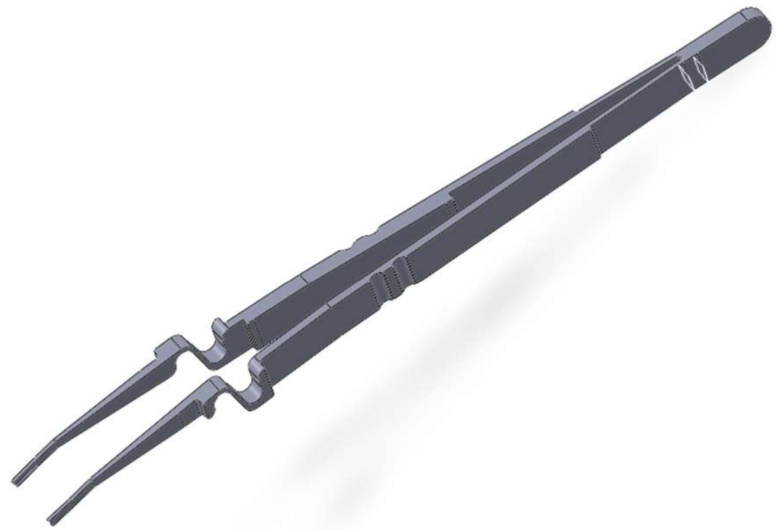
Force-Sensing Forceps for Cochlear Implant Surgery

Laboratory for Computational Sensing + Robotics



Group 02:
Justin Kim
kkim141@jhu.edu

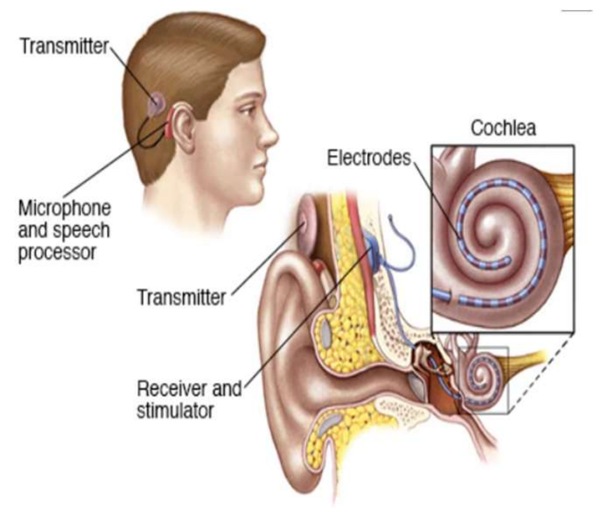
Principal Investigator: Prof. Russ Taylor
Primary Mentor: Anna Goodridge
Surgeon Mentor: Dr. Deepa Galaiya
Secondary Mentor: Prof. Iulian Iordachita

Project Summary

- Problem
  - Electrode insertion during cochlear implant surgery has a high likelihood (17.6%) for trauma (Hoskison, 2017)
  - Below the resolution of surgeon tactile sensation (Seta, 2017)

