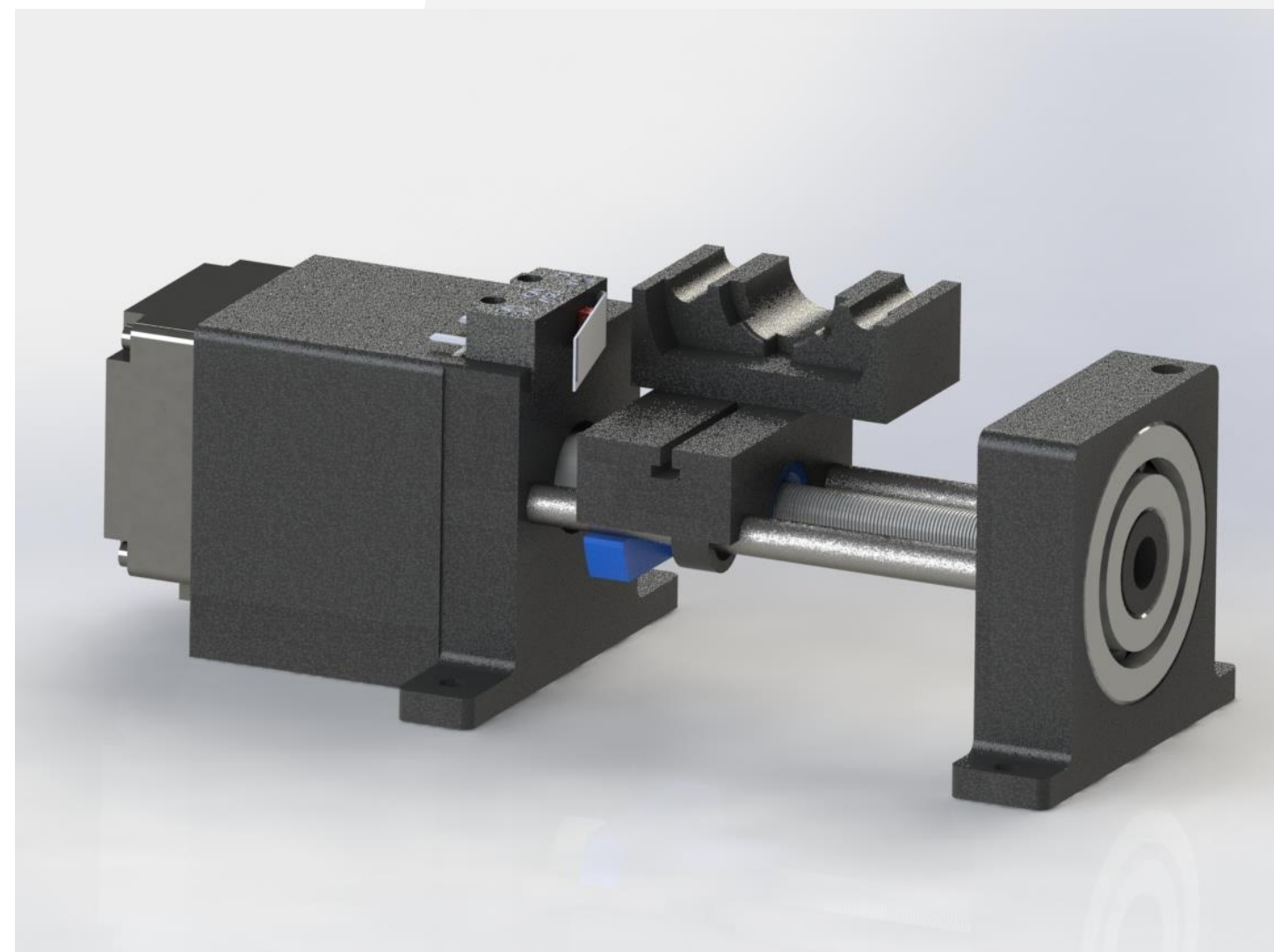
OPTICS AND POWER SYSTEM

- 20X magnification
- 8MP SONY IMX219 sensor
- 0.35 $\mu\text{m}/\text{px}$
- Powers motors and Raspberry Pi 4



X-STAGE

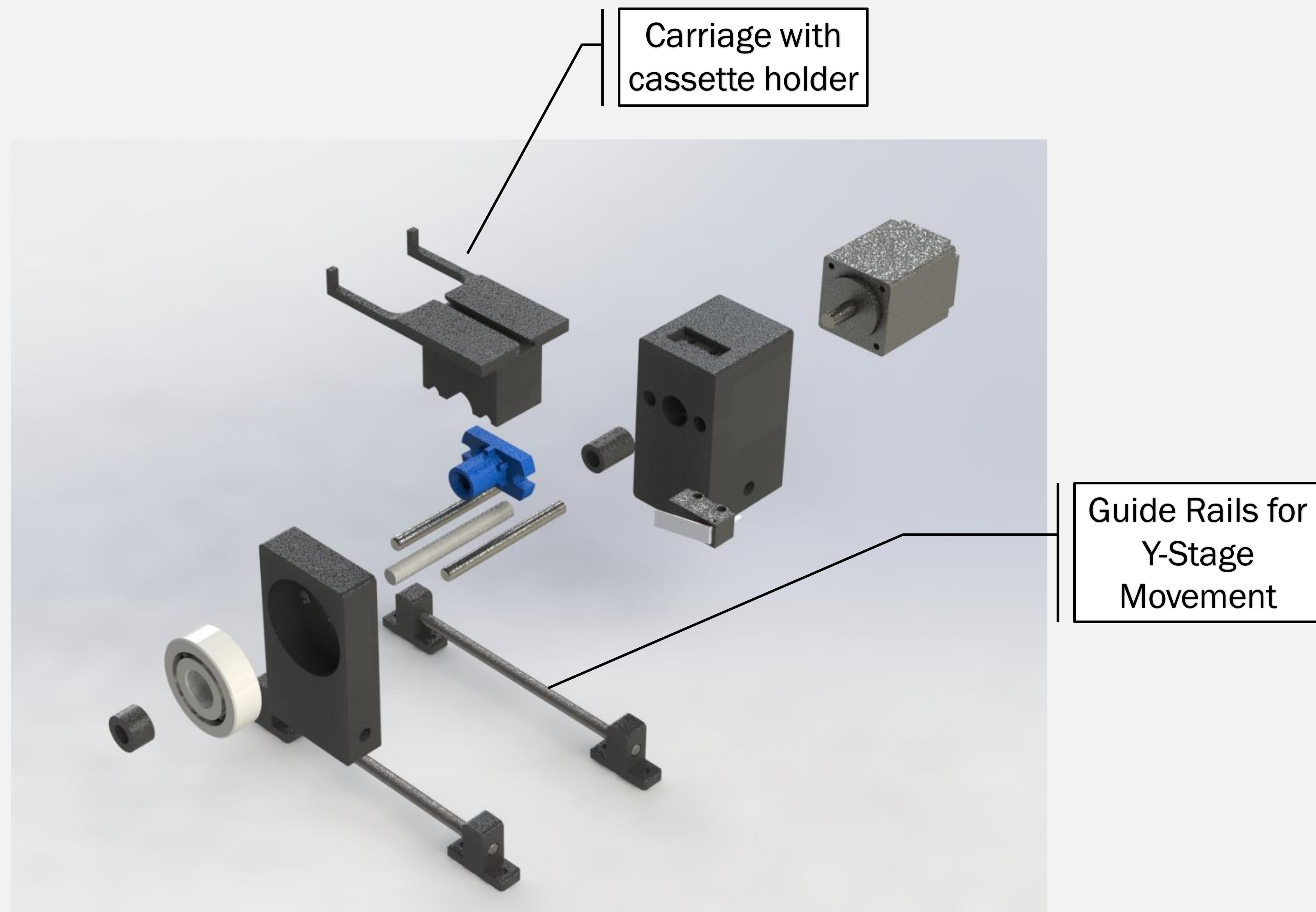
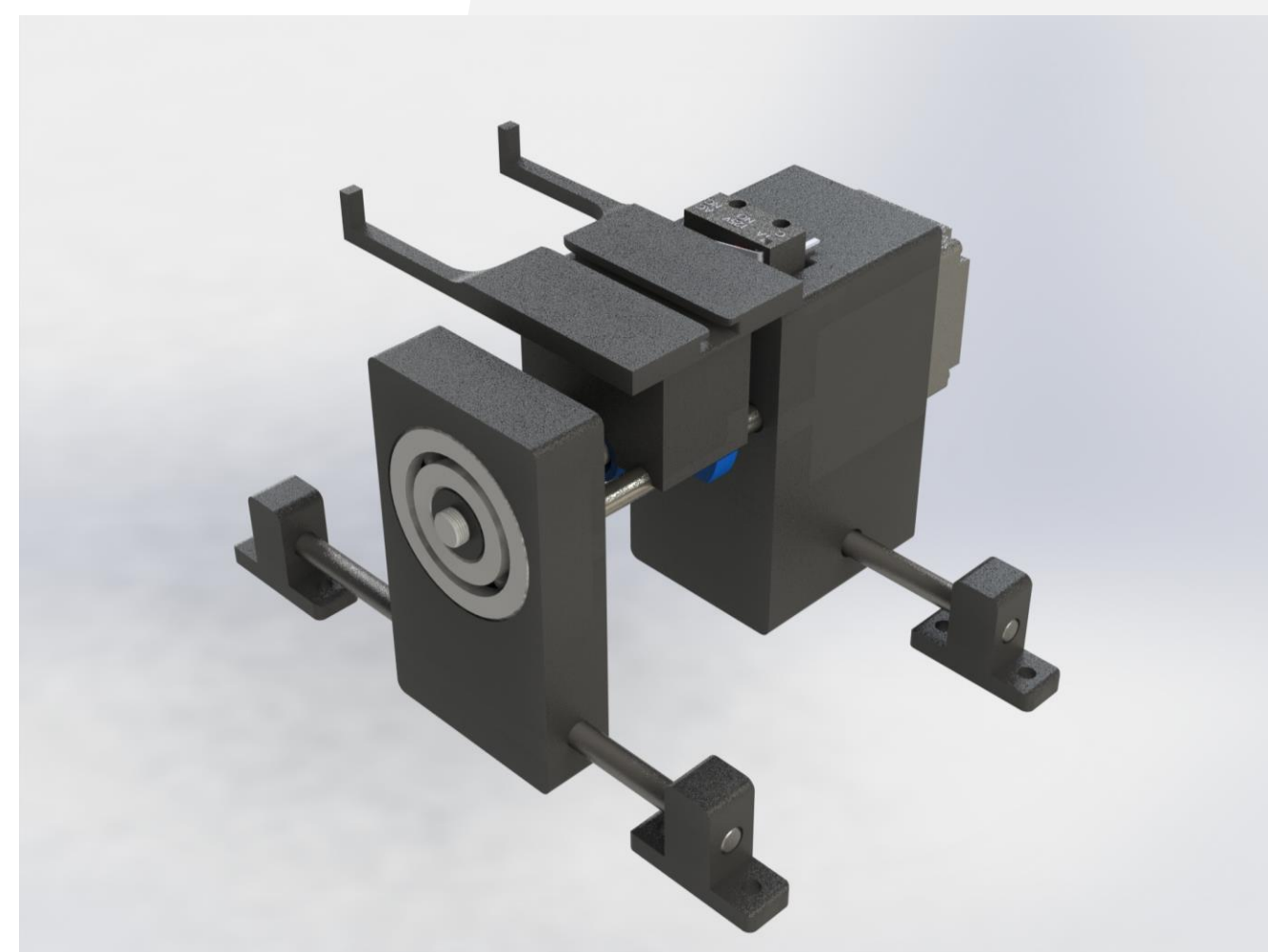
- Precise, planar movement for image stitching
- Stepper motor: 1.8° per step, 0.3 mm/rev
- 1.495 cm travel distance





