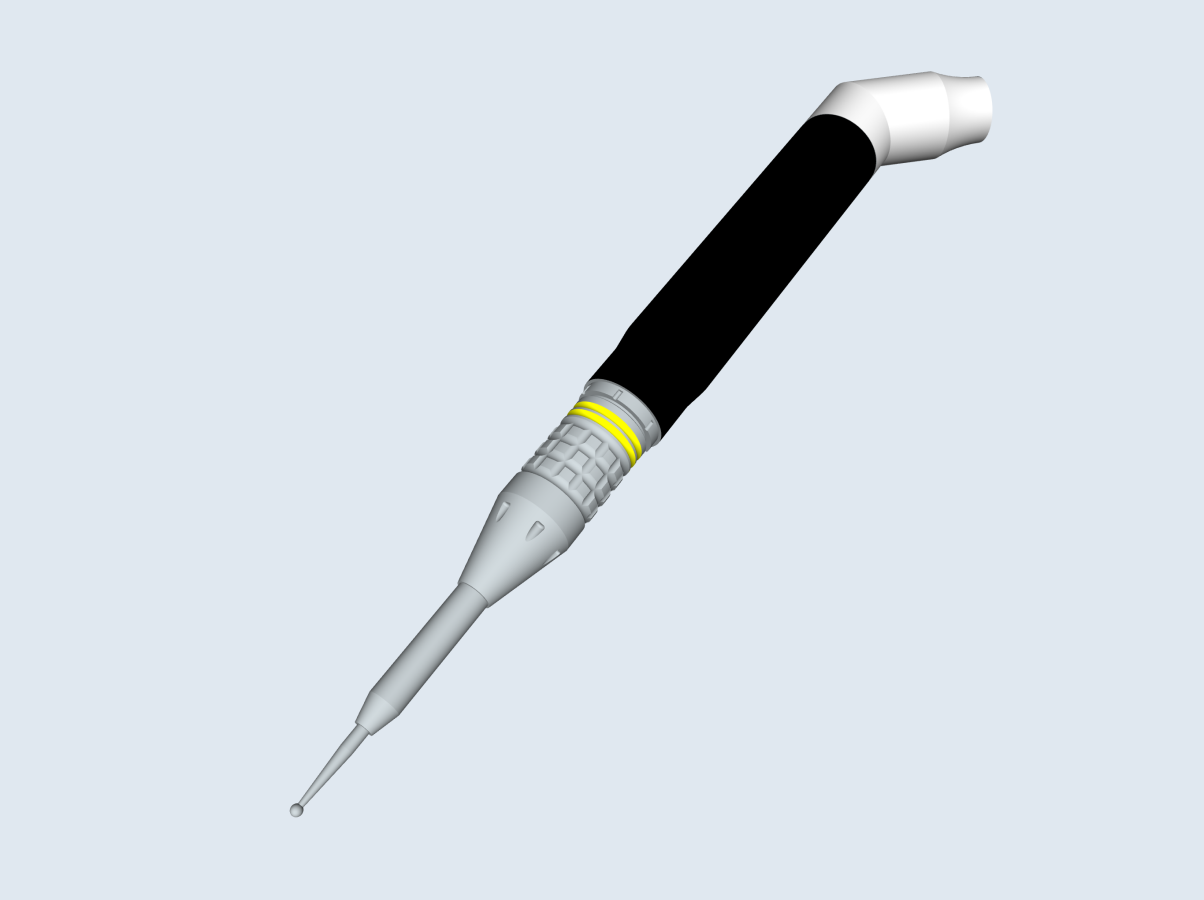
Force-Sensing Drill for Skull-Base Surgery

