Cortical Spreading Depression Simulator

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Angela Beck
Bill Harlam
Brian Rhindress

Sponsor: Dr. Stephen Jones

cerebrosim

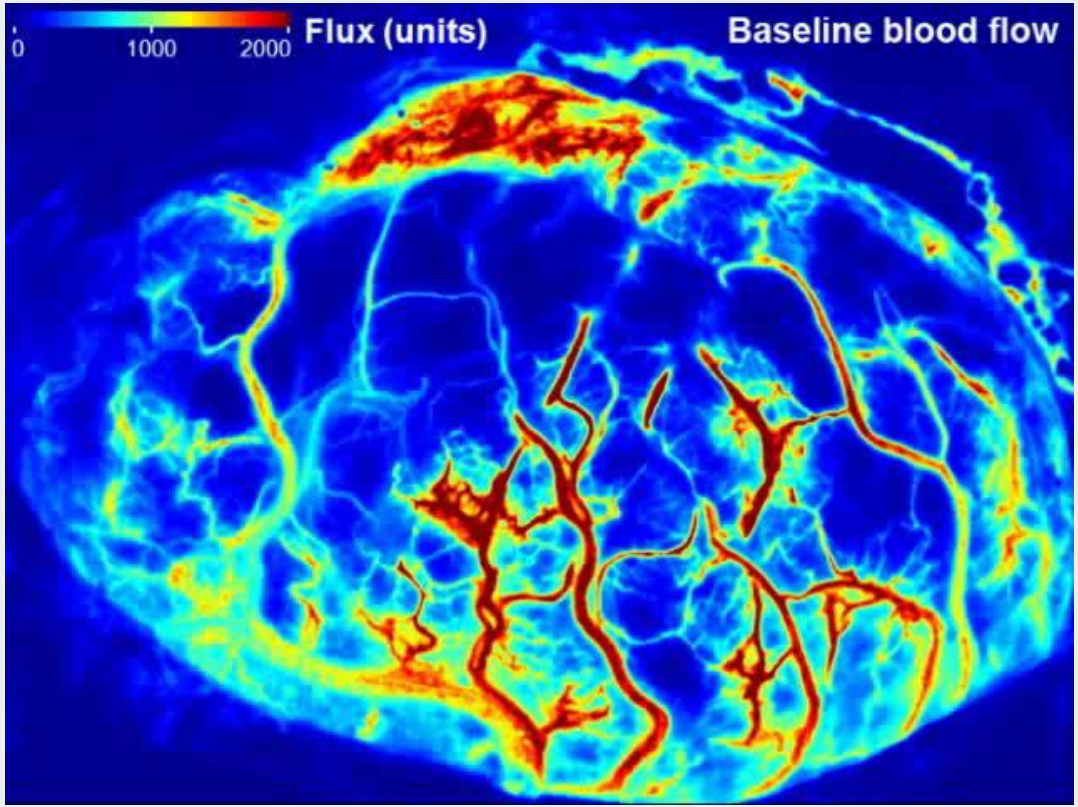
PITT | SWANSON ENGINEERING

Motivation

3.2 million Americans suffer acute brain injuries each year

- **Severe-TBI** (2.5M)
- **Stroke** (691k)
- **Hemorrhage** (30k)

CSD Overview

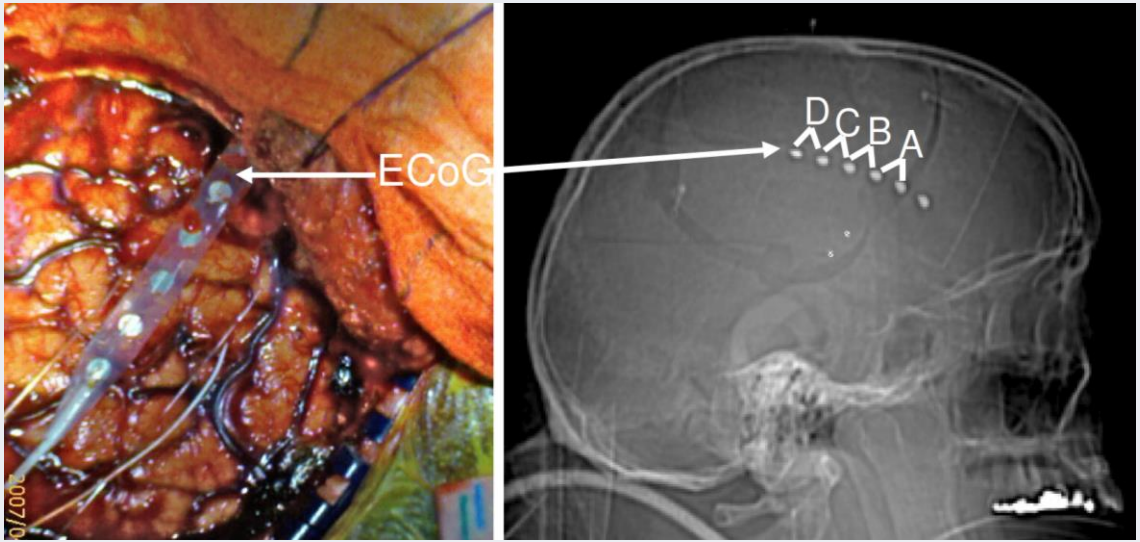


Propagating CSD in the human cortex after malignant stroke. Woitzik et al., Neurology 2013:80:1095-1102,PMID:23446683

Current Standard of Care

An **invasive** procedure that involves the direct placement of electrode strips onto the brain surface.