- Goal
  - Design a 3 DOF force-sensing forceps to assist insertion

- Status
  - Slightly behind

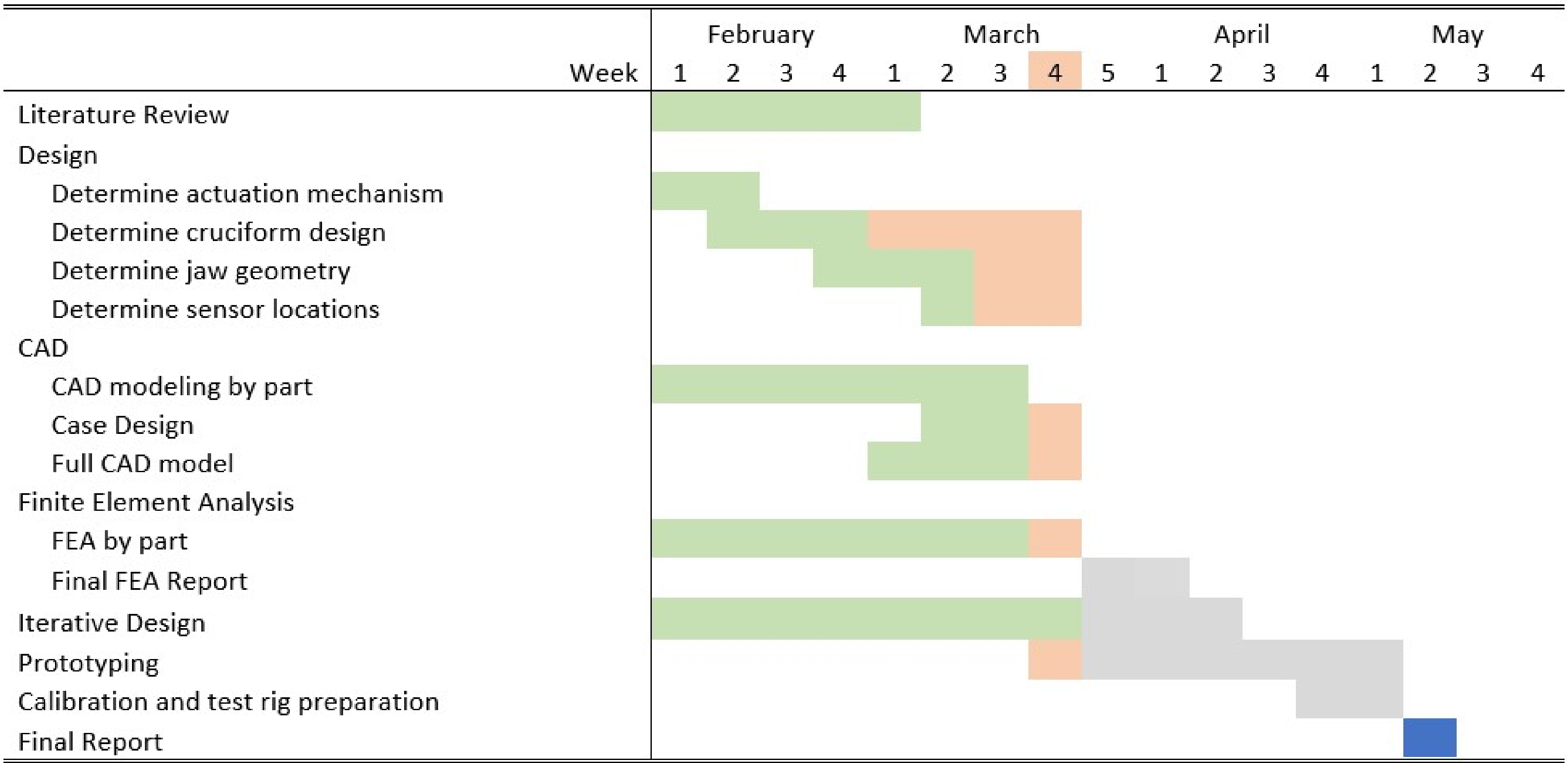


Deliverables

Laboratory for Computational Sensing + Robotics

	Deliverables	Date	Status
Minimum	Final CAD model	23-Mar	80%
	Report of Finite Element Analysis results	23-Mar	Behind
Expected	Fabricated prototype with sensors attached	20-Apr	
	Preparation for calibration and test rig	4-May	
	Plan for further tests	4-May	
Maximum	Report of calibration data analysis	TBD	
	More tests under different conditions	TBD	
	Plan for design iteration and future work	TBD	

Timeline


February
March
April
May
Week
1
2
3
4
1
2
3
4
5
1
2
3
4
1
2
3
4
Literature Review
Design
Determine actuation mechanism
Determine cruciform design
Determine jaw geometry
Determine sensor locations
CAD
CAD modeling by part
Case Design
Full CAD model
Finite Element Analysis
FEA by part
Final FEA Report
Iterative Design
Prototyping
Calibration and test rig preparation
Final Report

Dependencies

- Major dependency: Prototyping
  - In-house: preferred, may be affected by in-campus activity status
  - Outsourcing: not preferred, wait for quote & build time
  - Budget: Resolving – Dr. Galaiya is reviewing budget proposal

- Testing
  - Dr. Galaiya's schedule

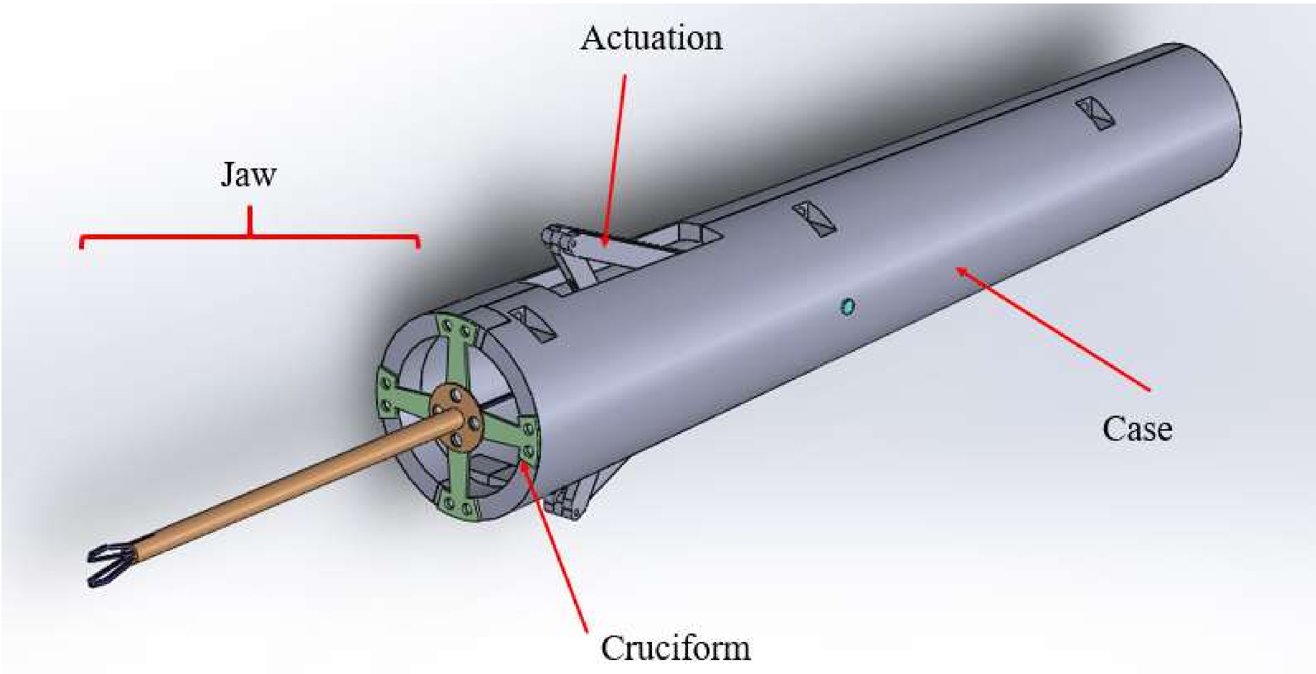
Current status & Cause of delay

Laboratory for Computational Sensing + Robotics

- Jaw design: 80%
- Cruciform design: 90%
- Actuation design: 90%
- Case design: 70%