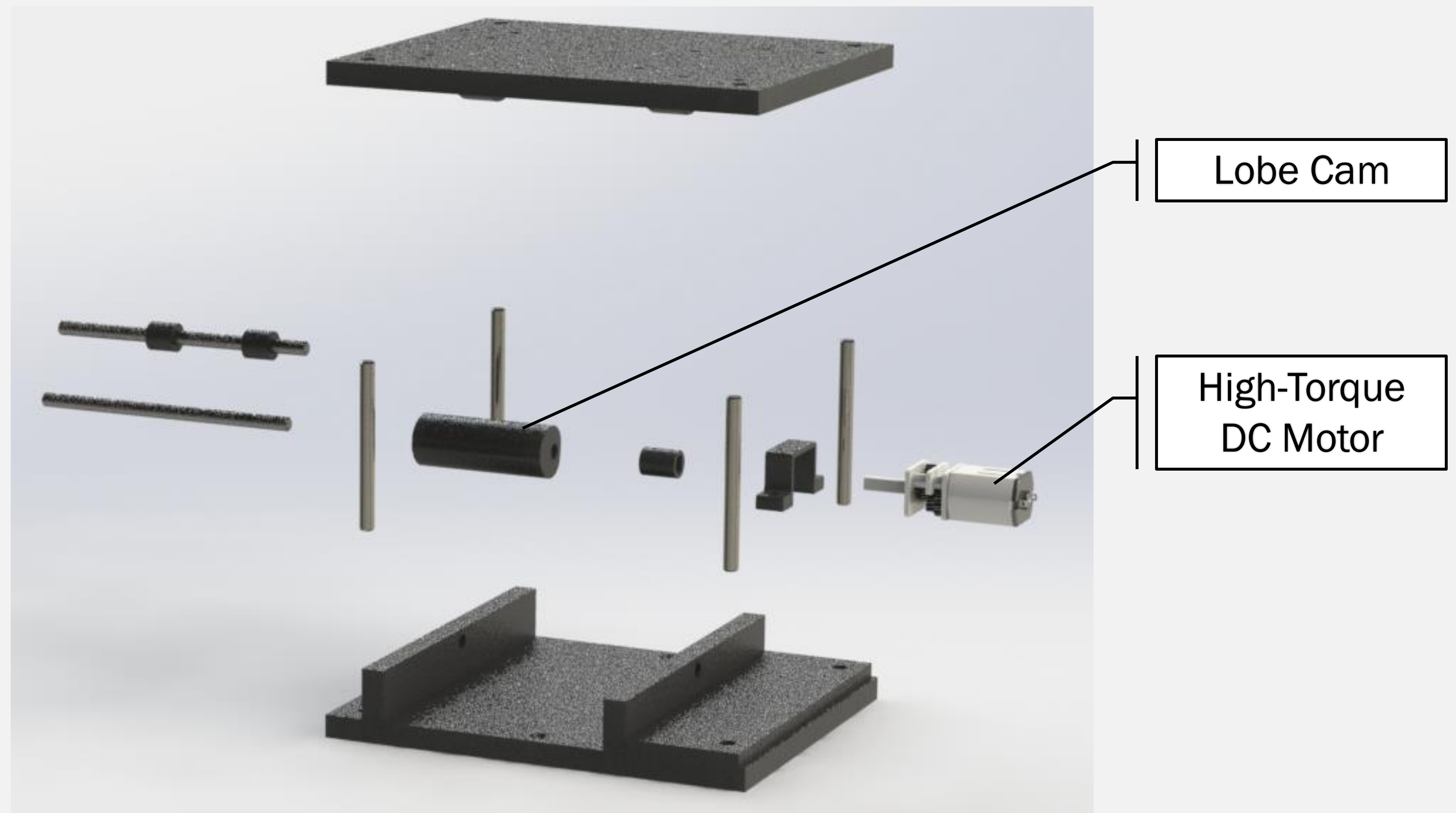
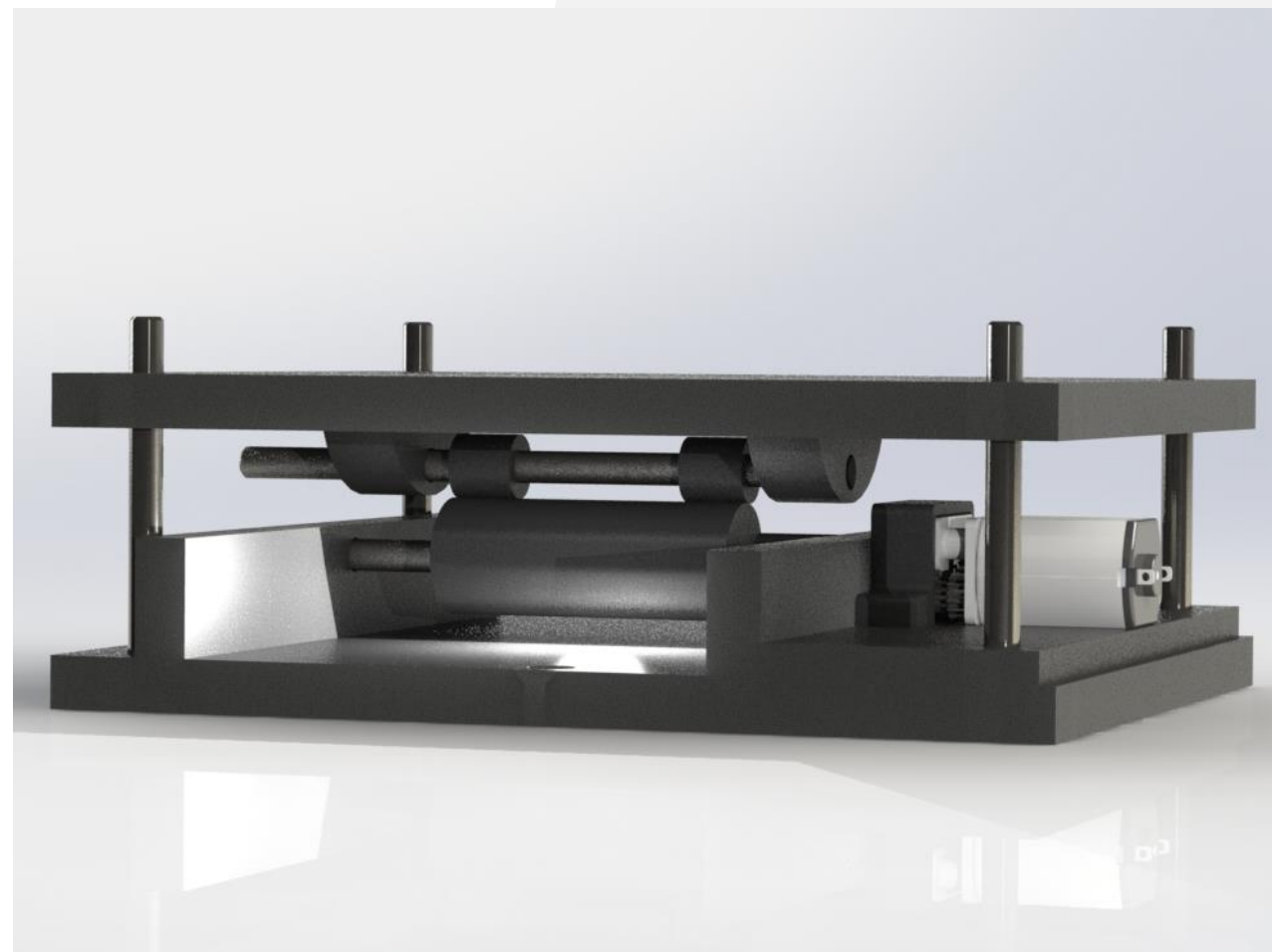
Y-STAGE

