

Group 9: Checkpoint Presentation

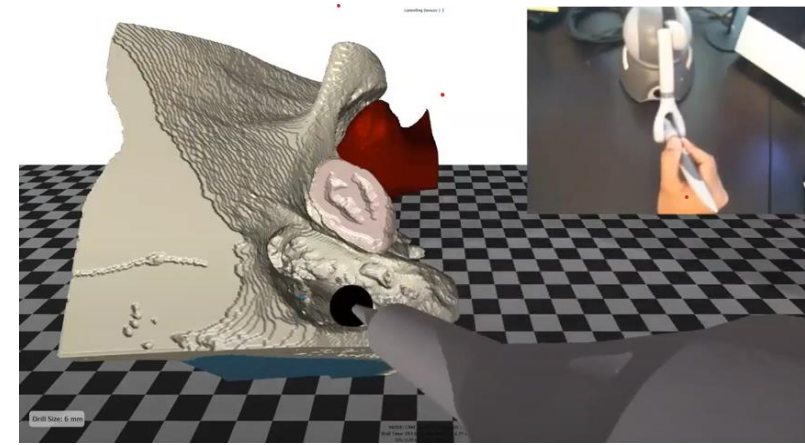
Team Members: Tommy Liang, Jintan Zhang, HongYi Fan

Mentors: Max Li, Dr. Adnan Munawar, Dr. Francis Creighton,
Prof. Mathias Unberath, Prof. Russ Taylor

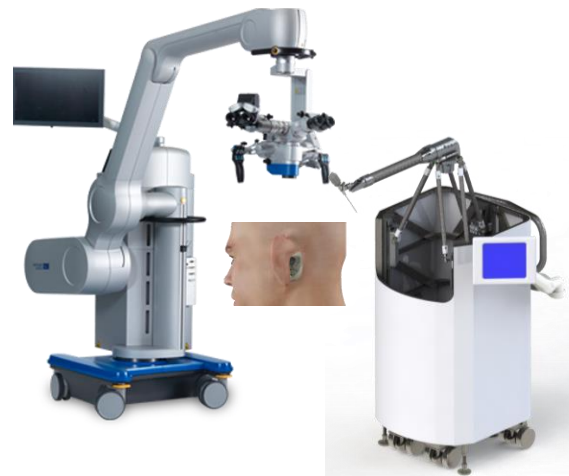
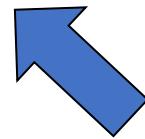
Project Background



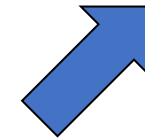
Context Situation Awareness



Actual Surgical State



Simulated Surgical State



Video credit:

[1] <https://www.youtube.com/watch?v=jnonLwxW2Cg>

[2] Munawar, A., Li, Z., Kunjam, P., Nagururu, N., Ding, A.S., Kazanzides, P., Looi, T., Creighton, F.X., Taylor, R.H. and Unberath, M., 2021. Virtual reality for synergistic surgical training and data generation.

Project Goals

- Create virtual environment in AMBF for skull-base surgery with the following components:
 - Galen Robot
 - Skull-base Model
- Sync Galen robot in VR space with physical Galen robot.
 - Establish mode of communication between robot and AMBF simulation
 - Develop control scheme to keep both in sync:
 - Movement in physical robot is mapped to the virtual space.
 - Constraints in virtual space reflected in physical robot.

Technical Approach

High Level Controller

1. Update simulator joint state based on sent joint state from robot.
2. Higher level controller determines payload to send back to the Galen System based on the simulator location and constraints.

Payload: Force/Distance Vector indicating proximity to nearest sensitive tissue voxel