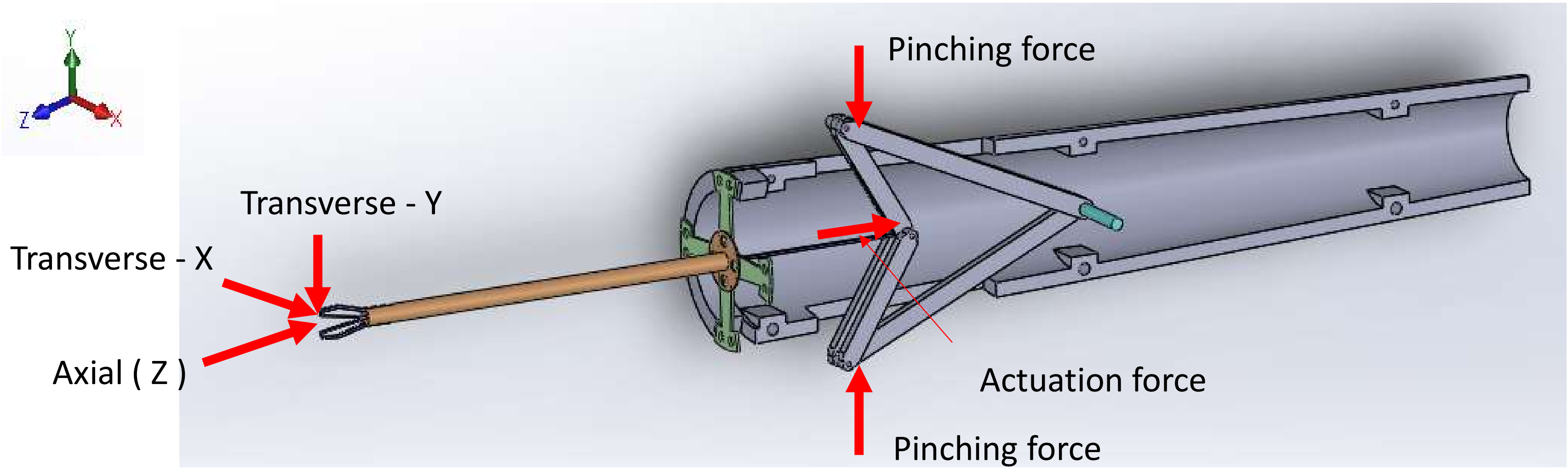
- Underestimated the complexity of the design
- Currently, the general design is developed, but needs a lot of editing to produce an actual prototype

Overview of Design



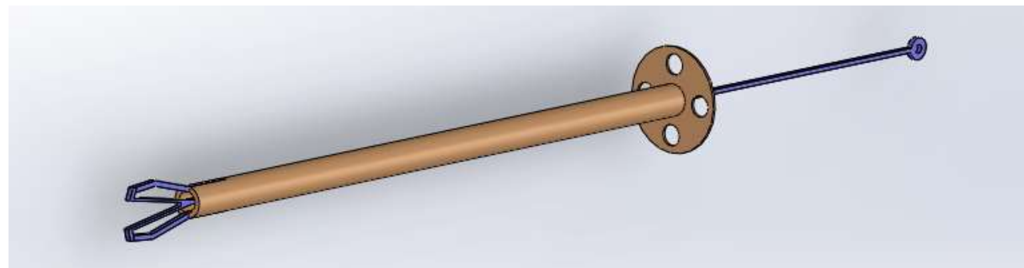
- Jaw: 2 mm dia, 45 mm length
- Body: 20 mm dia, 100 mm length

Terminology



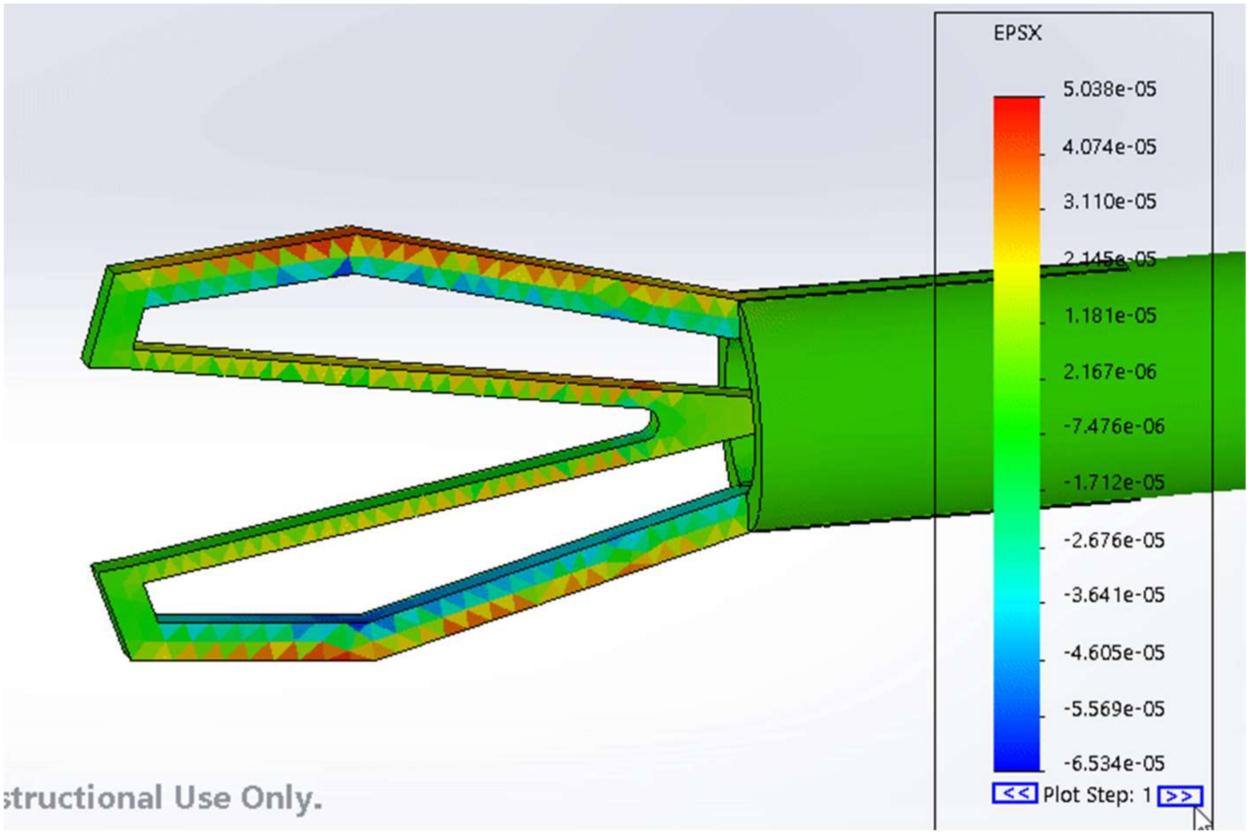
- Finite Element Analysis (FEA)
  - Computer simulation used to predict how a part / assembly behaves physically given some physical parameters