- 1.01 cm travel distance
- 1.5cm² scannable area range



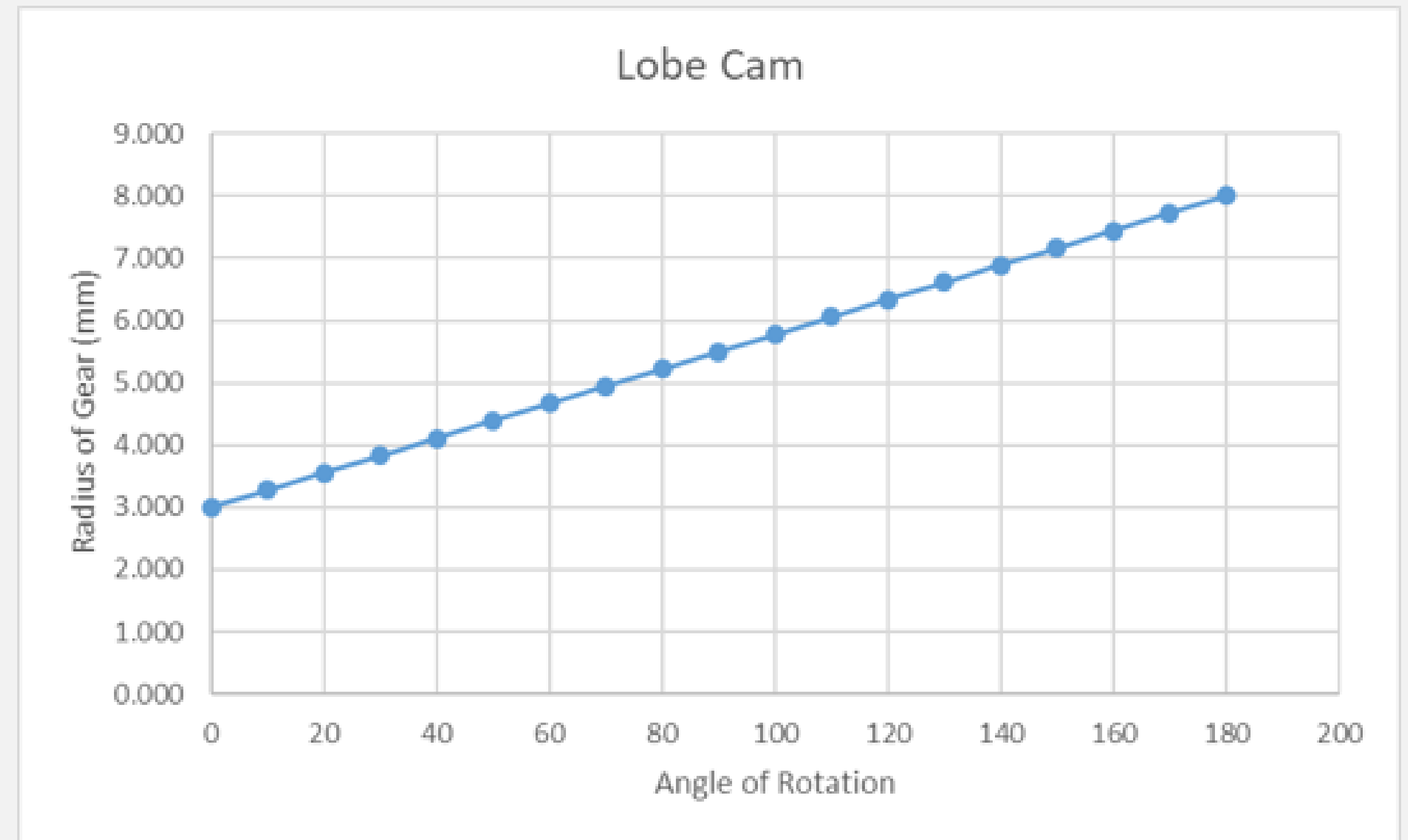
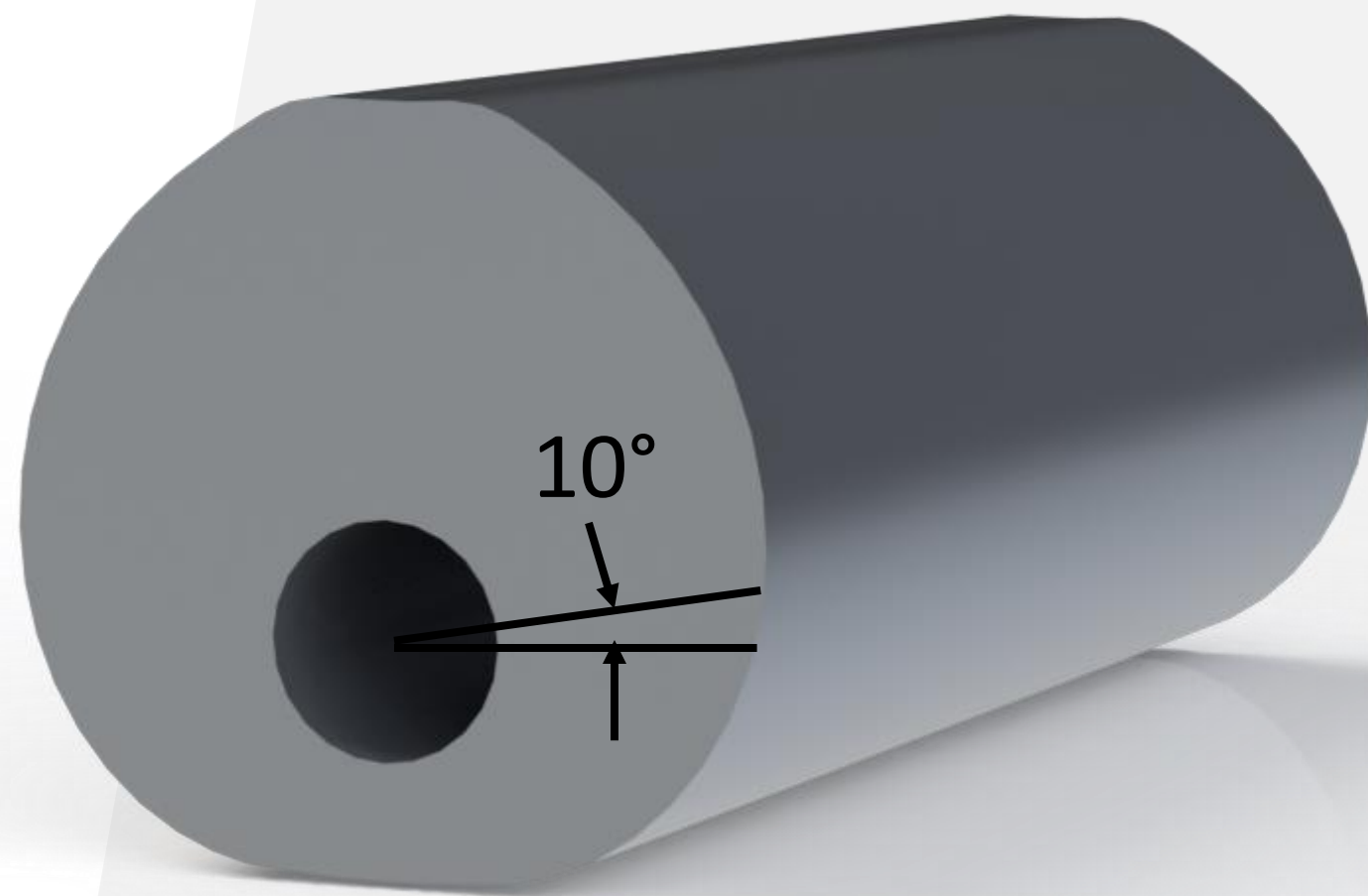
Z-STAGE

- DC motor used for auto-focusing system
- Negative feedback loop with microcontroller and camera



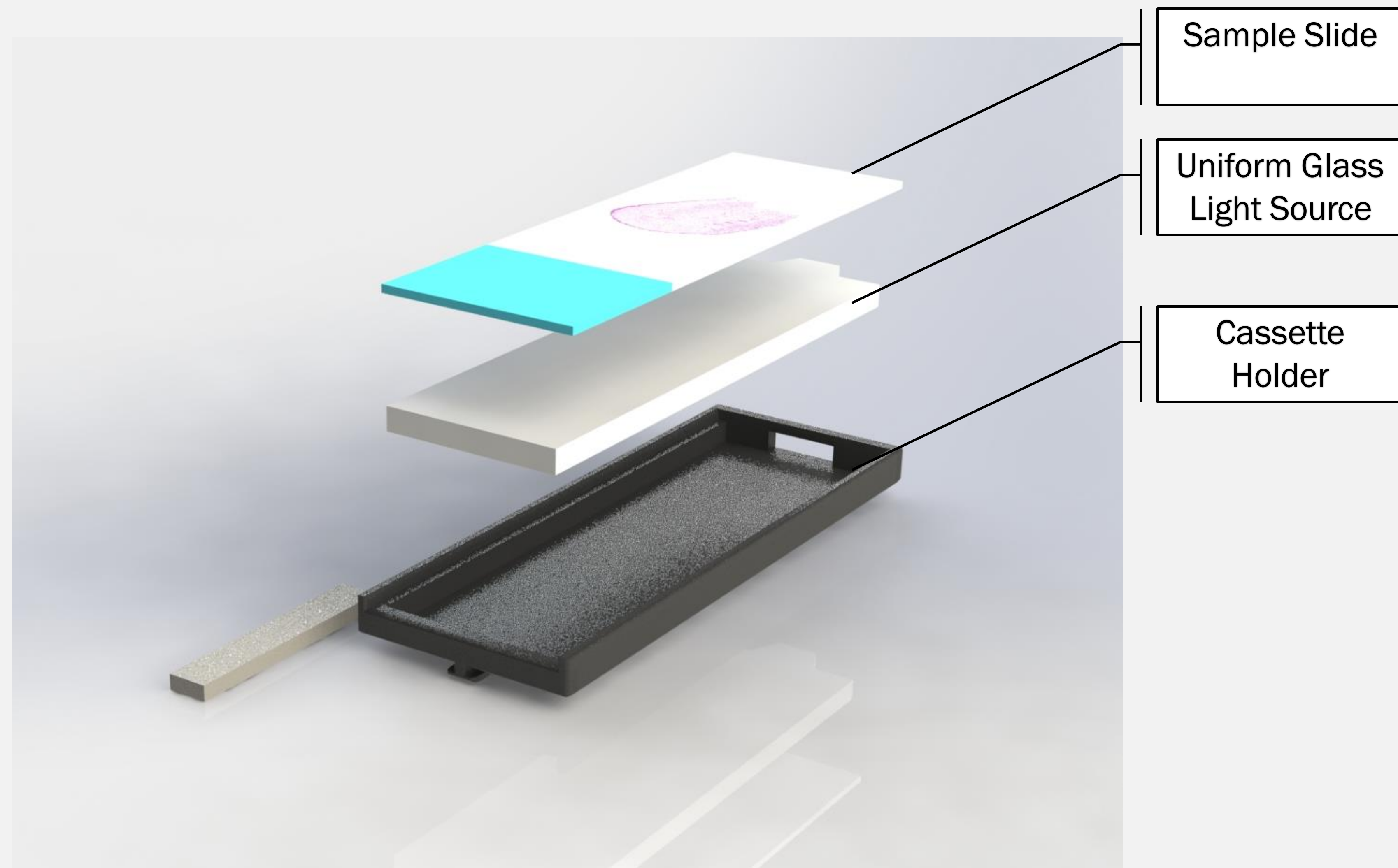
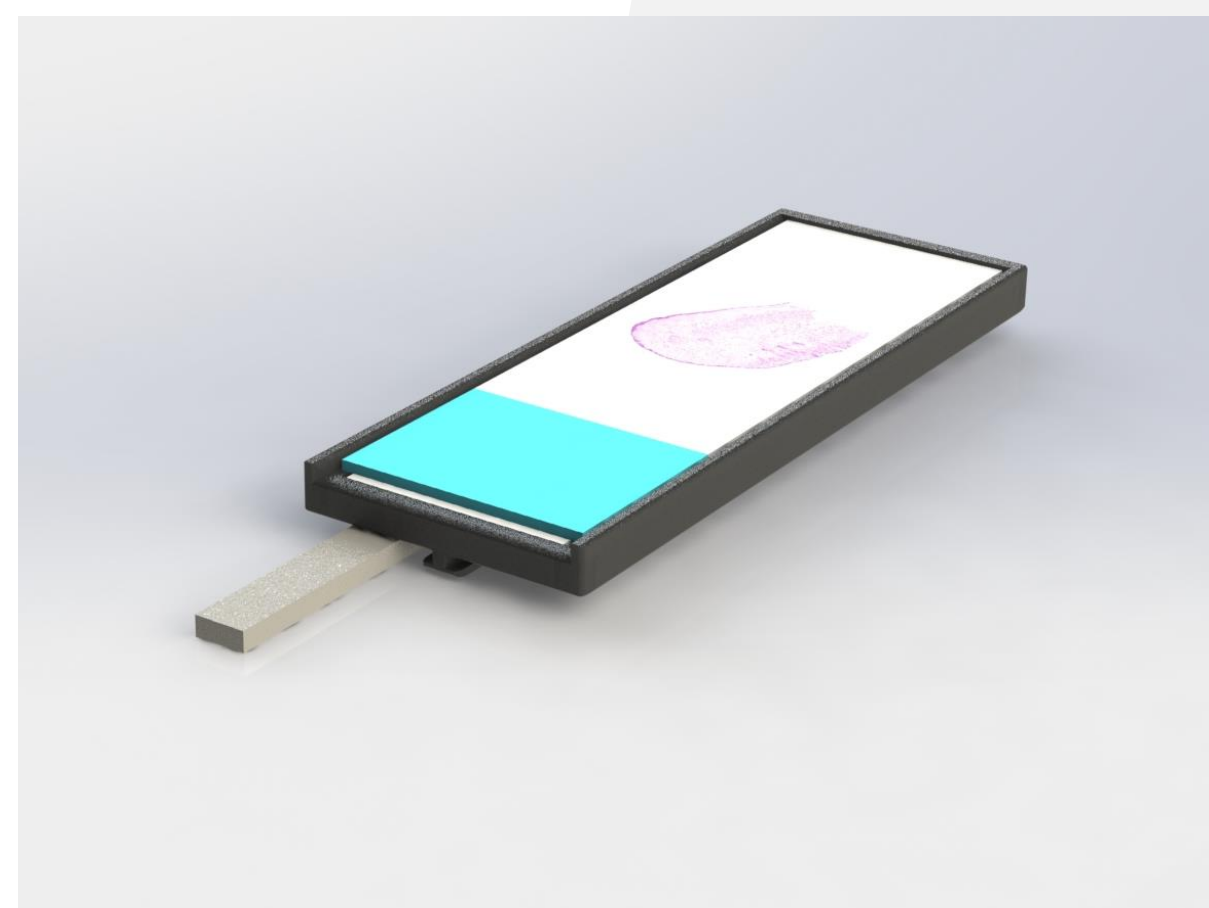
Z-STAGE