AMBF Plugin: ROS interface, Model State Update

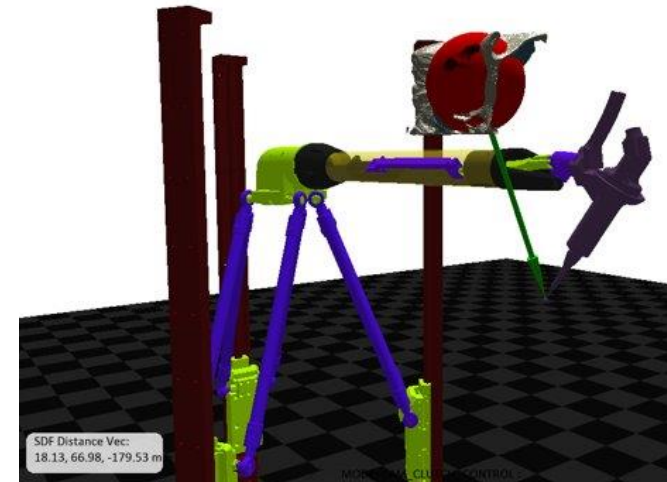
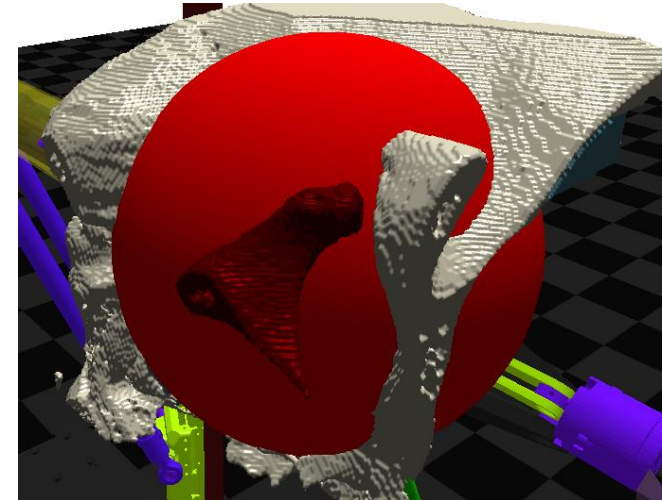
Payload: Robot Joint State

Galen Force Behavior Mode

1. Follow standard Galen force control pipeline.
2. **Resolve Payload From simulator**
3. Solve for desired joint displacement by minimizing an $AX+B$ problem in optimizer.
4. Send desired joint displacements to actuators

Simulator Progress - Accomplished

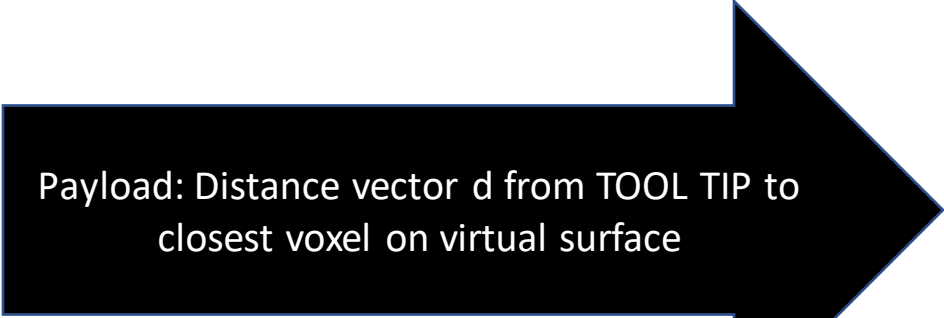
- Galen model in simulator
- Pseudo-SDF using a red sphere
 - Approximate distance vector to sensitive tissue
- Simulator – Robot information pipeline
 - Simulator follows robot
 - Robot receives pseudo-SDF vector from simulator
- Volumetric drilling integration
- Some usability improvements



Simulator Progress - Continuing

- Finetune Galen model
 - Joint position calibration
 - Size scaling
- Finetune controller of simulated robot
 - PID gains of the simulated robot
- Software documentation
- Usability improvements
- Integration with other VR-Guided Skull Surgery teams

Galen Side Controls



Payload: Distance vector d from TOOL TIP to closest voxel on virtual surface

This distance vector can be replaced by a gradient term from the SDF team, the math should still be largely the same

1. Force applied to tool tip

$$d = (x, y, z, 0, 0, 0)$$

If $\|d\| > \alpha$, $d = (0, 0, 0, 0, 0, 0)$ where α is a maximum distance threshold