Electrocorticography (ECoG)



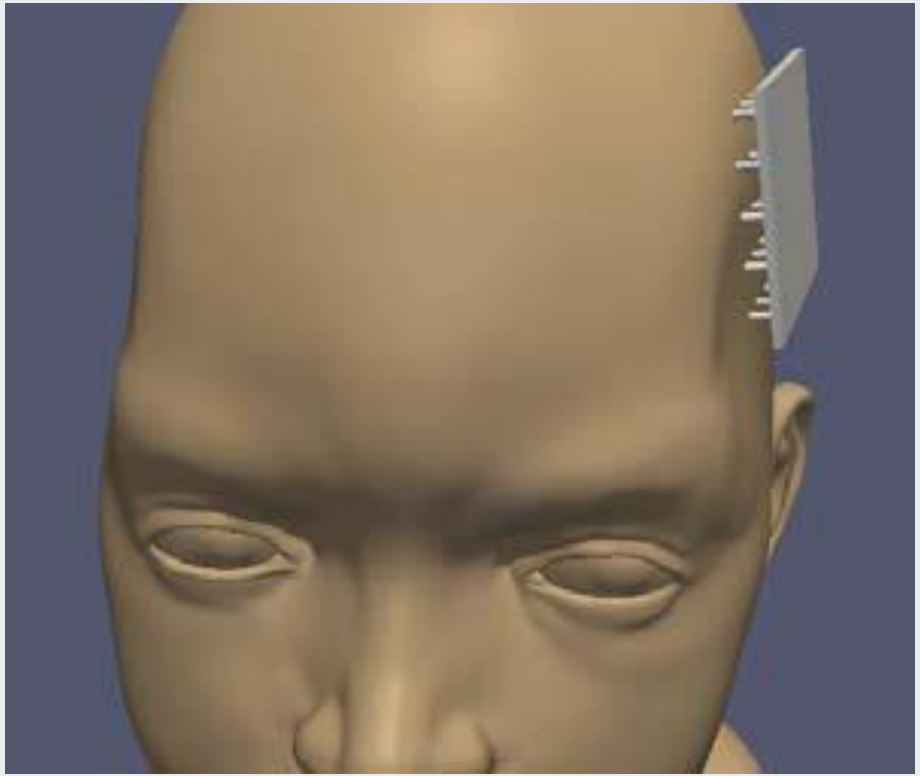
New sensors for non invasive monitoring of spreading brain depolarisation. Feuerstein, et.al.

CerebroScope Role

Creating a device that

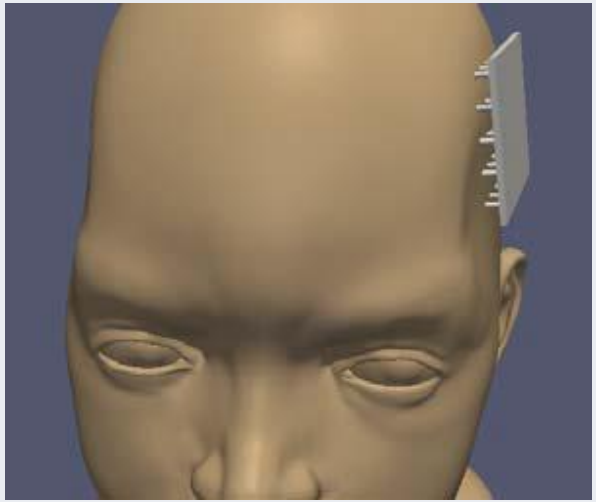
non-invasively

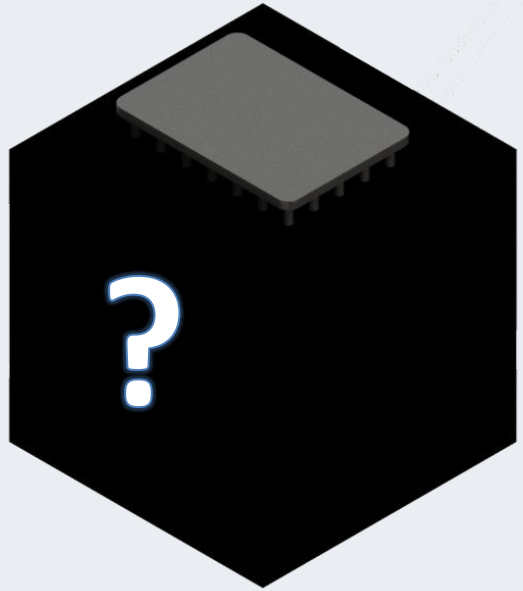
detects cortical spreading depression in acute brain injury patients.