Group 08:
Harsha Mohan
Seena Vafaee

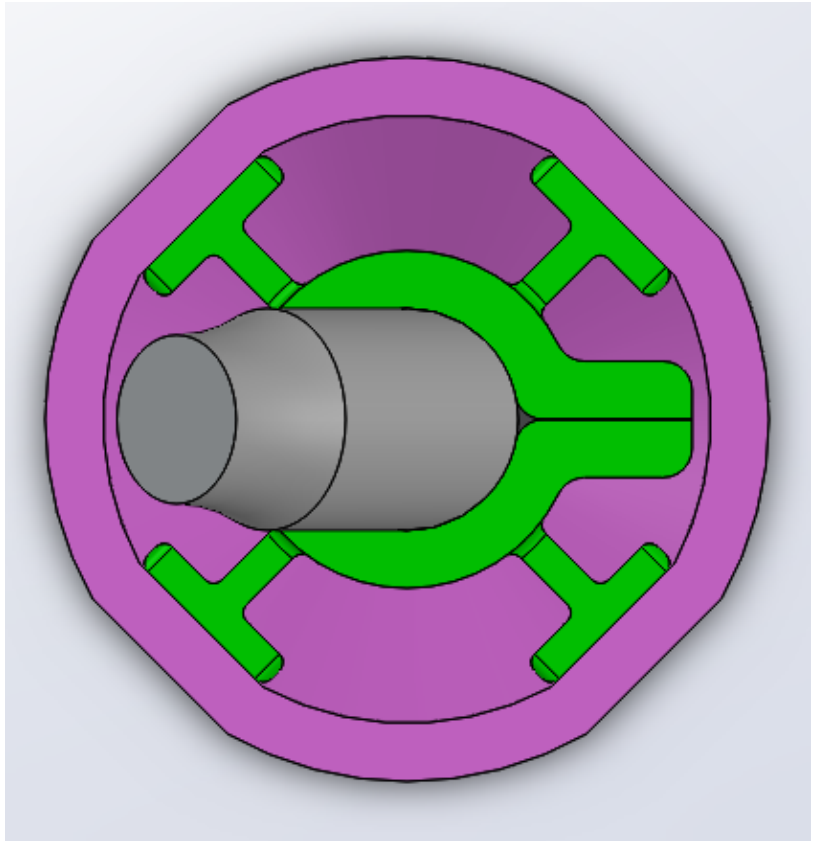
Principal Investigator: Prof. Russ Taylor
Engineering Mentor: Anna Goodridge
Surgeon Mentor: Dr. Deepa Galaiya
Dr. Pete Creighton

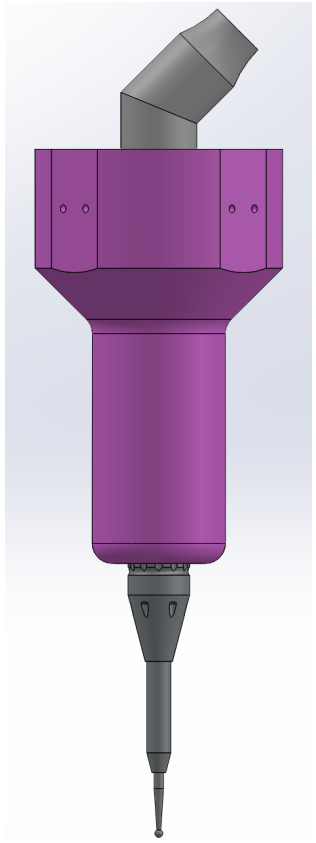
Semester Goal

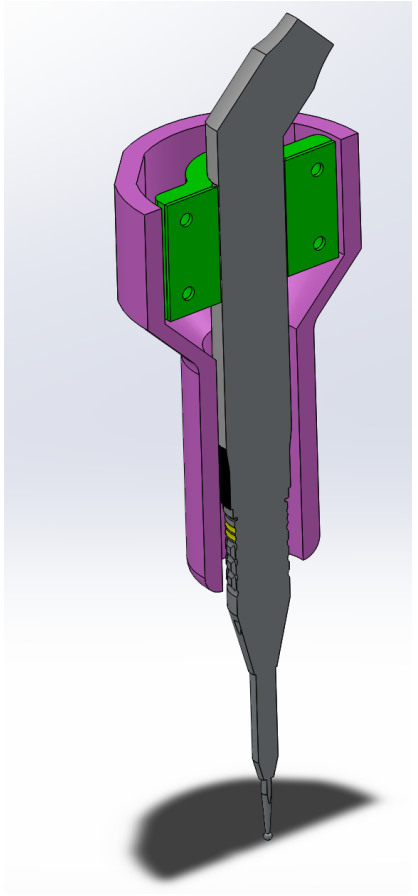
- Develop a force-sensing drill attachment for the Anspach + Galen