$$F_{s_tip} = (1/\|d\|) * k_p * (\text{normalized}(d)) + k_d$$

term <- this is in robot frame

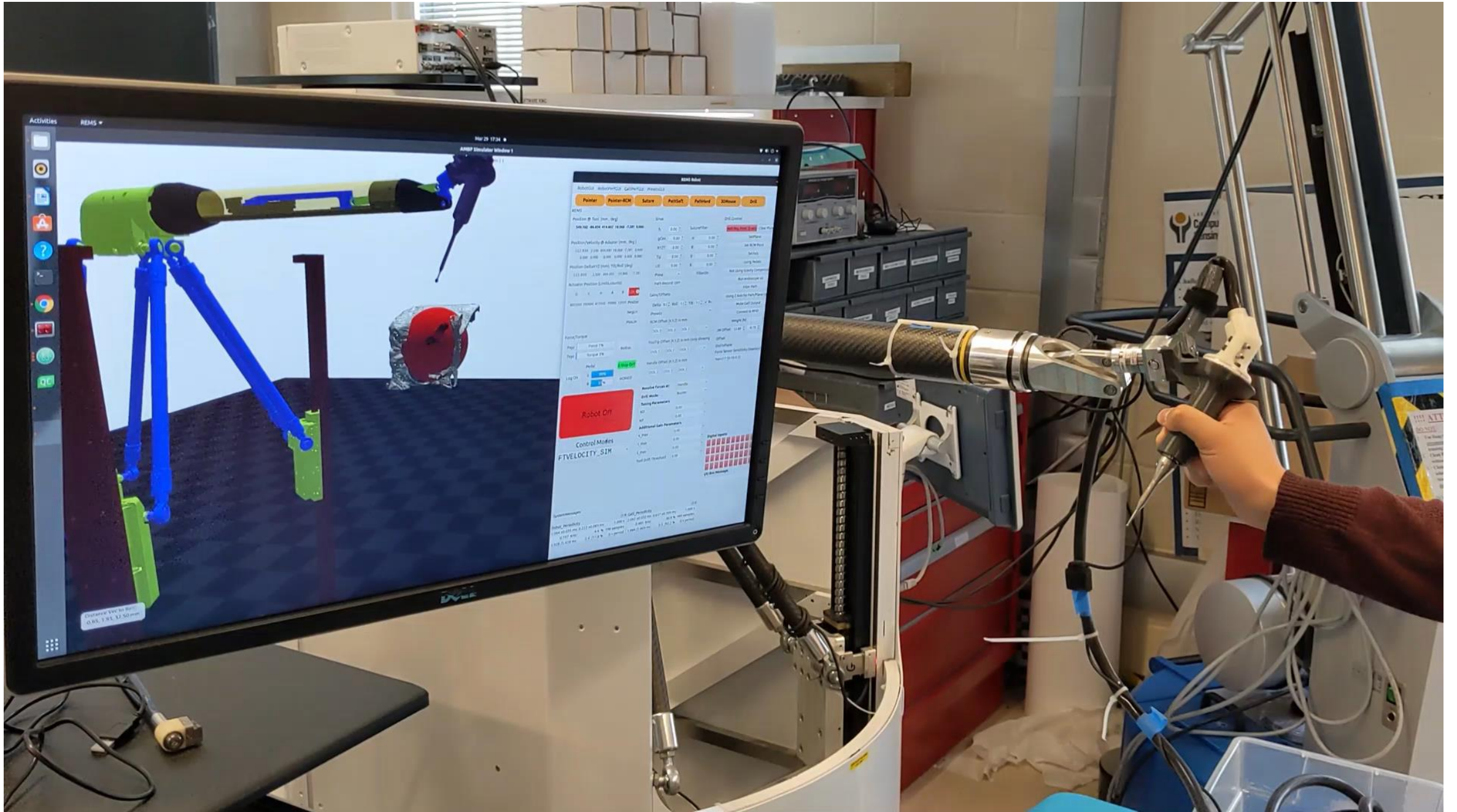
$$F_{s_ee} = Ad_{tip_ee}^T * F_{s_tip}$$

2. Resolve Force Vector at End Effector and Sum

$$F_{total} = w_1 * F_{s_ee} + w_2 * F_{handle}$$

w_1 and w_2 are adjustable weights

3. F_{total} get shipped to the optimizer



Activities REAS

Mar 29 17:24

ARMED Simulator Window 1

Position: Pos (mm, deg)