Our Role

There is a need for a mechanical-electrical device that simulates the scalp surface voltage of a brain surface CSD





Specifications

- Simulated CSD region on the brain surface is ~3 mm
- Simulated CSD potential difference is -20mV
- Simulated CSD region moves at ~3 mm/min
- Simulated CSD must propagate a total displacement of 8cm
- Simulated scalp size is 12cm x 12cm (at minimum)
- Simulated scalp is a flat surface (curved scalp not required)
- Simulated CSD measurement is comparable to CerebroScope data
- Simulated CSD accounts for the lumped electrical properties of the layers from the brain surface to the scalp (either through simulation or material design)
- Simulated CSD can at least propagate in a linear motion
- Simulated CSD documentation defining device specifications for current and future reference

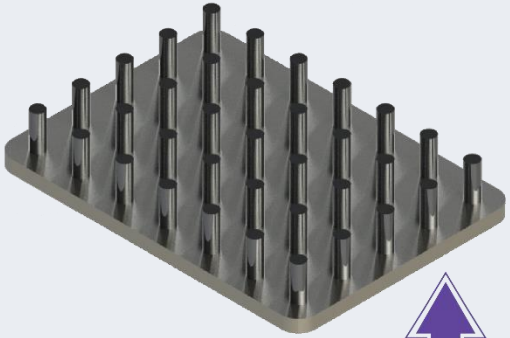
Key Objective

- Simulated CSD region on the brain surface is ~3 mm
- Simulated CSD potential difference is -20mV
- Simulated CSD region moves at ~3 mm/min
- Simulated CSD must propagate a total displacement of 8cm
- Simulated scalp size is 12cm x 12cm (at minimum)
- Simulated scalp is a flat surface (curved scalp not required)
- Simulated CSD motor amplitude comparable to electroencephalography
- Simulated CSD accounts for the lumped electrical properties of the layers from the brain surface to the scalp (either through simulation or material design)
- Simulated CSD can at least propagate in a linear motion
- Simulated CSD documentation defining device specifications for current and future reference

A system that generates a simulated CSD that propagates through electrically modeled layers of head tissue.

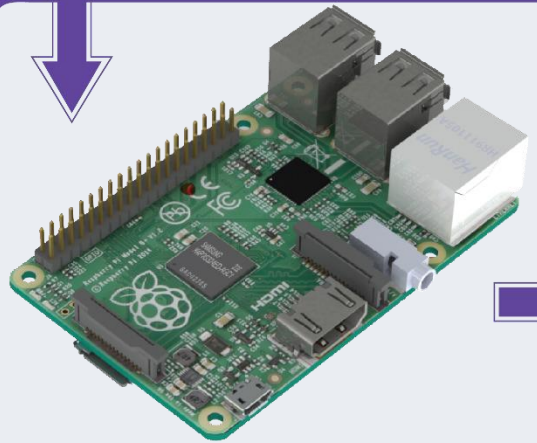
User

A mechanical-electrical system to simulate a scalp level CSD.