Jaw - 1



- Ergonomic:
    - Tip width when closed > 12 mm
    - Optimal length: 40 mm

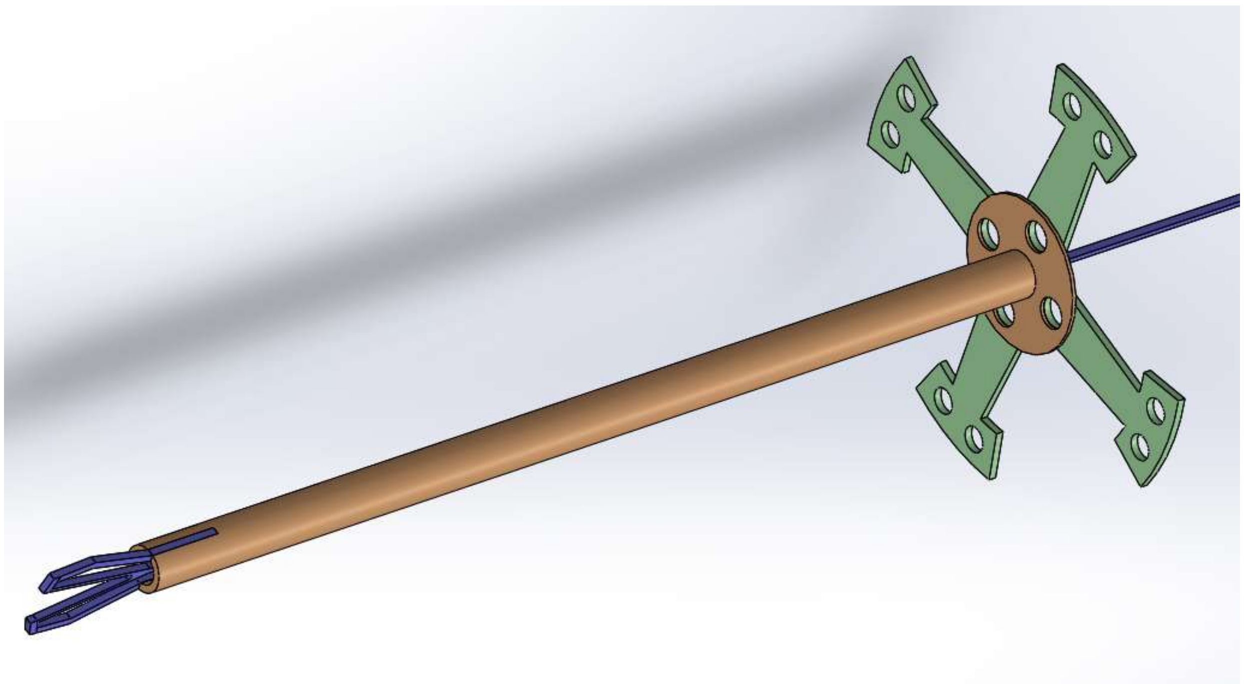
Jaw - 2

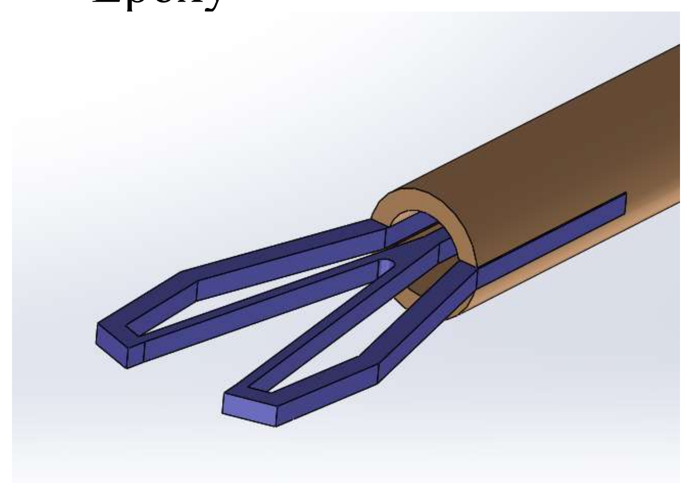


- When fully actuated
  - < 12 mm total width
  - Able to grab 0.5 mm electrode
- Middle segment thinner
  - Guides deformation

Jaw - 3

- Tube (orange)
  - Adds rigidity
  - Translates transverse force evenly to the cruciform
- Connection to the tube
  - Epoxy