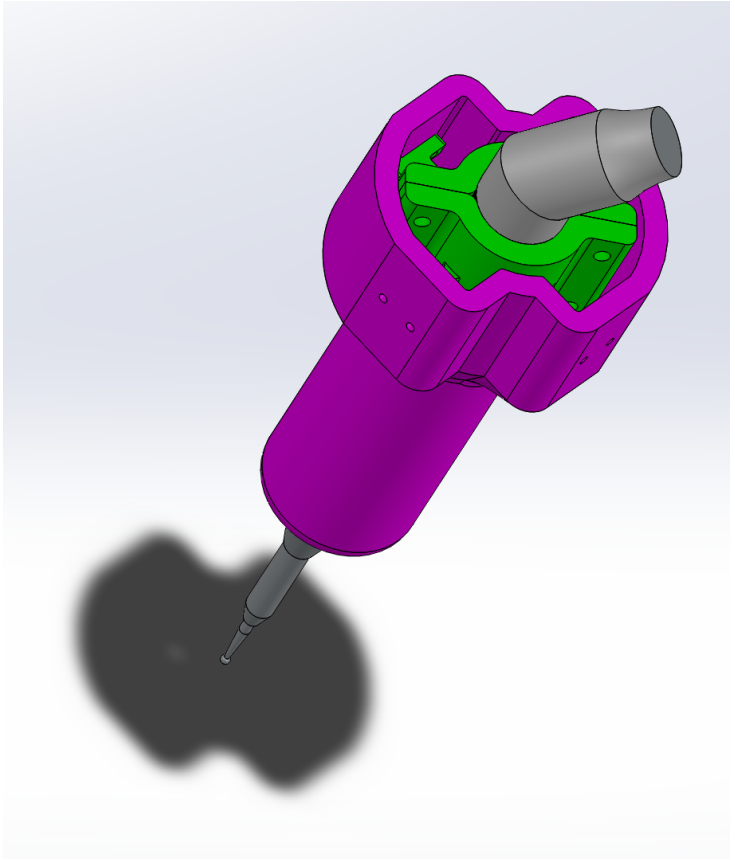


Design Progress









Motivation – Skull-Base Surgery

- Galen provides a steady hand, but surgeon cannot feel tool-tissue interaction.
- Surgeons navigate around critical anatomy during skull-base surgery
- For some tasks, it is useful to control/limit the tool-tissue forces.

- A force-sensing drill is needed to provide tool-tissue haptic feedback during microsurgery.
- A force-sensing tool can help to evaluate surgeon skill

Technical Approach - Design

- Select strain gauges & flexure geometry
  - Analyze drilling data to understand range and resolution of forces
  - Given strain gauge specs and loading conditions, determine the required deformation of each flexure
  - Select material and geometry of flexures
- Select force sensor

- Design an ergonomic form factor
  - Present various prototypes to surgeon
  - Select best ergonomic form factor

Technical Approach - Prototype

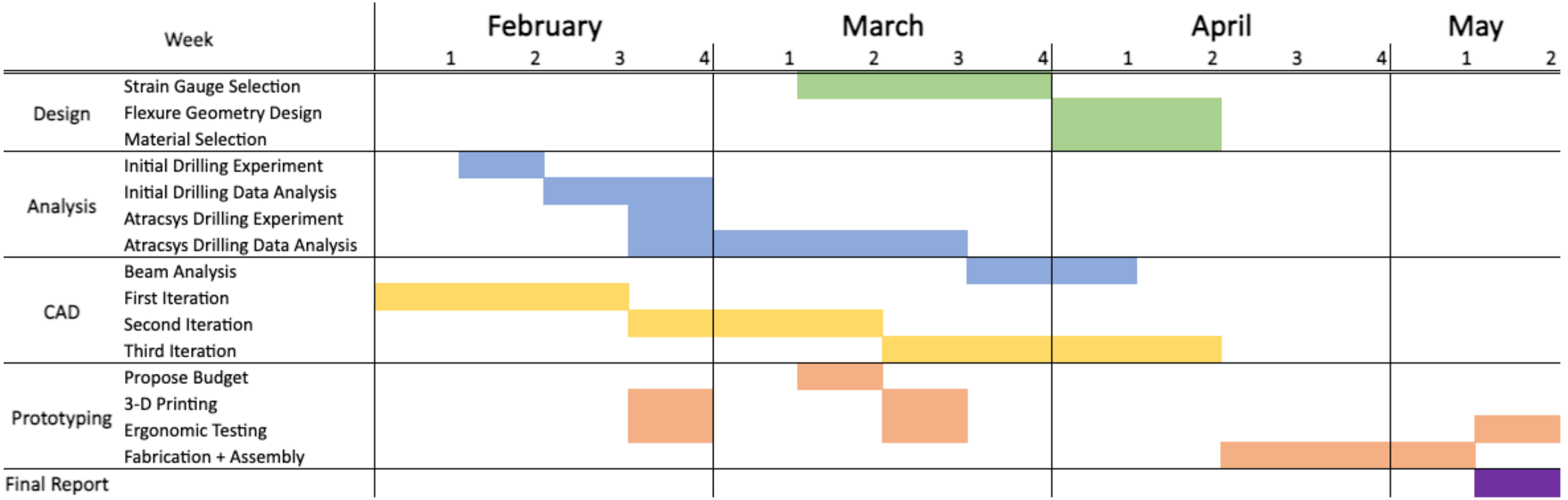
- Build CAD model of the design

- Build prototype
  - In-house: 3-D Print, CNC, Lathe, Mill
  - Outsource: Expert machining

Deliverables

	Deliverables	Date
Min	Initial prototype (3-D printed) of instrument	5-Mar
	Drilling Experiment Results Documentation	13-Mar
	CAD Assembly in Zip File	21-Apr
	Final Report & Documentation	10-May
Expected	BOM describing all components	26-Mar
	Three 3-D printed iterations of designs	26-Apr
	Fully fabricated (machined) & assembled prototype	5-May
Max	White paper with force readings from instrument measured during eggshell drilling experiment	TBD