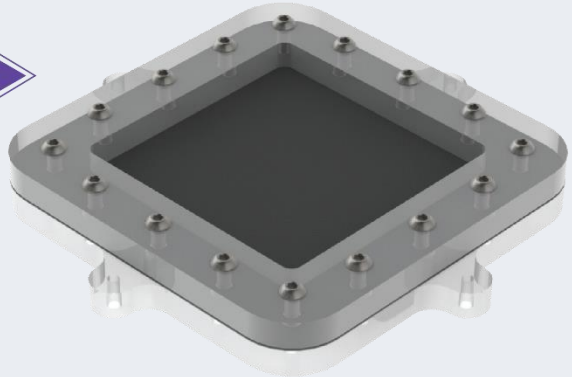


Sensor

Interface



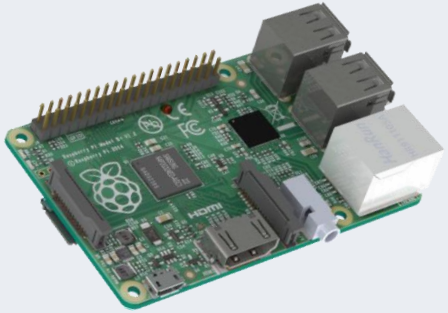
Electrical



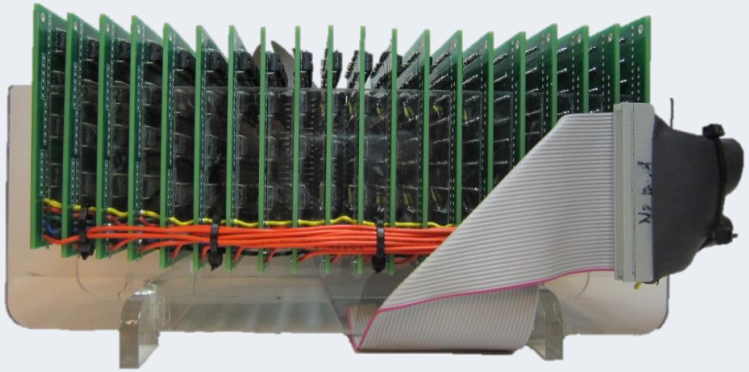
Materials

Electrical Subsystem

Custom PCB



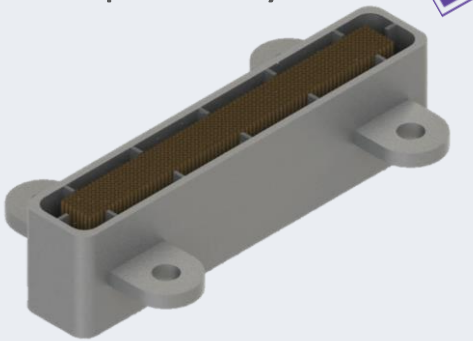
Raspberry Pi

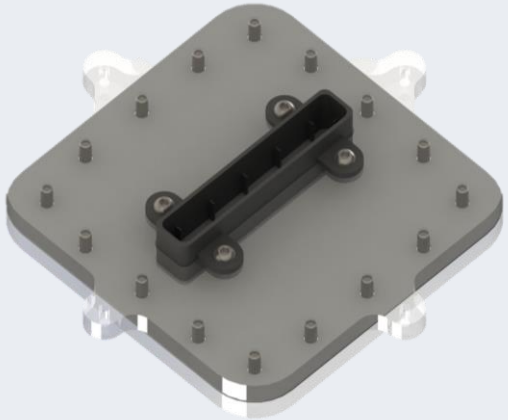


Pin Communication

Electrical Material Interface

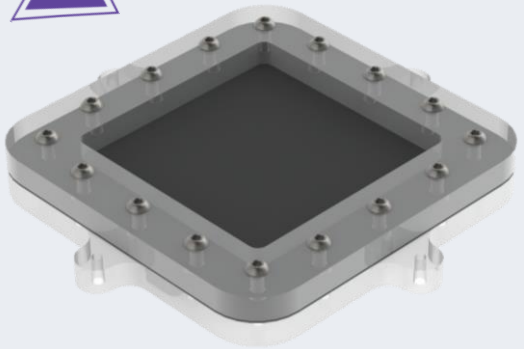
Machined
800 pin array



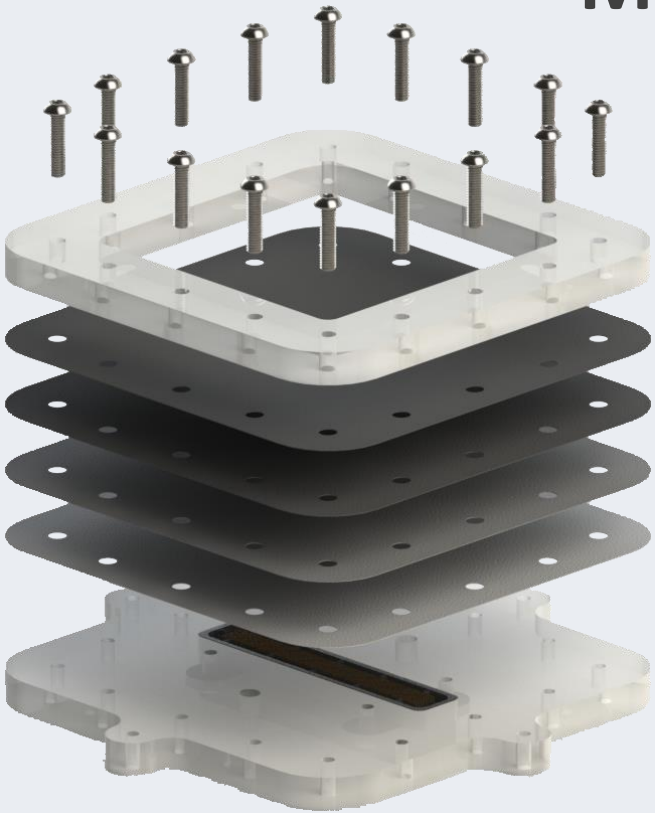


Surrounding ground plate

Material
contact



Material



Resistive properties of anatomical layers:

- Skin
- Skull
- Dura mater
- Cerebral spinal fluid

Totaling an approximate thickness of:

10mm

Housing


Power Input
Off / On
cerebrosim
Cortical Spreading
Depression Simulator

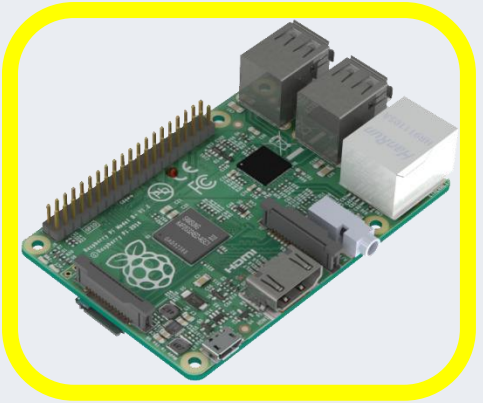
Housing

Nanuk case:

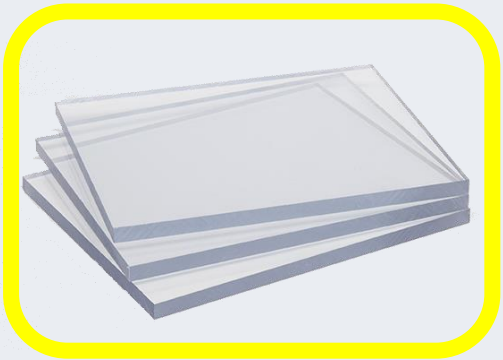
- Durable
- Waterproof
- Protective
- Inner Seal