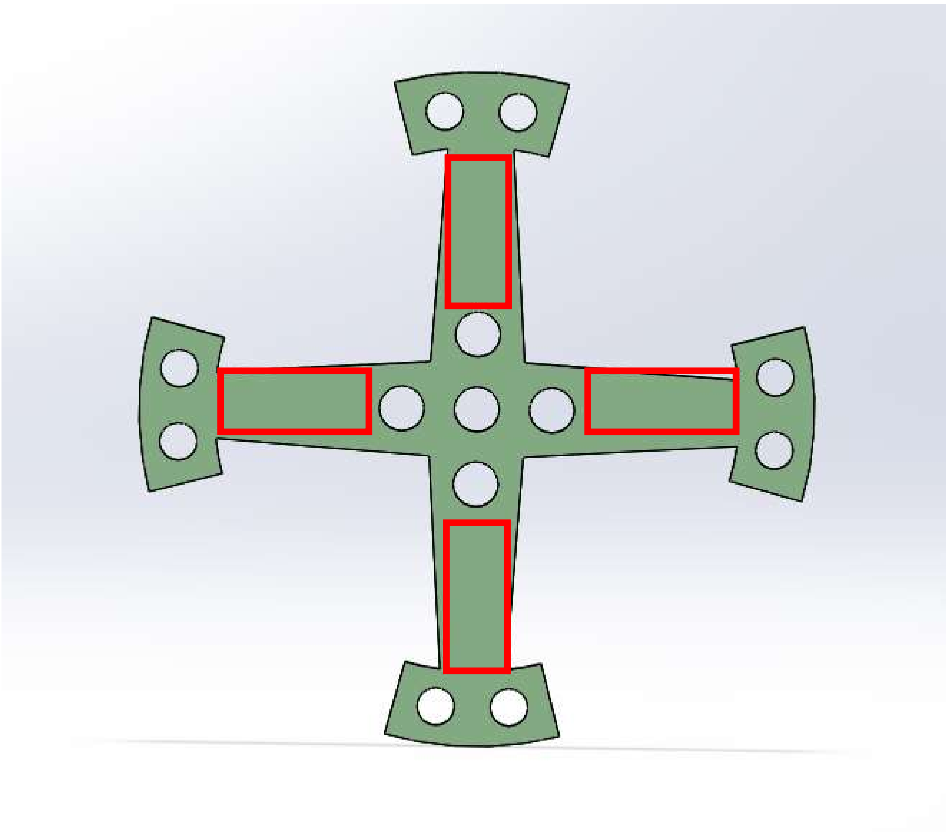
Jaw – Next Steps

- Too thin to easily prototype
- However, increasing thickness changes:
  - Grasping force
  - Actuation force

- Want to keep an optimal grasping force while minimizing actuation force
- While meeting ergonomics requirement