- Lobe cam raises stage at a linear rate
- Provides vertical distance uplift of 0.418 cm



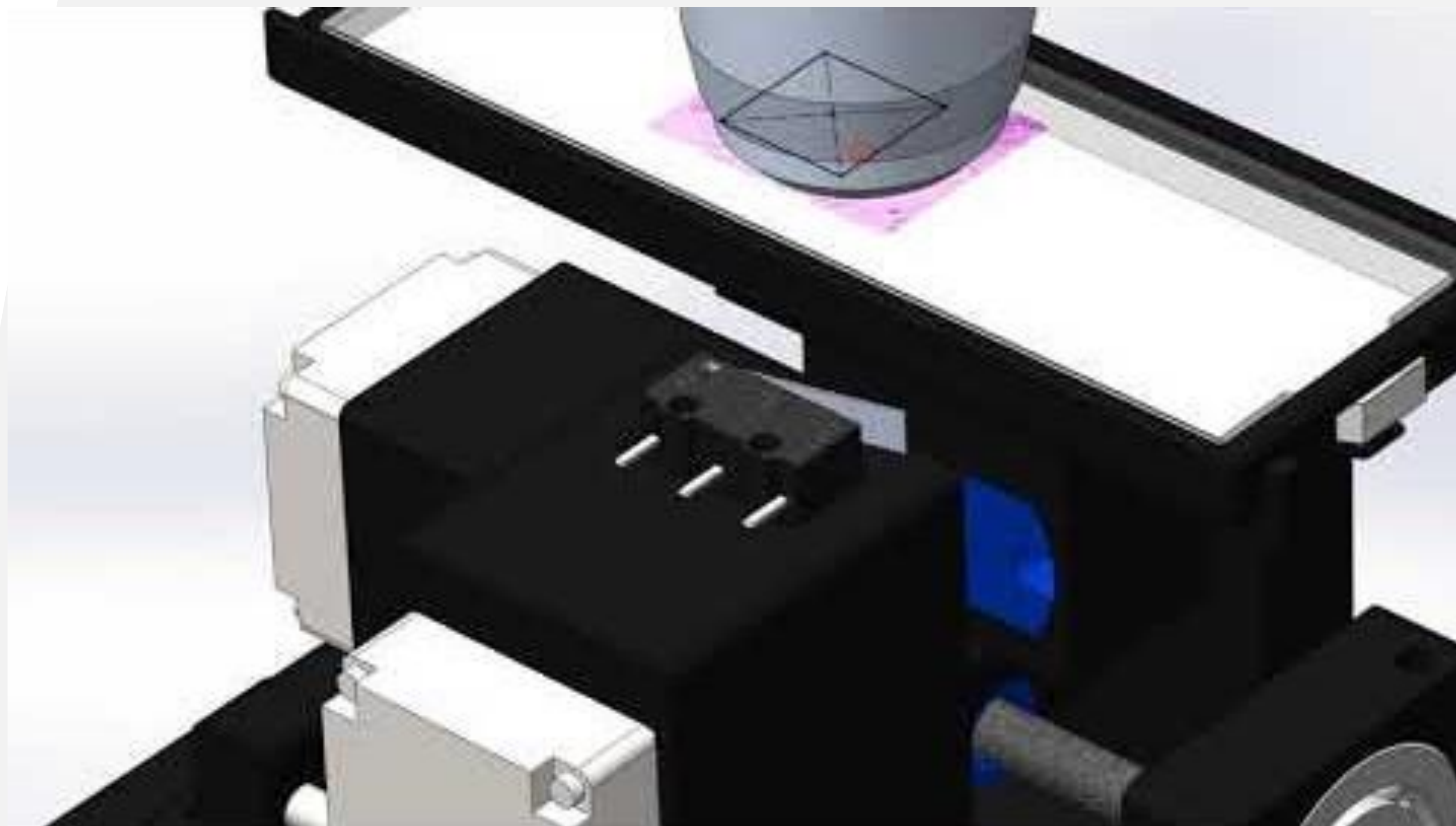
CASSETTE

- Holds Sample Slide
- 5600K uniform lighting





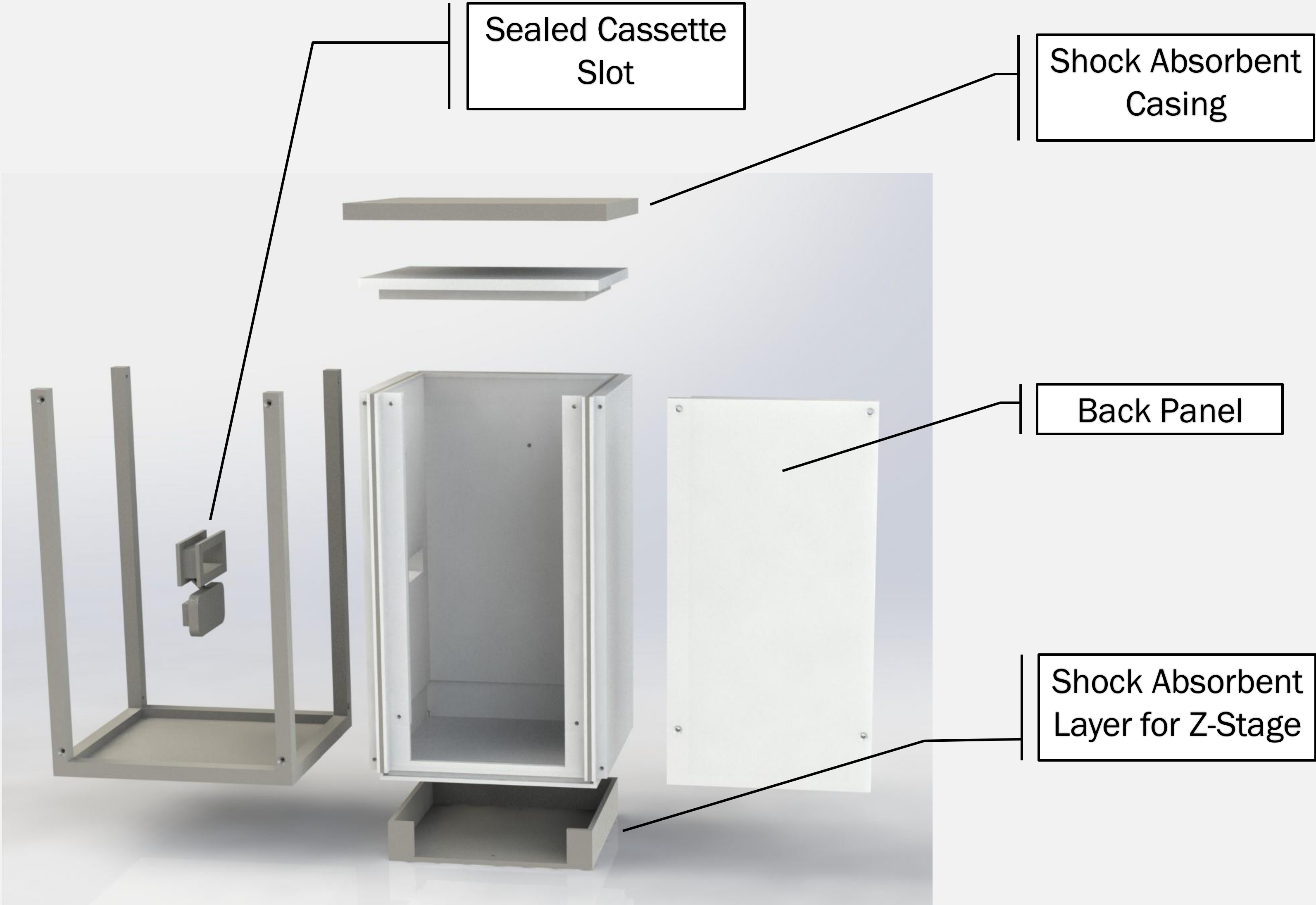
SLIDE SCANNING ANIMATION





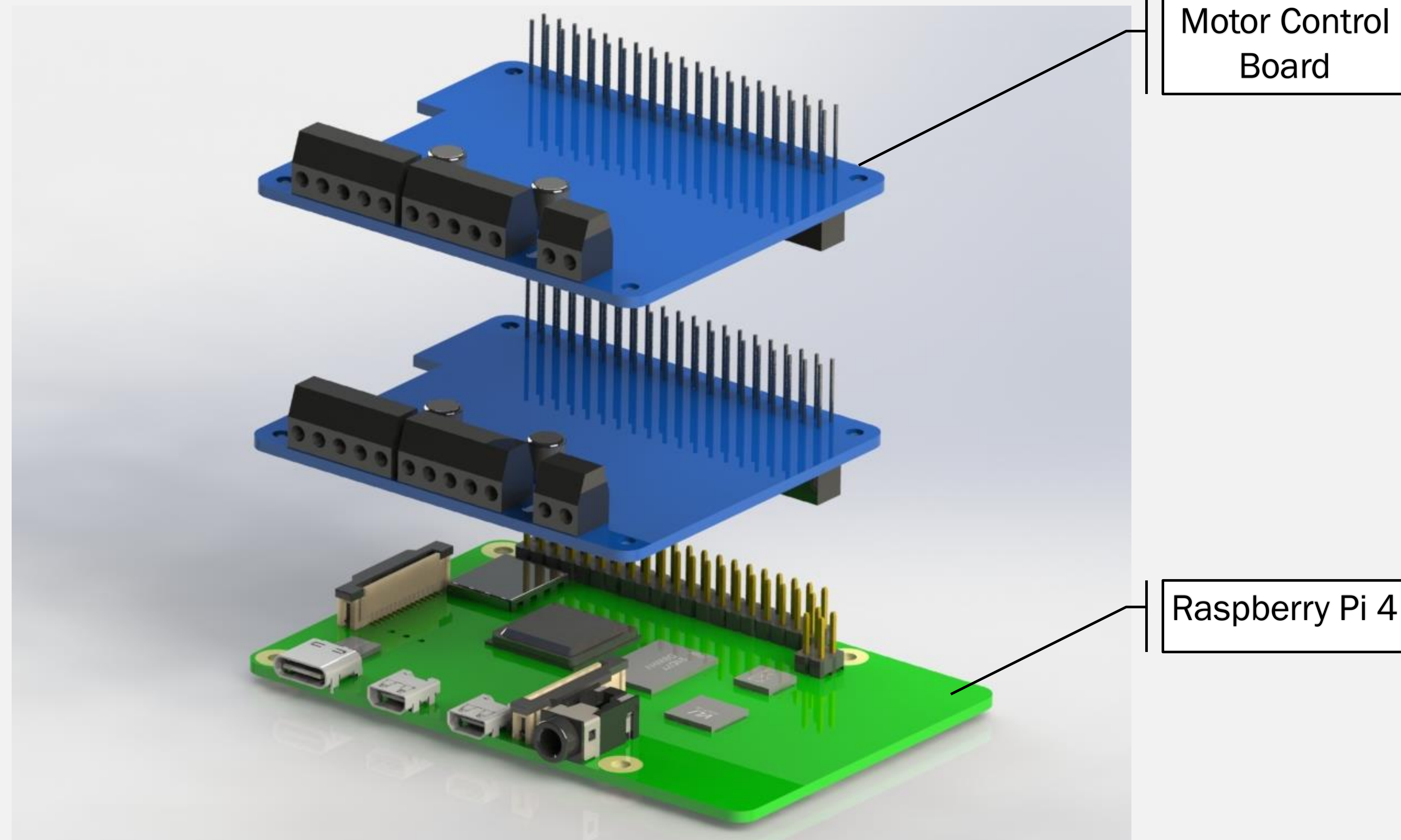
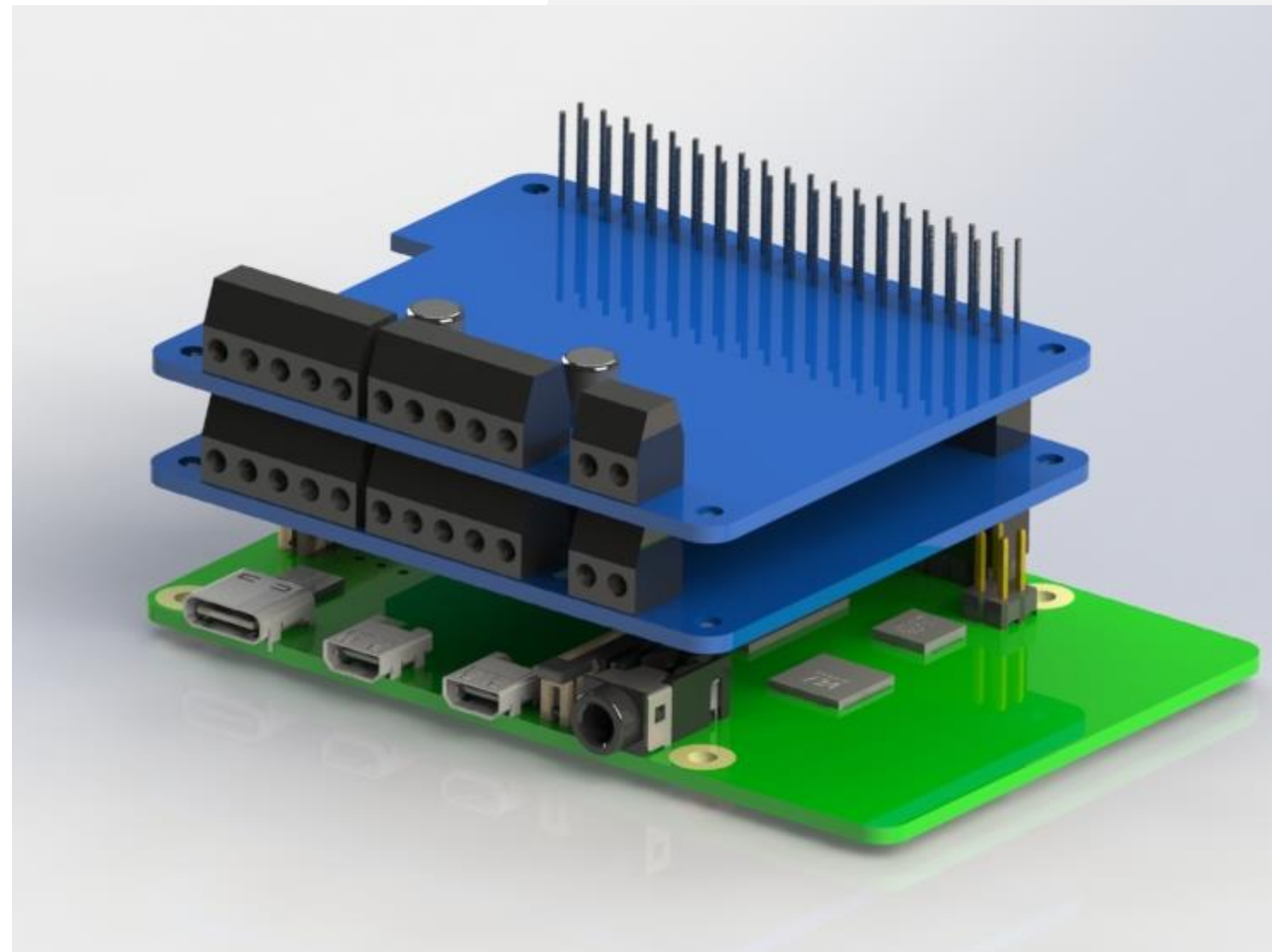
ENCLOSURE

- Holds other sub-assemblies
- ABS Plastics
- Shock-absorbent outer casing
- H7.75" x W4.65" x D4.35"



MICROCONTROLLER

- Controls Stepper and DC motors
- Performs image stitching and user input control from Apollo App (Future Development)



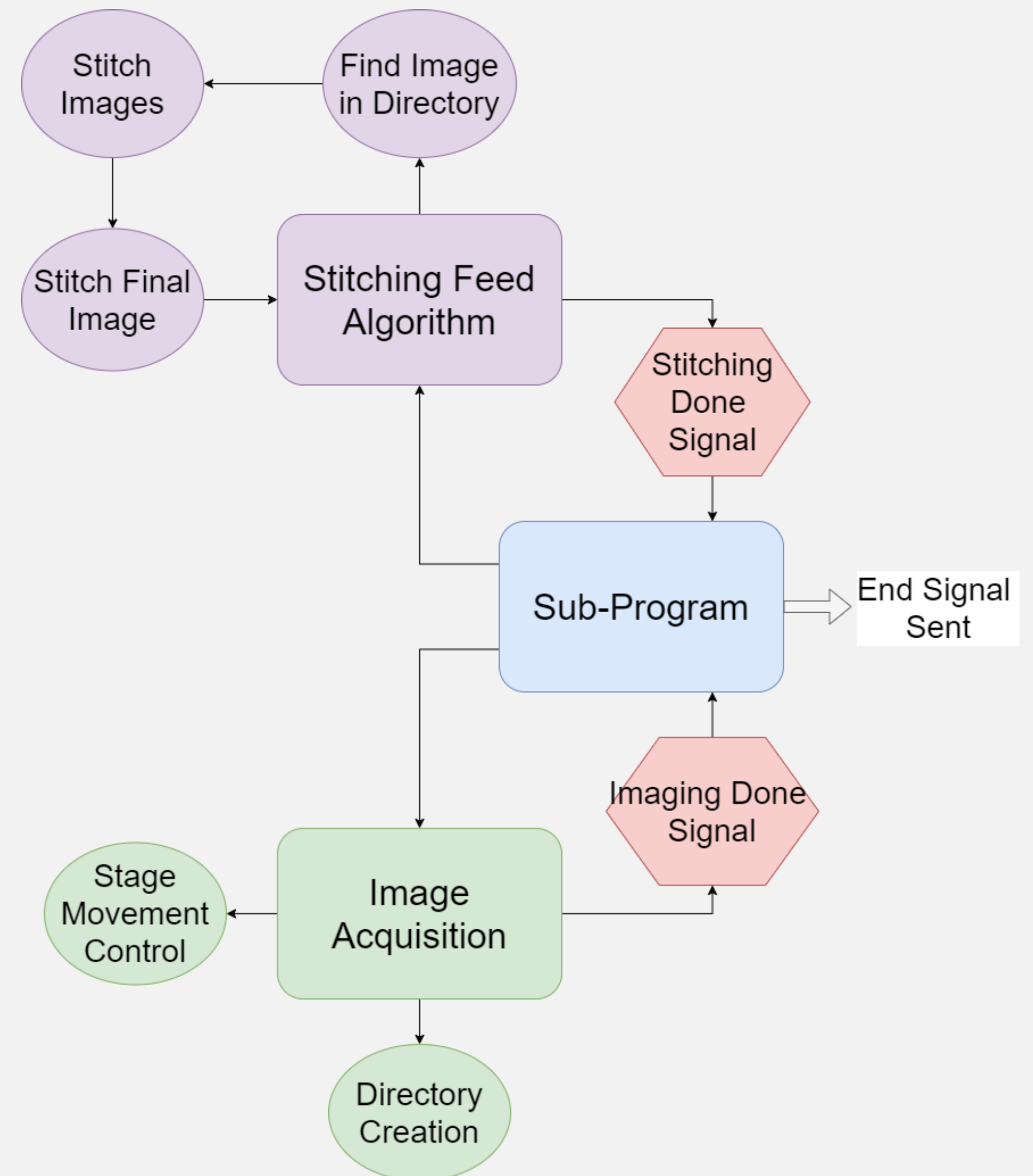
Motor Control Board

Raspberry Pi 4

SOFTWARE DEVELOPMENT

OVERVIEW OF THE PROGRAM

1. Initialize camera and stage components
 - a. Turning on Camera & tune Camera
 - b. Resetting Stage to Zero Position
 - c. Creation of Dir.
2. User Inputs parameters
 - a. Adjusts stage, Zoom as needed
 - b. Send Action Signal
3. Stitching Feed Algorithm Starts
 - a. Searches for Image in Dir.
 - b. Stitches images going in a zigzag pattern
 - c. When Column stitched images are finished, stitches final image
4. Sends Signal to Sub-Program
 - a. Sub-Program sends final stitched image to Clients Machine Learning Server