Housing

Raspberry Pi

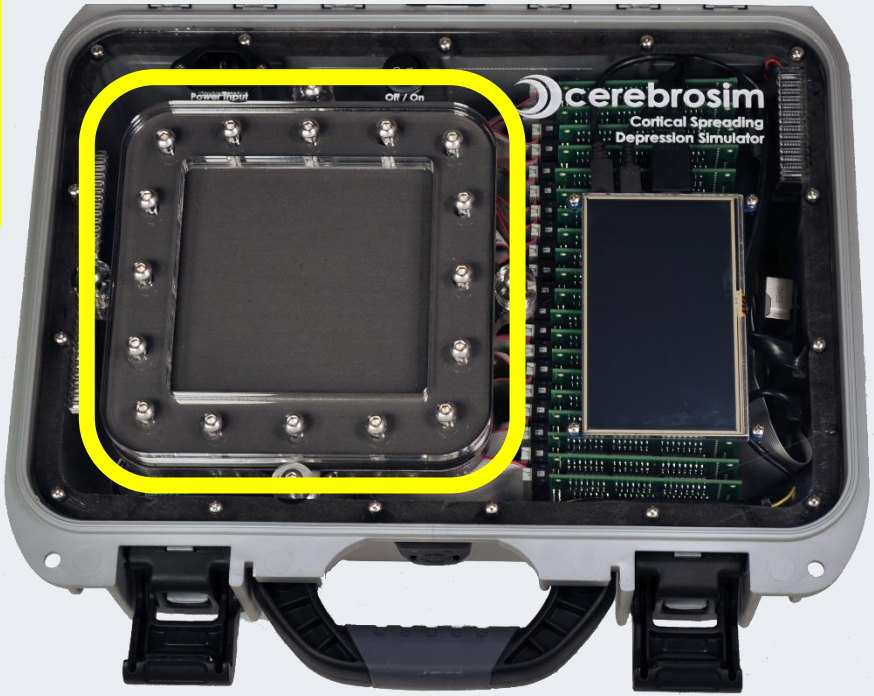


Housing



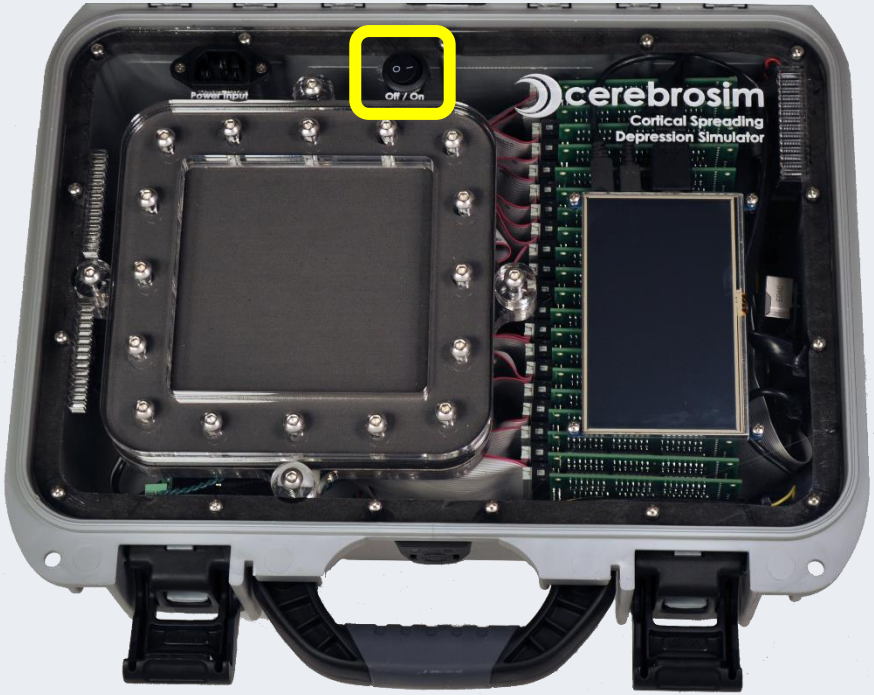
Acrylic

Durable and able to be laser cut



Housing

On/off Switch

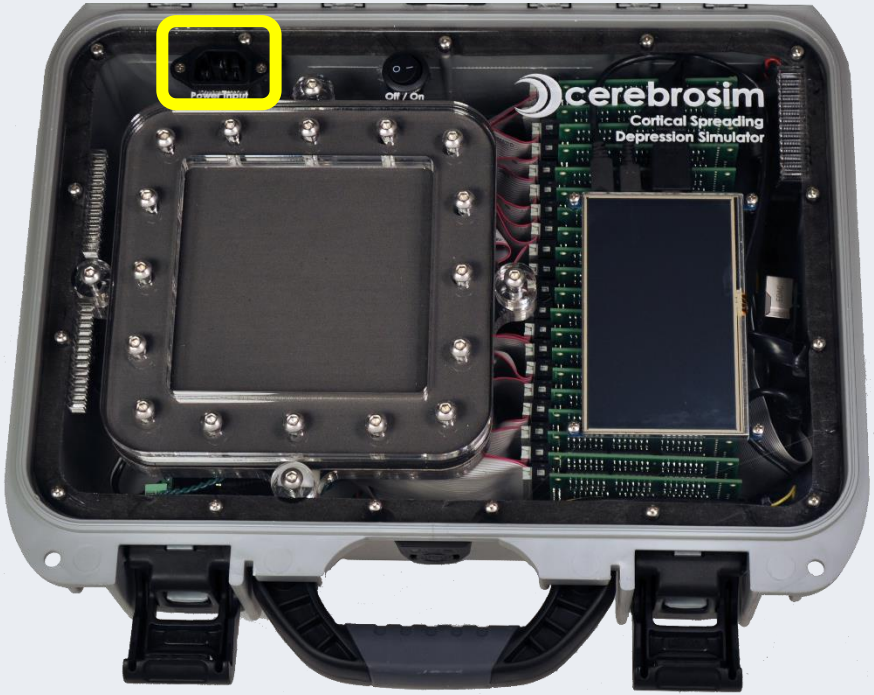


Fan

Power Jack

Housing

On/off Switch

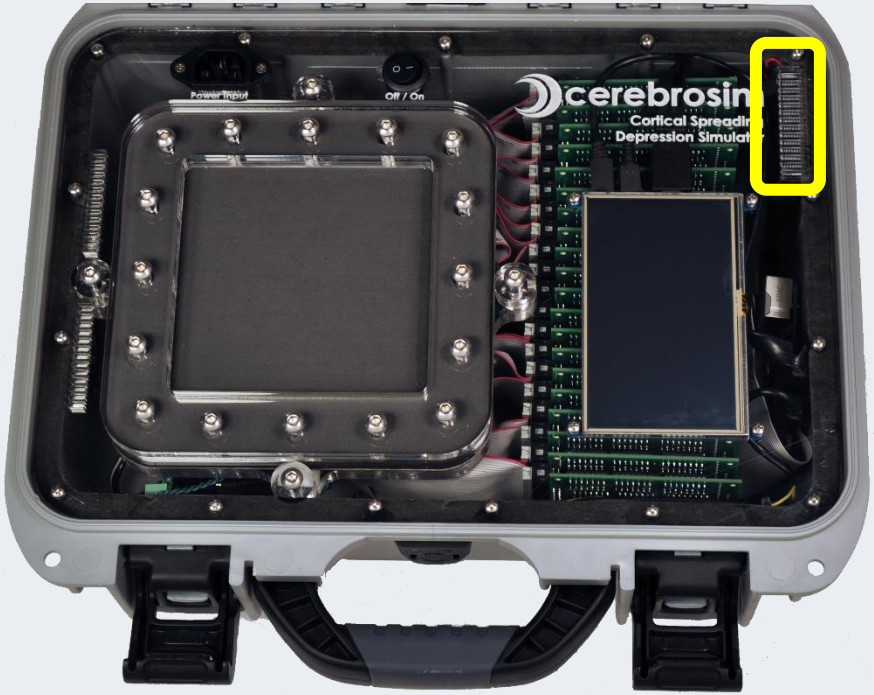


Fan

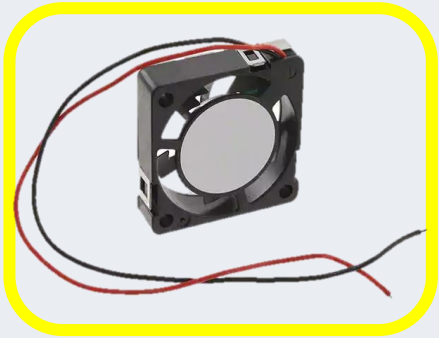
Power Jack

Housing

On/off Switch



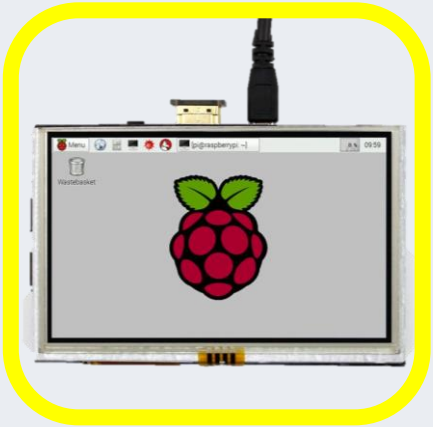
Fan



Power Jack

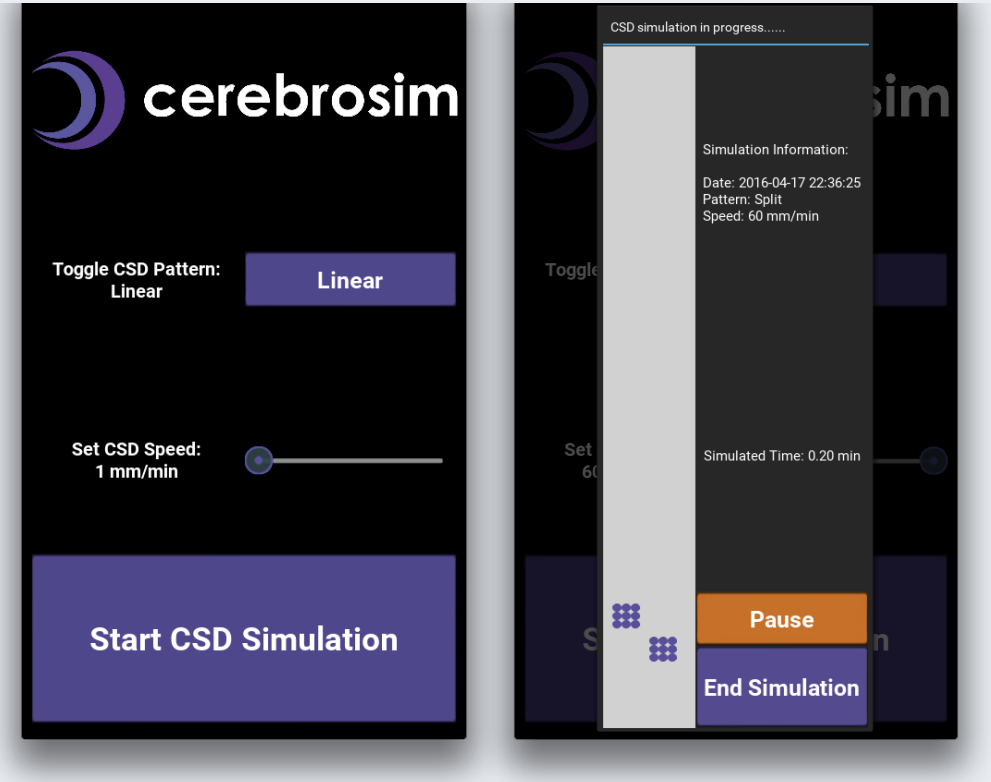
Housing

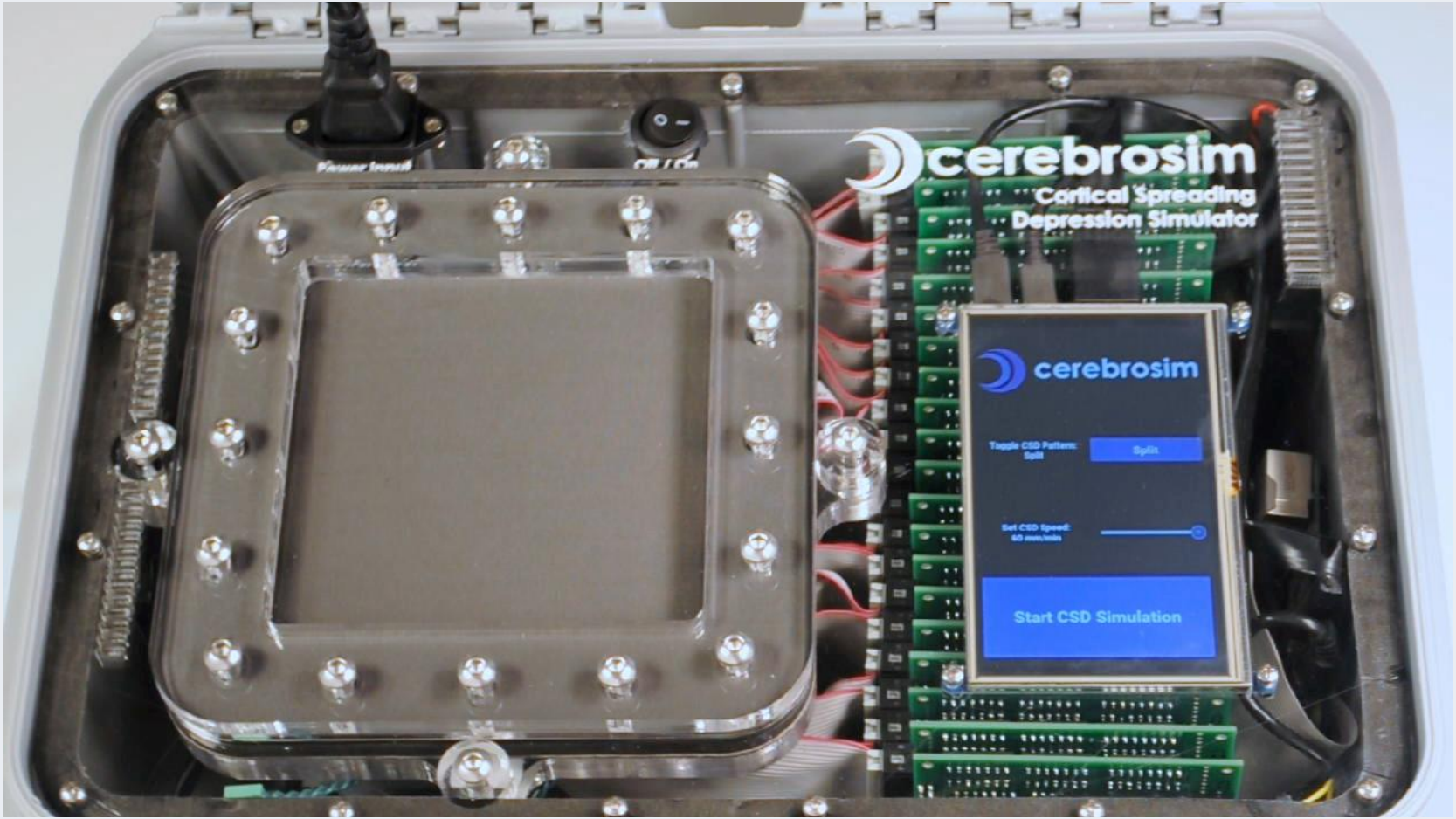