Timeline


Week
February
March
April
May
1 2 3 4 1 2 3 4 1 2 3 4 1 2
Design
Strain Gauge Selection
Flexure Geometry Design
Material Selection
Analysis
Initial Drilling Experiment
Initial Drilling Data Analysis
Atracsys Drilling Experiment
Atracsys Drilling Data Analysis
CAD
Beam Analysis
First Iteration
Second Iteration
Third Iteration
Prototyping
Propose Budget
3-D Printing
Ergonomic Testing
Fabrication + Assembly
Final Report

Dependencies

Dependency	Need	Status	Followup	Contingency Plan	Estimated Deadline	Hard Deadline	Resolved?
MockOR Access	For testing with Galen	Seena has access	N/A	Wait for time when Galen is not being use	N/A	N/A	Yes
Temporal Bone Lab Access	To conduct additional drilling experiments	Can accompany surgeon	N/A	Procede with available data	N/A	N/A	Yes
Funding	For prototyping	Submitted budget for $8,	N/A	Use low-cost on-campus resources	26-Feb	12-Mar	No
Phantom/Temporal Bones	For drilling experiments	Need to acquire more for	Find out how to get more specimens	Use egg shells as alternative			No
6DOF F/T Sensor	For drilling experiments	Available in the lab	N/A	Proceed with available data			Yes
Atracsys System	For drilling experiments	Available in the lab	N/A	Default to experiment without Atracasys			Yes
Surgeons' Time/Schedule	For ergonomic feedback and performing drilling epx	Coordinating with surgeo	Communicate with Deepa	Work around their schedule	N/A	N/A	Yes
LCSR 3-D Printer	For rapid prototyping	Seena has access	N/A	Use 3-D printer in Wyman Park Building			Yes
LCSR Machine Shop	For rapid prototyping	Seena has access	N/A	Use student shop or senior design lab			Yes

Roles and Responsibilities

Harsha Mohan

- Data Analysis, CAD modeling

Seena Vafaee

- Beam Analysis, CAD modeling, Rapid Prototyping

Management Plan

- Weekly Galen meeting (Wednesday 4:00 pm eastern)
- Weekly Team Meeting w/ Anna (Friday 1:00 pm eastern)
- Consult with Deepa as needed
- Seena + Harsha working meeting 3x weekly

Reading List

[1] T. B. C Gaudeni, GM Achilli, M Mandala, D Prattichizzo, "Instrumenting Hand-Held Surgical Drills with a Pneumatic Sensing Cover for Haptic Feedback," Cham, 2020: Springer International Publishing, in Haptics: Science, Technology, Applications, pp. 398-406.

[2] R. M. H Sang, E Wilson, H Fooladi, D Preciado, K Cleary, "A New Surgical Drill Instrument With Force Sensing and Force Feedback for Robotically Assisted Otologic Surgery," *Journal of Medical Devices,* vol. 11, September 2017.

[3] J. H. M Hessinger, PP Pott, R Werthschutzky "Handheld Surgical Drill With Integrated Thrust Force Recognition," presented at the IEEE International Conference on E-Health and Bioengineering, Grigore T Papa University a/Medicine and Pharmacy, Iasi, Romania, November 21-23,2013, 2013.

[4] S. L. Y Guo, JB Mann, "Piezo-Actuated Modulation-Assisted Drilling System With Integrated Force Sensing," *Journal of Manufacturing Science and Engineering,* vol. 139, January 2017 2017.

[5] R. L. D Schurzig, A Hyssong, T Rau, RJ Webster III, "Design of a Tool Integrating Force Sensing With Automated Insertion in Cochlear Implantation," presented at the IEEE/ASME Transactions on Mechatronics, 2012.

[6] I. D. M Louredo, JJ Gil, "DRIBON: A mechatronic bone drilling tool," *Mechatronics,* vol. 22, no. 8, pp. 1060-1066, 2012, doi: //doi.org/10.1016/j.mechatronics.2012.09.001.

[7] L. W. PJ Berkelman, RH Taylor, P Jensen, "A Miniature Instrument Tip Force Sensor for Robot/Human Cooperative Microsurgical Manipulation with Enhanced Force Feedback," presented at the IEEE Transactions on Robotics and Automation, October 2003, 2003.

[8] J. R. DL Rothbaum, D Stoianovici, P Berkelman, GD Hager, RH Taylor, LL Whitcomb, HW Francis, JK Niparko, "Robot-assisted stapedotomy: Micropick fenestration of the stapes footplate," *Otolaryngology– Head and Neck Surgery,* vol. 127, 5, pp. 417-426, 2002.