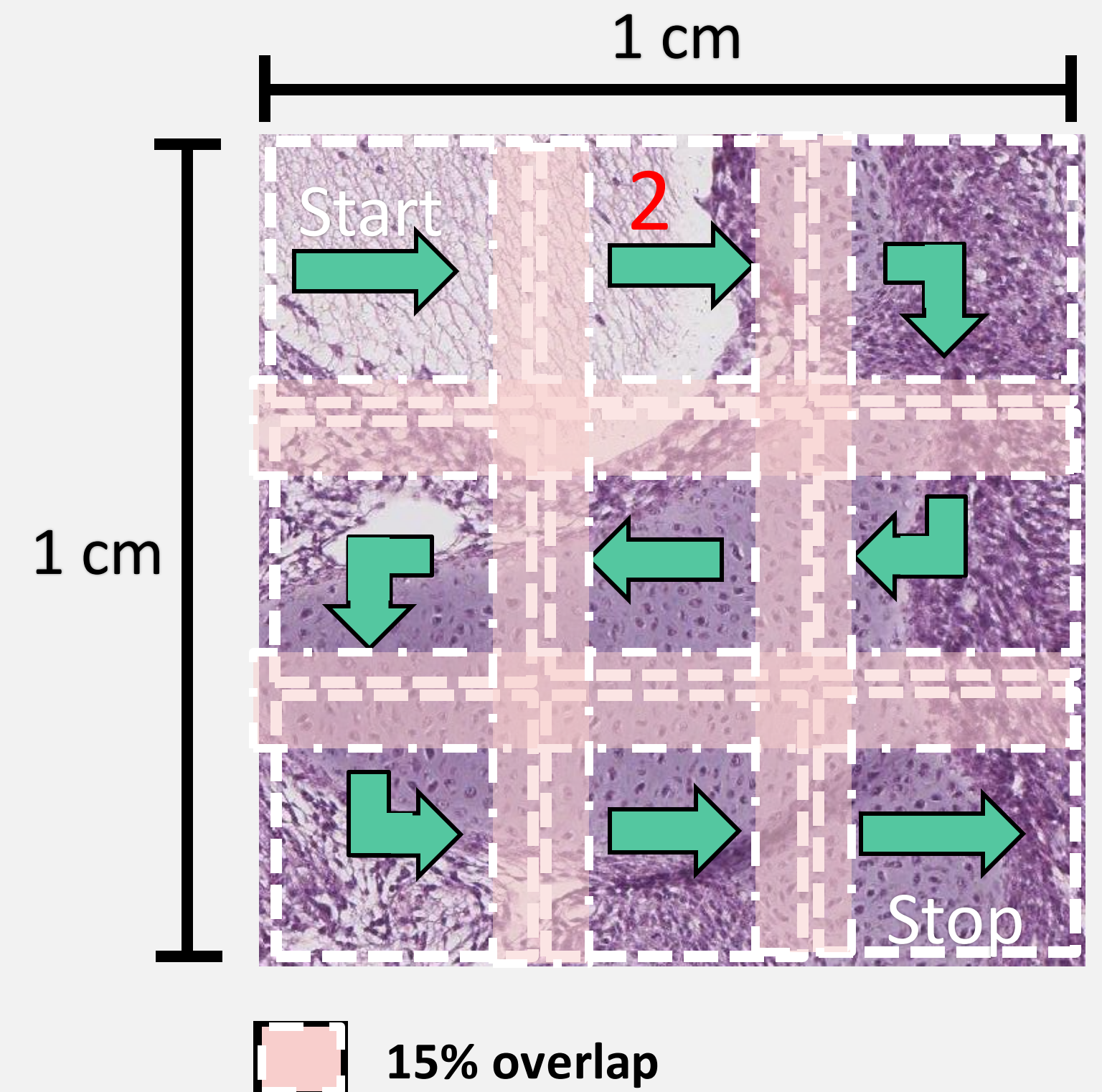
SOFTWARE DEVELOPMENT

MEMORY ALLOCATION AND USAGE EFFICIENCY

```

If( Pic.X && Pic.Y != NULL) // PSEUDO Code{
  Method_Right(i, pic)
}
Method_Right{
  Take.Pic, i++, Take Pic, Stitch, Delete i-1, i.
  i++, Take Pic, Stitch, delete i-1 (Repeat)
  If(Pic.X == NULL && Pic.Y+1 != NULL){
    Store Col.Pic,
    Method_Left) }
Method_Left{
  Make_New Col.Pic & New.Dir
  j++, Take Pic i, & i-1, stitch, delete i & i-1
  i--, Take pic, Stitch, delete i+1 (Repeat)
  If(Pic.X == NULL && Pic.Y+1 != NULL){
    Store Col.Pic,
    Method_Right) }

```



SOFTWARE DEVELOPMENT CHALLENGES

- Visual Studio & Android Studio Forced an update for AndroidX
- After Updating and "Migrating" the app and converting it to the new updated template, app broke.

```
The build failed likely due to AndroidX incompatibilities in a plugin. The tool is about to try using Jetifier to solve the incompatibility.
Building plugin adv_camera...
√ Built build\app\outputs\repo.
Building plugin camera...
√ Built build\app\outputs\repo.
Building plugin esys_flutter_share...
√ Built build\app\outputs\repo.
Building plugin image_picker...
√ Built build\app\outputs\repo.
Building plugin path_provider...
√ Built build\app\outputs\repo.
Building plugin starflut...
Starting a Gradle Daemon, 1 incompatible and 1 stopped Daemons could not be reused, use --status for details
WARNING: Configuration 'compile' is obsolete and has been replaced with 'implementation' and 'api'.
It will be removed at the end of 2018. For more information see: http://d.android.com/r/tools/update-dependency-configurations.html

FAILURE: Build failed with an exception.

* What went wrong:
A problem occurred configuring root project 'starflut'.
> The SDK directory 'E:\Downloads\flutter\.pub-cache\hosted\pub.dartlang.org\starflut-0.6.0\android\home\lihm\Android\Sdk' does not exist.

* Try:
Run with --stacktrace option to get the stack trace. Run with --info or --debug option to get more log output. Run with --scan to get full insights.

* Get more help at https://help.gradle.org

BUILD FAILED in 29s

The plugin starflut could not be built due to the issue above.
Exited (sigterm)
```

SOFTWARE DEVELOPMENT

APOLLO APP: PRE-UPDATE



App Successes:

- Take Picture
- Adjust Resolution
- Adjust Brightness
- Adjust Image Ratio
- Share over Data over Network through apps of choice
- Directory Management
- Python Console

The collage illustrates the app's workflow: starting with the main camera interface, moving to gallery selection, then image preview and sharing options. A Python console is also shown, demonstrating the app's ability to execute code.