LCD Screen



Graphical User Interface

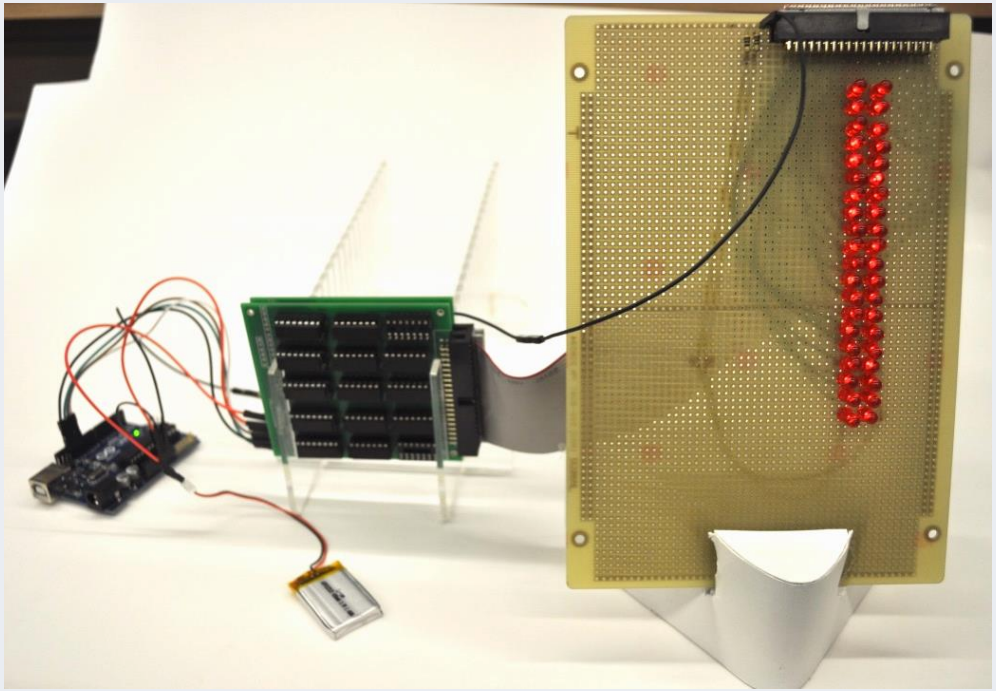
- User selects:
  - CSD type
  - CSD speed
- Displays selected propagation in real time
- Allows the user to pause/start/stop the CSD




cerebrosim
Cortical Spreading
Depression Simulator
cerebrosim
Toggle CSD Pattern:
Split
Split
Set CSD Speed:
60 mm/min
Start CSD Simulation

Electrical System Verification

- Board function
- Software control
- Signal propagation



Material Verification

- Created a reproducible test to confirm material resistivity based on manufacturing specifications