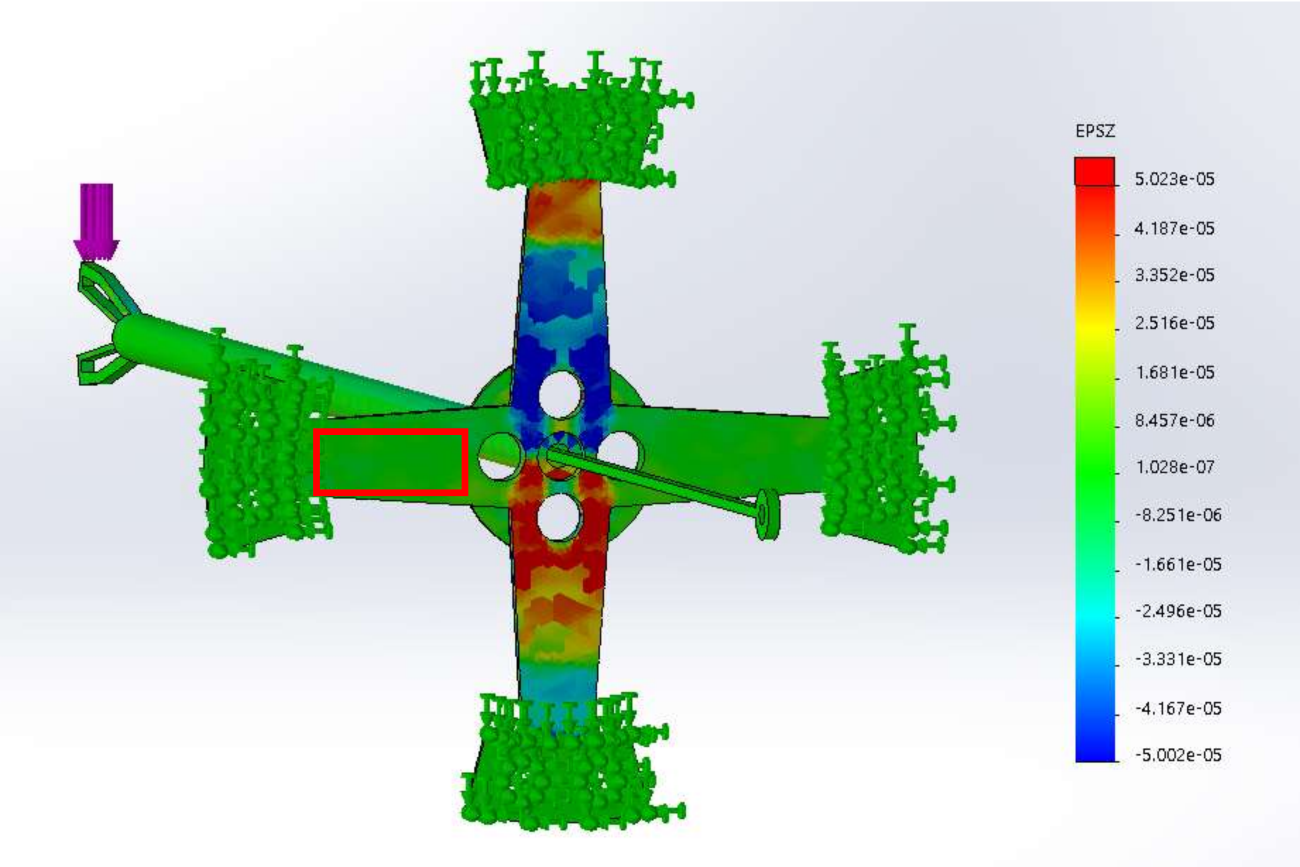
- Fatigue study

Cruciform



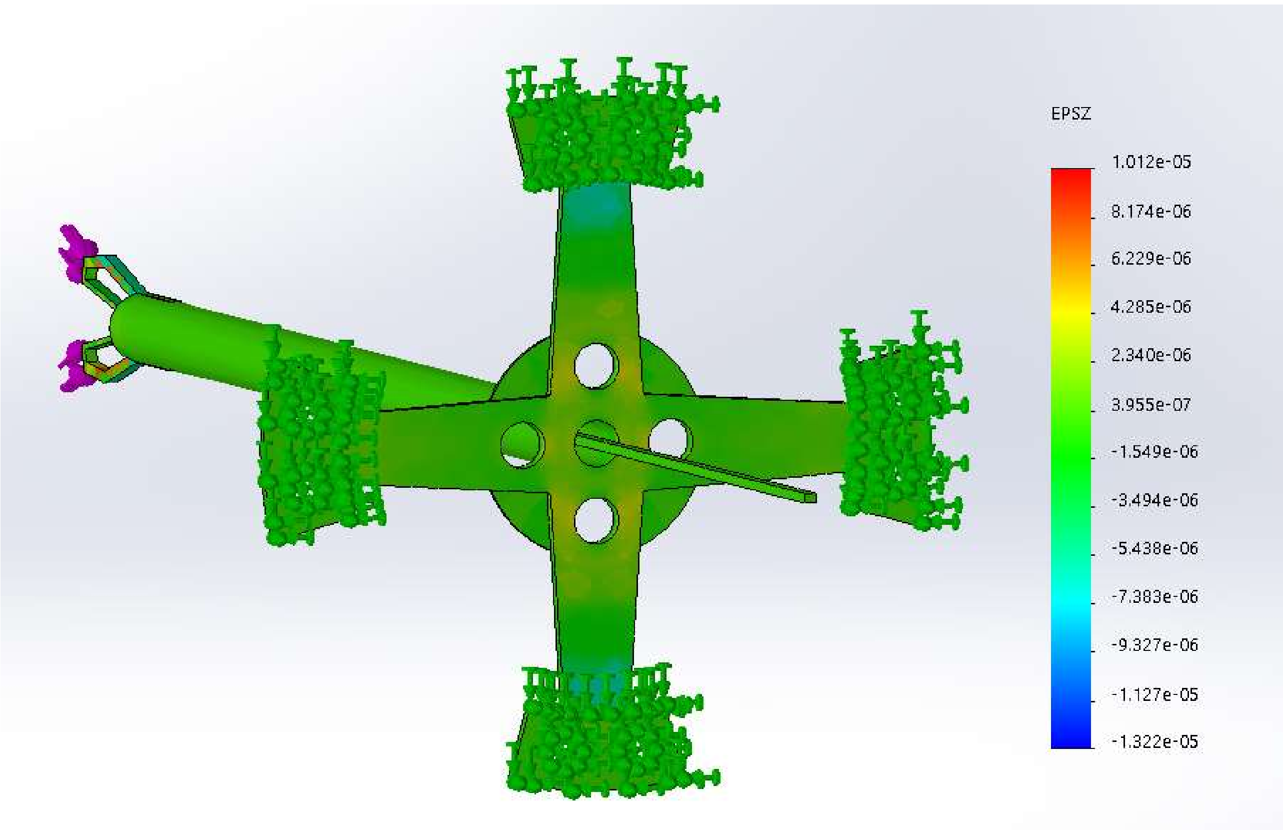
- Force-sensing part
- Red: strain gauge mount
- Ergonomic
  - < 20mm in dimameter

Cruciform – Transverse loading



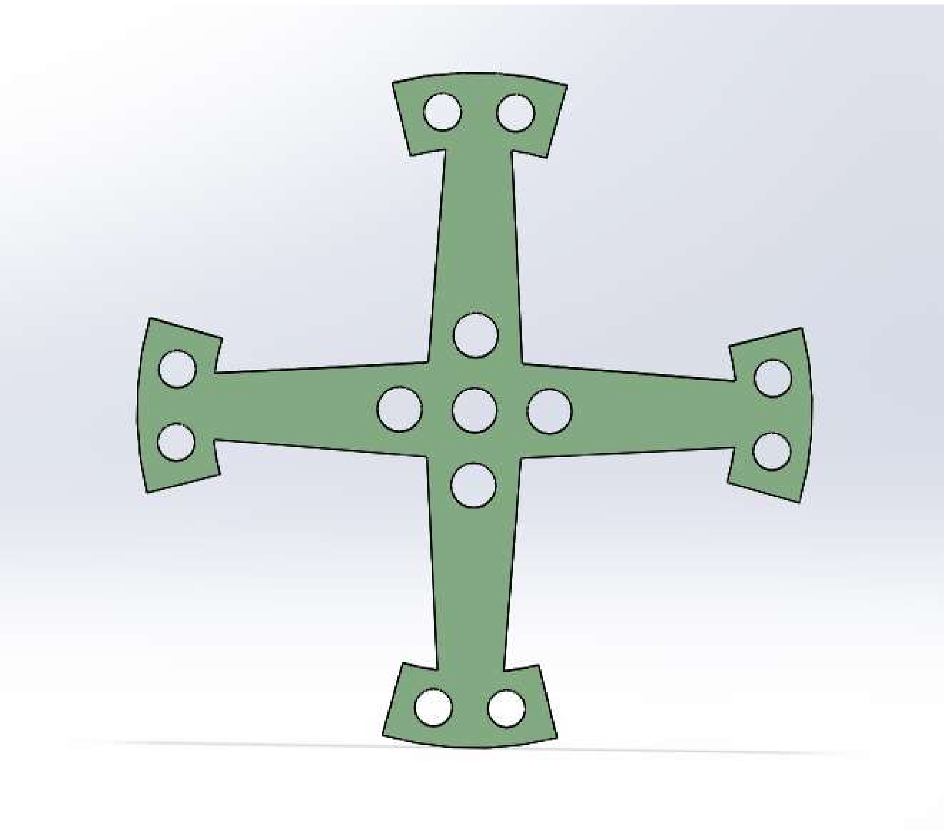
- Minimum strain:
  - 50 um at minimum force (20 um)
- Strain is inconsistent through out
  - Need to find where the active region of the strain gauge lies