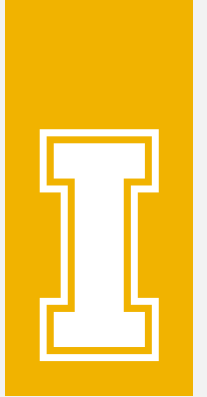
Flashlight
Zoom
Resolution

Flip
Capture
Set path
Home

Flutter
Dart

SOFTWARE DEVELOPMENT

WEBSITE AND EXPO

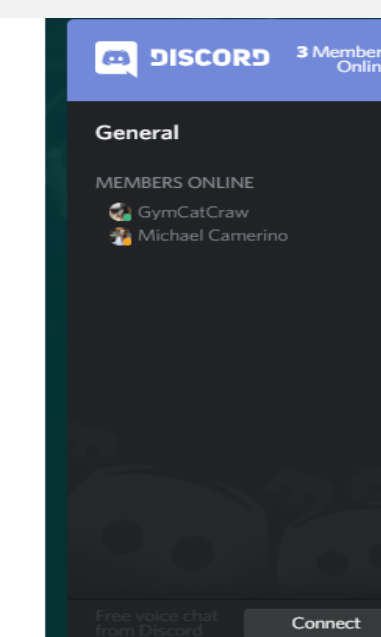
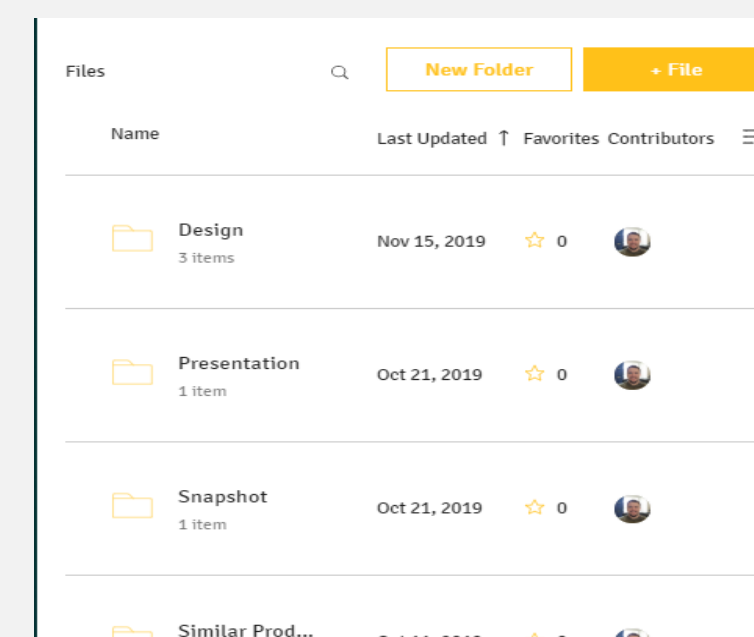
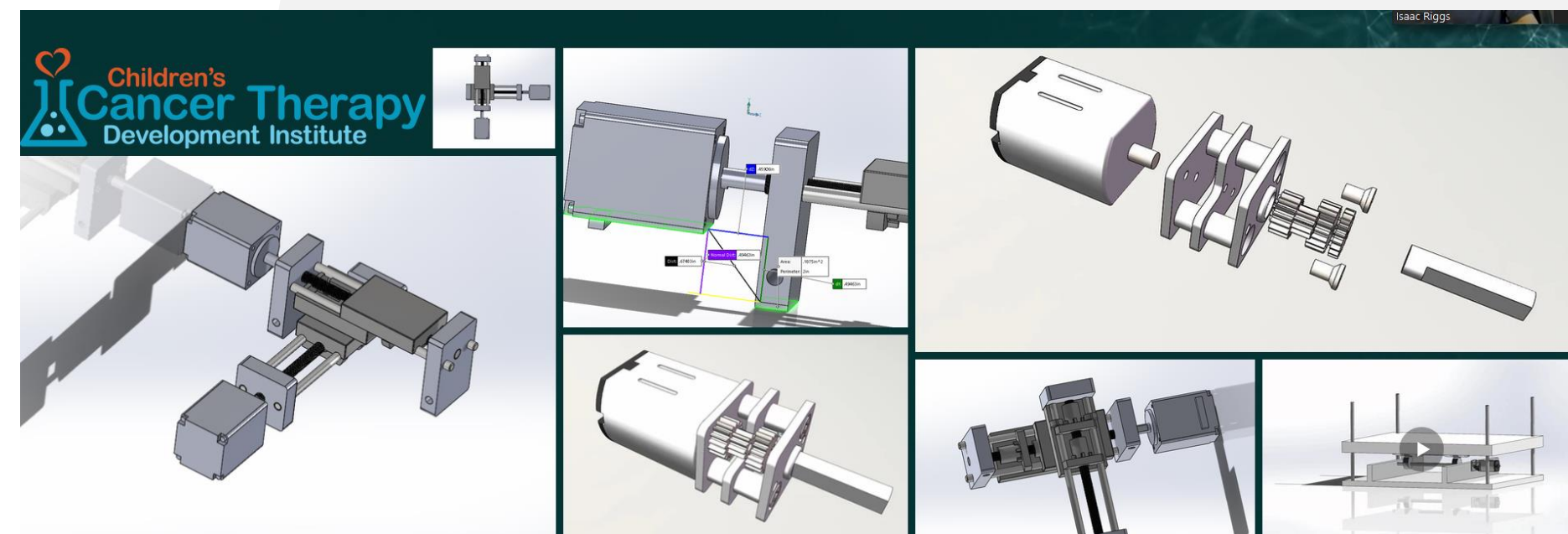
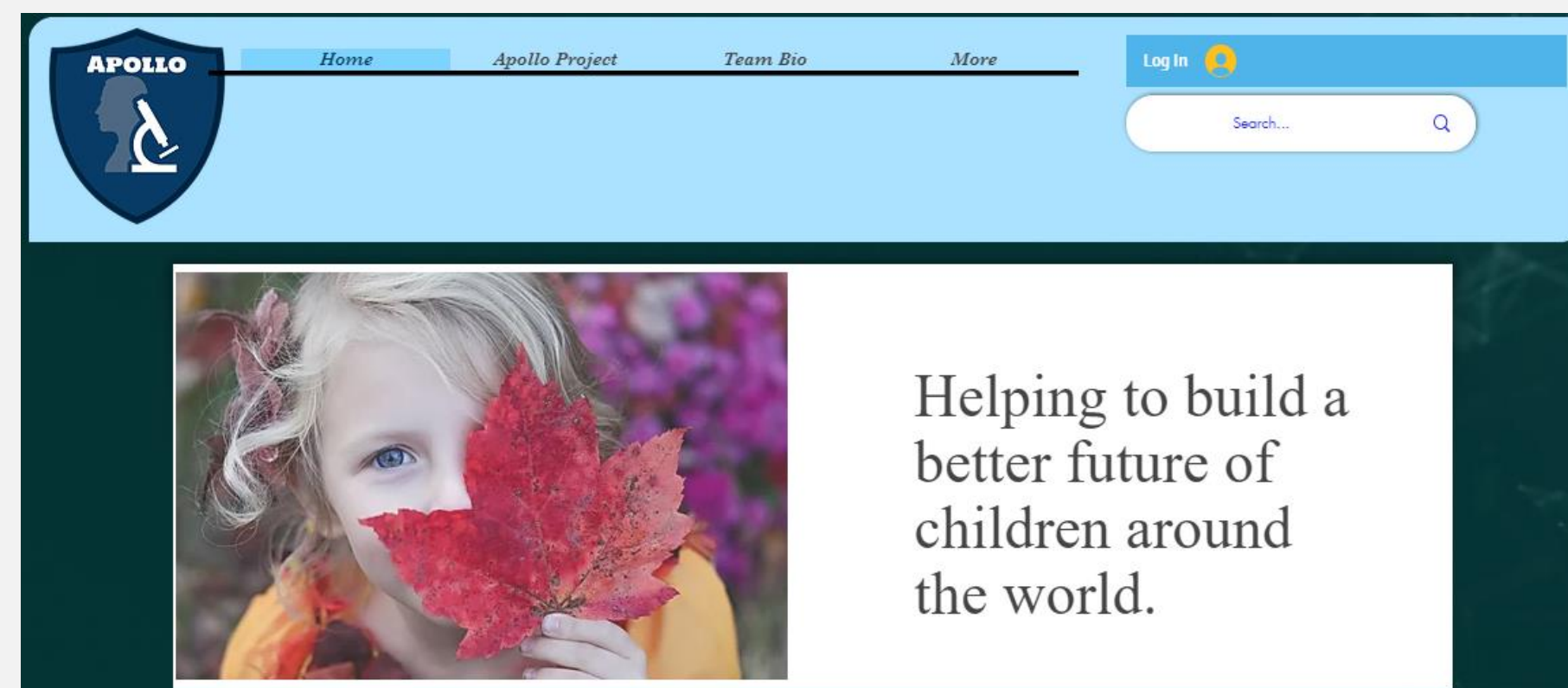
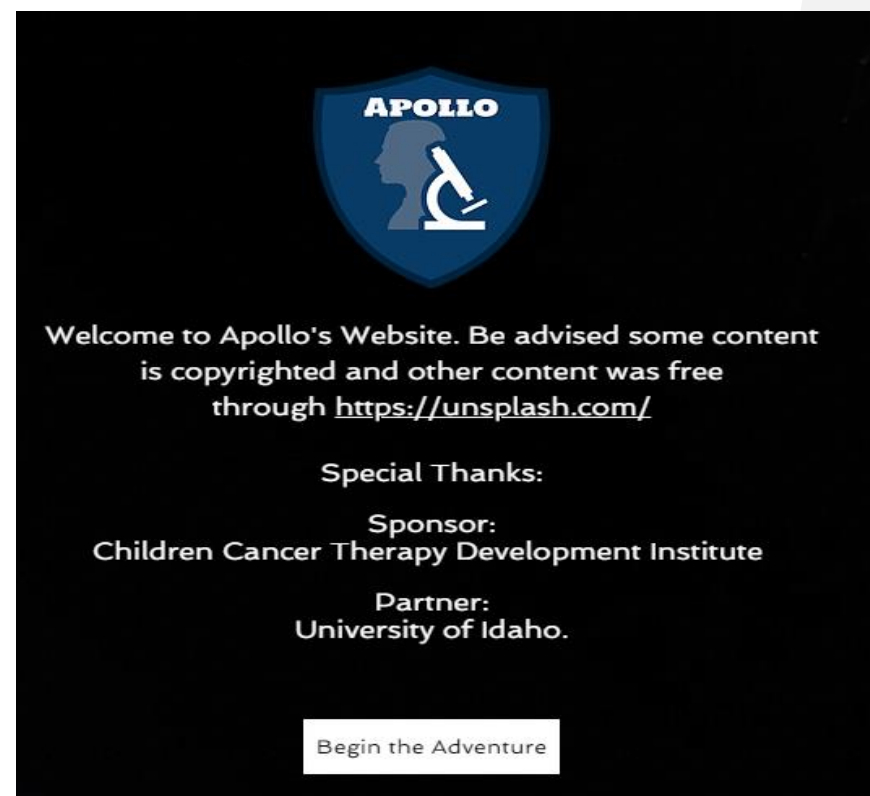


Apollo Website:

<https://www.apolloslidescan.com/>

EXPO Plan:

- Acquire 72-inch TV
 - Split Screen
 - Display gallery and videos utilizing website
- Show product in motion with image stitching and final product



SOFTWARE DEVELOPMENT



STAGE MOVEMENT & PICTURE TAKING CODE

```
1  #!/usr/bin/python
2  #import Adafruit_MotorHAT, Adafruit_DCMotor, Adafruit_Stepper
3  from Adafruit_MotorHAT import Adafruit_MotorHAT, Adafruit_DCMotor, Adafruit_StepperMotor
4  from picamera import PiCamera
5
6  import time
7  import atexit
8
9  # create a default object, no changes to I2C address or frequency
10 mh = Adafruit_MotorHAT()
11 camera = PiCamera()
12
13 def init():
14     # Initialize stage to zero position
15     # Setup limit switch
16     # Once done call auto-focus function
17     autoFocus()
18
19 def autoFocus():
20     camera.start_preview()
21     # Move Z-axis motor till focused and call mainExec
22     myDCMotorZ.run( Adafruit_MotorHAT.FORWARD or BACKWARD )
23     camera.stop_preview()
24
25 def takePic( num ):
26     # Takes pictures
27     camera.capture( '/home/pi/Desktop/img%s.jpg' % i )
28
```

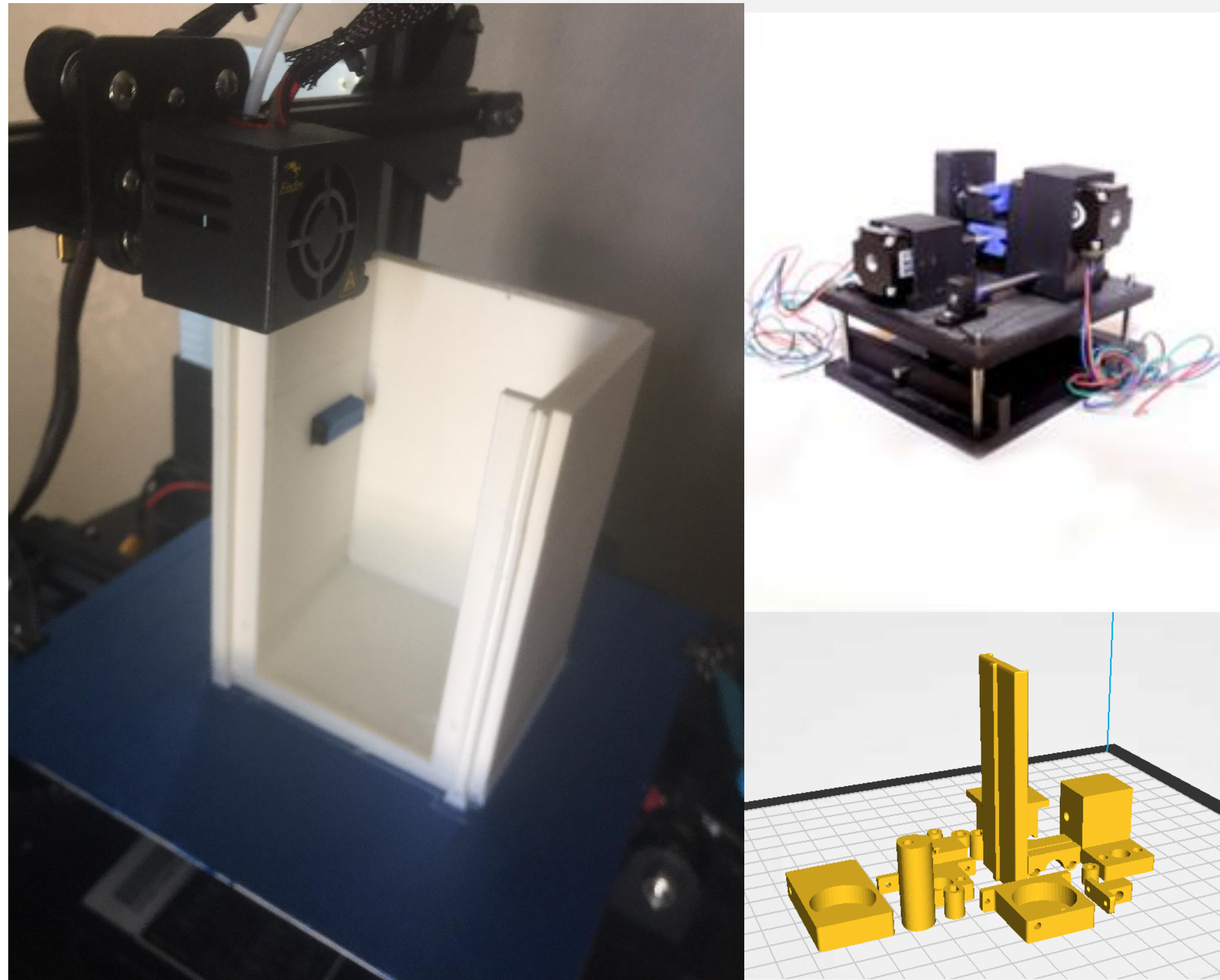
SOFTWARE DEVELOPMENT



STAGE MOVEMENT & PICTURE TAKING CODE

```
28
29 def main():
30     init()
31     mainExec()
32     # Call the stitcher code
33
34 # recommended for auto-disabling motors on shutdown!
35 def turnOffMotors():
36     mh.getMotor( 1 ).run( Adafruit_MotorHAT.RELEASE ) # X-axis motor
37     mh.getMotor( 2 ).run( Adafruit_MotorHAT.RELEASE ) # Y-axis motor
38     mh.getMotor( 3 ).run( Adafruit_MotorHAT.RELEASE ) # Z-axis motor
39
40 atexit.register( turnOffMotors )
41
42 myStepperX = mh.getStepper( 10, 1 ) # 10 steps/rev, motor port #1
43 myStepperX.setSpeed( 30 ) # 30 RPM
44 myStepperY = mh.getStepper( 10, 2 ) # 10 steps/rev, motor port #2
45 myStepperY.setSpeed( 30 ) # 30 RPM
46 myDCMotorZ.getMotor( 3 ) # DC motor at port #3
47 myDCMotorZ.setSpeed( 1 ) # Set to speed of 1 to allow accurate auto-focus
48
49 main()
50 def mainExec():
51     i = 1
52     while ( i < 196 ):
53         # If positive X-axis limit
54         myStepperY.step( 100, Adafruit_MotorHat.FORWARD, Adafruit_MotorHAT.MICROSTEP )
55         myStepperX.step( 100, Adafruit_MotorHAT.FORWARD, Adafruit_MotorHAT.MICROSTEP )
56         takePic( i )
57         i += 1
58         # else negative X-axis limit
59         myStepperY.step( 100, Adafruit_MotorHat.FORWARD, Adafruit_MotorHAT.MICROSTEP )
60         myStepperX.step( 100, Adafruit_MotorHAT.BACKWARD, Adafruit_MotorHAT.MICROSTEP )
61         takePic( i )
62         i += 1
```