Joint	Position	Velocity	Acceleration	Current	Max Current
0	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000
31	0.000	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000	0.000
33	0.000	0.000	0.000	0.000	0.000
34	0.000	0.000	0.000	0.000	0.000
35	0.000	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000	0.000
37	0.000	0.000	0.000	0.000	0.000
38	0.000	0.000	0.000	0.000	0.000
39	0.000	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000
41	0.000	0.000	0.000	0.000	0.000
42	0.000	0.000	0.000	0.000	0.000
43	0.000	0.000	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000	0.000
45	0.000	0.000	0.000	0.000	0.000
46	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000
52	0.000	0.000	0.000	0.000	0.000
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56	0.000	0.000	0.000	0.000	0.000
57	0.000	0.000	0.000	0.000	0.000
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59	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000
61	0.000	0.000	0.000	0.000	0.000
62	0.000	0.000	0.000	0.000	0.000
63	0.000	0.000	0.000	0.000	0.000
64	0.000	0.000	0.000	0.000	0.000
65	0.000	0.000	0.000	0.000	0.000
66	0.000	0.000	0.000	0.000	0.000
67	0.000	0.000	0.000	0.000	0.000
68	0.000	0.000	0.000	0.000	0.000
69	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.000	0.000
71	0.000	0.000	0.000	0.000	0.000
72	0.000	0.000	0.000	0.000	0.000
73	0.000	0.000	0.000	0.000	0.000
74	0.000	0.000	0.000	0.000	0.000
75	0.000	0.000	0.000	0.000	0.000
76	0.000	0.000	0.000	0.000	0.000
77	0.000	0.000	0.000	0.000	0.000
78	0.000	0.000	0.000	0.000	0.000
79	0.000	0.000	0.000	0.000	0.000
80	0.000	0.000	0.000	0.000	0.000
81	0.000	0.000	0.000	0.000	0.000
82	0.000	0.000	0.000	0.000	0.000
83	0.000	0.000	0.000	0.000	0.000
84	0.000	0.000	0.000	0.000	0.000
85	0.000	0.000	0.000	0.000	0.000
86	0.000	0.000	0.000	0.000	0.000
87	0.000	0.000	0.000	0.000	0.000
88	0.000	0.000	0.000	0.000	0.000
89	0.000	0.000	0.000	0.000	0.000
90	0.000	0.000	0.000	0.000	0.000
91	0.000	0.000	0.000	0.000	0.000
92	0.000	0.000	0.000	0.000	0.000
93	0.000	0.000	0.000	0.000	0.000
94	0.000	0.000	0.000	0.000	0.000
95	0.000	0.000	0.000	0.000	0.000
96	0.000	0.000	0.000	0.000	0.000
97	0.000	0.000	0.000	0.000	0.000
98	0.000	0.000	0.000	0.000	0.000
99	0.000	0.000	0.000	0.000	0.000
100	0.000	0.000	0.000	0.000	0.000

Robot Off

Control Modes
FTVELOCITY_SIM

Update Deliverables

- **Minimum:** Working Software and Documentation for VR - robot communication, including:
 - Controls to keep physical Galen in sync with simulated Galen
 - AMBF simulated environment with all relevant components. Registration assumed to be provided/fixed.
- **Expected:**
 - Environment constraints fed back to robot.
 - Interfaces developed for ease of integration with registration and SDF teams.
 - Any additional UI components or scripts for updating settings/modes to improve usability.
 - Documentation of system architecture.
- ~~**Maximum: Conduct Internal User Study**~~
 - Unlikely to achieve due to operational delays from the Galen system.

Updated Dependencies

Dependencies	Who to contact	Status/Date	Failure Consequences	Resolution
Mentor Availability	Mentors	Meetings Schedule Set	Insufficient feedback may impact quality of project	Weekly meetings set up with mentors
Linux System	LCSR	Acquired	Available in MockOR. Availability issues may set timeline back.	Schedule ahead of time on shared calendar for shared use
Galen Surgical System	Galen Robotics, Inc	Not Functional	Availability issues may set timeline back.	Schedule ahead of time on shared calendar for shared use
Desktop and monitors for running software	LCSR	Acquired	Available in MockOR. Availability issues may set timeline back.	Schedule ahead of time on shared calendar for shared use
Surgical Drill	LCSR	Acquired	Testing Synchronization could be impacted.	Reach out to LCSR for acquiring tool if unavailable.
C++, Python, OpenGL, ROS	Open Source	Acquired	Publicly available	N/A

Updated Timeline



#Week 1-3	4	5	6	7	8	9	10	11	12	13	14	15-16
Preparation	Presentation											
	Simulation follows robot											
		Robot gets feedback from simulation										
		Add "Volumetric Drilling" to Galen World		Testing synced Robot and simulation <i>(Dependency Failed)</i>								
				Assemble and test combined virtual environment	Interface for combining other groups' work							
							Usability improvement					
								Software documentation				Presentation

QUESTIONS?