Cruciform – Axial loading



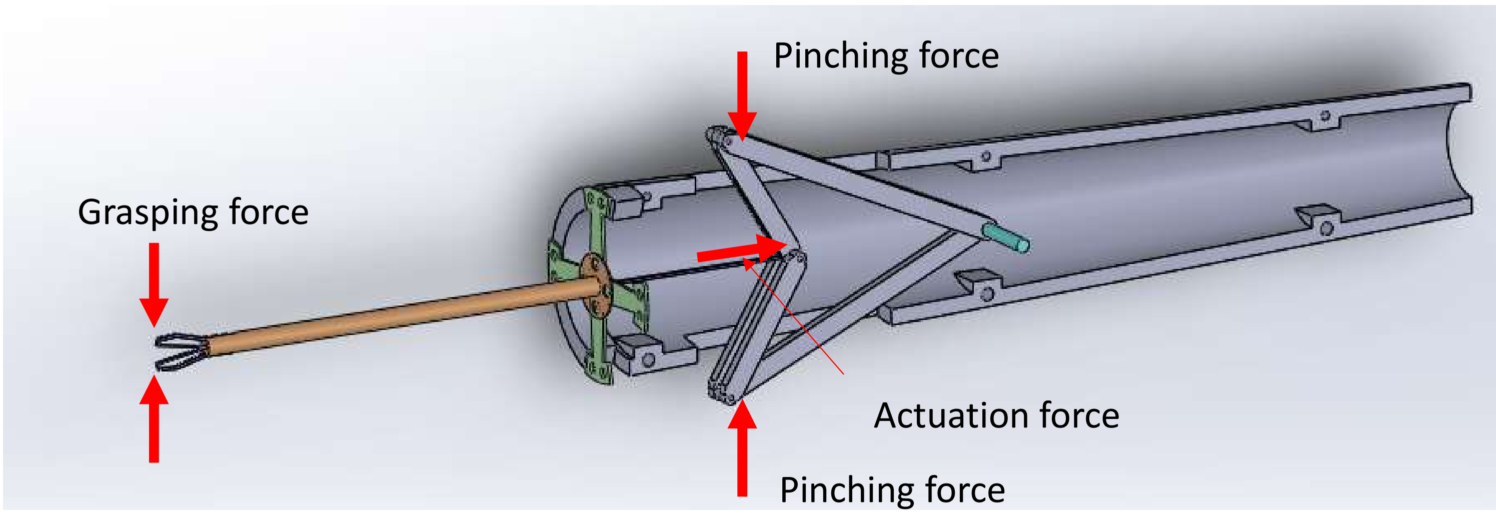
- Not as sensitive in axial
  - x 0.1 ~ 0.001
- Need additional feature to detect axial loading

Cruciform – Next Steps



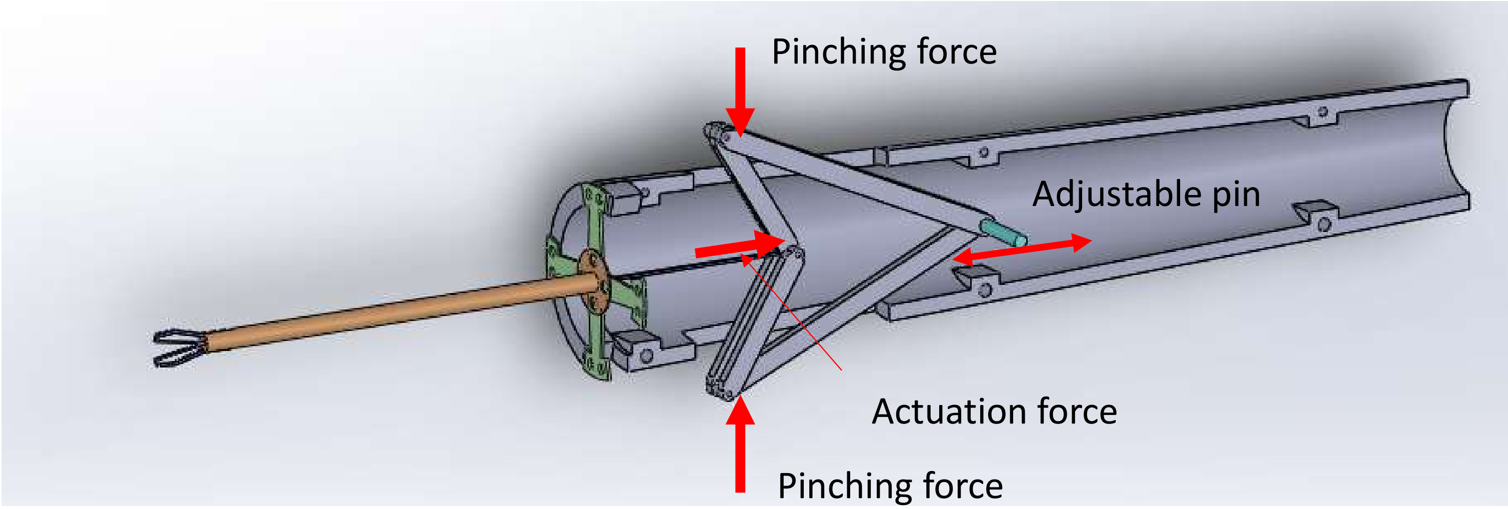
- Check location of active region of strain gauge
- FEA at max load
- Remove connection holes
  - Use epoxy instead