MANUFACTURING PROCESS



FDM 3D Printing Filaments

Parameter	PLA	TPU
Nozzle Temp (°C)	210	235
Bed Temp (°C)	40	60
Layer Height (mm)	0.06- 0.12	0.12- 0.20
Infill (%)	20-50	0-20

MANUFACTURING PROCESS

COVID 19 Challenges:

- Device requires very precise parts that push the limits of consumer printers
- Carbon fiber reinforced filament was initially planned for enclosure, but destroyed nozzle on printer
- Campus machine shop facilities are closed
- Extruder assembly currently under repair



Ender3 Printer Used for Part Fabrication
(Credit: Creality3D)

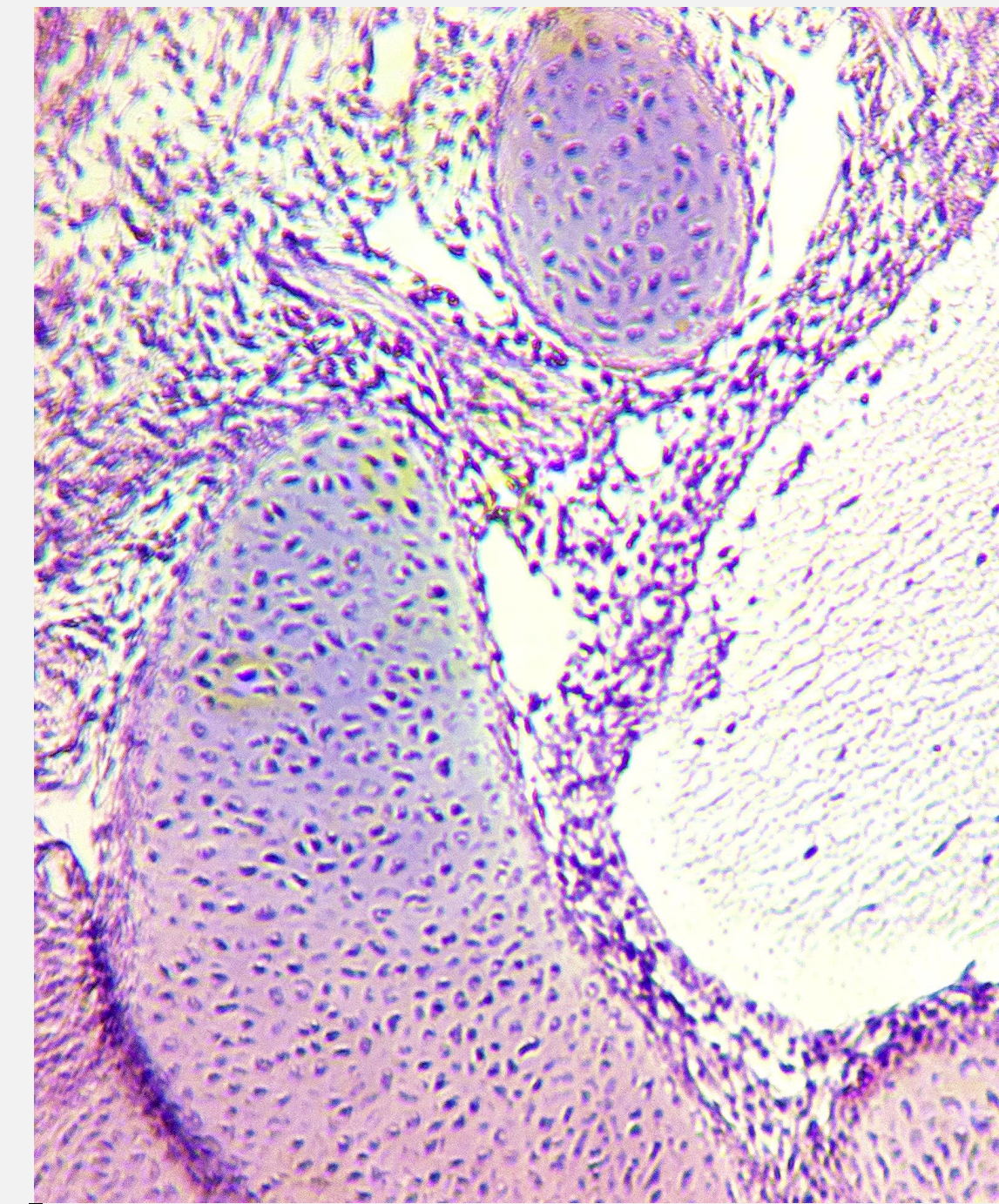
VALIDATION

Image Acquisition Time:

Parameters:	Value:
Lead Screw	300 μ m/rev
Motor Speed	10 rev/s
Motor Step Angle	1.8 $^{\circ}$
Number of Images @ 15% overlap	196

18 minutes required

Image Resolution:

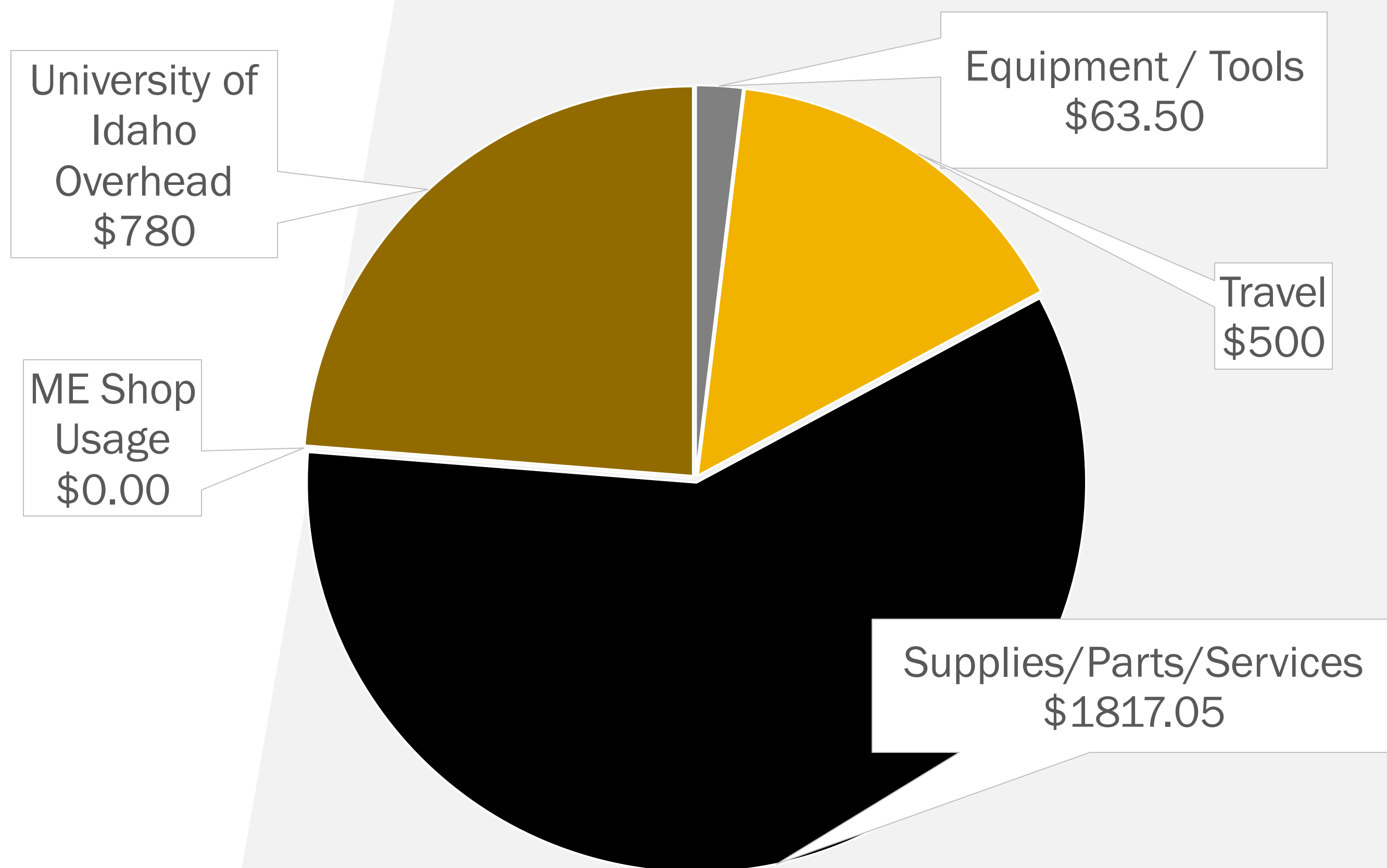


1573 pixels (550.55 μ m)

$$\frac{550.55\mu\text{m}}{1573 \text{ pixels}} = 0.35 \mu\text{m/pixel}$$

BUDGET

Budget Contributions



Prototype Cost

Category	Cost
Optics and Sensor	\$81.8
Motors/Stage	\$299.63
Electronics	\$110.99
Bulk Material	\$40.00
Total:	\$532.56

FUTURE WORK

Hardware

- Limit switches
 - Wiring, testing, coding
- Quadrature encoder
 - Z-stage failsafe
 - Wiring, testing, coding
- BattBorg
 - 4 AA battery power adapter
 - Parallel circuit wiring for Pi-hats

Software

- Develop a new android app
- Autofocus tuning with Z-stage

Testing & Further Validation

- Physical stress tests
 - Drop
 - Water
 - Dust
- Battery validation
 - Battery life
 - Number of acquisitions
- Time trials
 - 1cm² image acquisition trial
- Real application
 - Cancerous tissue slide



THANK YOU



ANY QUESTIONS?