Actuation & Case



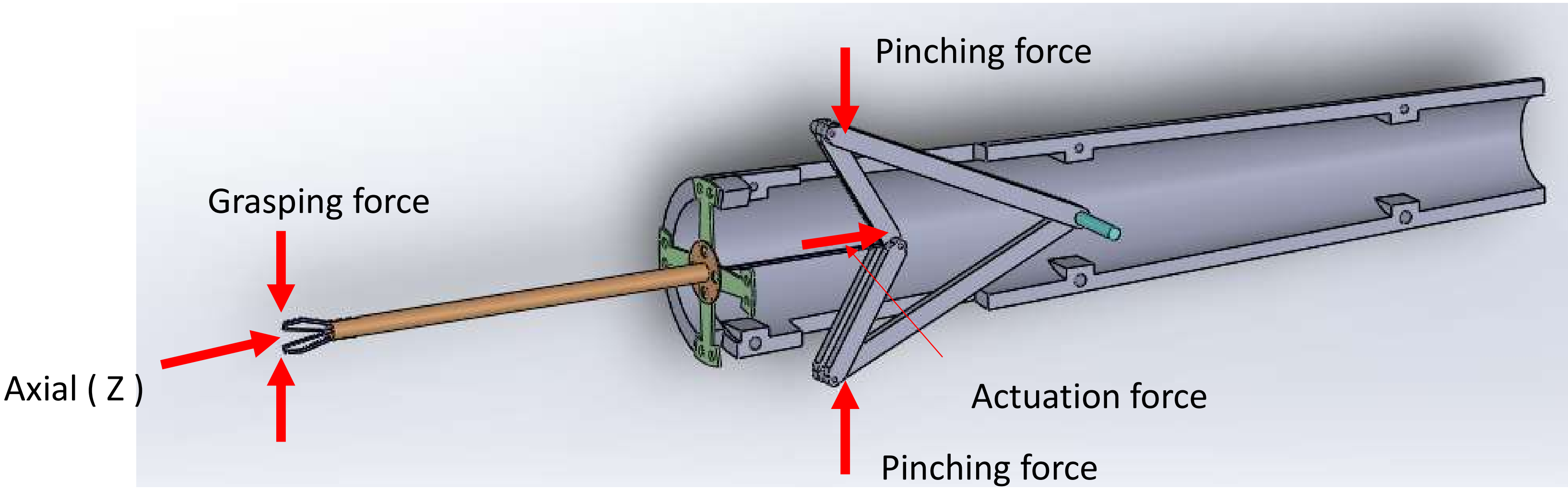
- Check location of active region of strain gauge

Actuation & Case



- Axial force and actuation force are in the same direction
  - Need to experimentally observe this behavior (with prototype)
- Teal pin needs to be able to slide & fix to adjust pinching force

Actuation & Case – Next Steps



- Rapid prototype (3D print) to check with Dr. Galaiya
- Pin design
- Sensor wires

Looking ahead - Design

- Jaw design (most amount of work)
  - Need to adjust dimensions
- Cruciform design
  - Need small adjustments
  - Figure out mounting
- Actuation & Case
  - Final adjustment and rapid prototyping
- Extra refinements
- Most likely…1~2 weeks amount of work before prototype begins
  - Will have a meeting with Anna today to make an estimations

Looking ahead - Prototyping

- Many parts
  - Different manufacturing methods
  - Different mounting methods
  - Difficult assembly
- Strain gauge placement & wires

- May need 3~4 weeks

Looking ahead – Revised timeline

Laboratory for Computational Sensing + Robotics

	Deliverables	Date
Minimum	Final CAD model	8-Apr
	Report of Finite Element Analysis results	15-Apr
Expected	Fabricated prototype with sensors attached	4-May
	Preparation for calibration and test rig	TBD
	Plan for further tests	TBD
Maximum	Report of calibration data analysis	Summer
	More tests under different conditions	Summer
	Plan for design iteration and future work	Summer

Management

- General LCSR Lab meeting
  - Weekly on Wednesday
- Meeting with Anna
  - Almost 2 times a week, mostly once a week
- Meeting with Dr. Iordachita
  - For consult
- Meeting with Dr. Galaiya
  - For consult

References

- De Seta D, Torres R, Russo FY, Ferrary E, Kazmitcheff G, Heymann D, Amiaud J, Sterkers O, Bernardeschi D, Nguyen Y. Damage to inner ear structure during cochlear implantation: Correlation between insertion force and radio-histological findings in temporal bone specimens. Hear Res. 2017 Feb;344:90-97. doi: 10.1016/j.heares.2016.11.002. Epub 2016 Nov 5. PMID: 27825860.
- Gao, Anzhu, et al. “3-DOF Force-Sensing Micro-Forceps for Robot-Assisted Membrane Peeling: Intrinsic Actuation Force Modeling.” *2016 6th IEEE International Conference on Biomedical Robotics and Biomechatronics (BioRob)*, 2016, doi:10.1109/biorob.2016.7523674.
- Handa, James, et al. “Design of 3-DOF Force Sensing Micro-Forceps for Robot Assisted Vitreoretinal Surgery.” *IEEE Engineering in Medicine and Biology Society*, 2013, doi:10.1109/EMBC.2013.6610841.
- Hoskison E, Mitchell S, Coulson C. Systematic review: Radiological and histological evidence of cochlear implant insertion trauma in adult patients. Cochlear Implants Int. 2017 Jul;18(4):192-197. doi: 10.1080/14670100.2017.1330735. Epub 2017 May 23. PMID: 28534710.
- “Implant Programs - Mankato.” *Mayo Clinic Health System*, www.mayoclinichealthsystem.org/locations/mankato/services-and-treatments/audiology/implant-programs.

Thank you! Questions