  - Discovered, donated materials did not meet device needs
- Confirmed multi-level isotropy
  - Suggests layered design is feasible approach for anatomical tissue layers based on resistivity measurements
- Confirmed voltage propagation through material layers

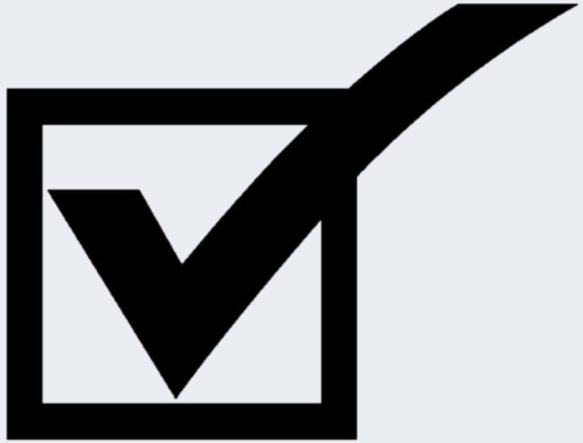
→ Feel confident that if we purchase materials with correct resistive properties, our device will function as intended.

Future Recommendations

- More accurately represent anatomical properties
  - Purchase materials (from Marktek, Inc.) that more closely fit the resistivity, thickness, and permittivity properties of the anatomical layers of the CSF, skull, dura mater, and scalp.
  - Modify test surface to have dimensions and curvature of a human skull
- Increase grid size, complexity, and nuance of CSD patterns
- Validate the device with the scalp-mounted, CSD-detection system produced by CerebroScope

Validation

From the initiation of the project to its finish, iterative and detailed feedback was outsourced from Dr. Jones to ensure the device design met the needs of the user.



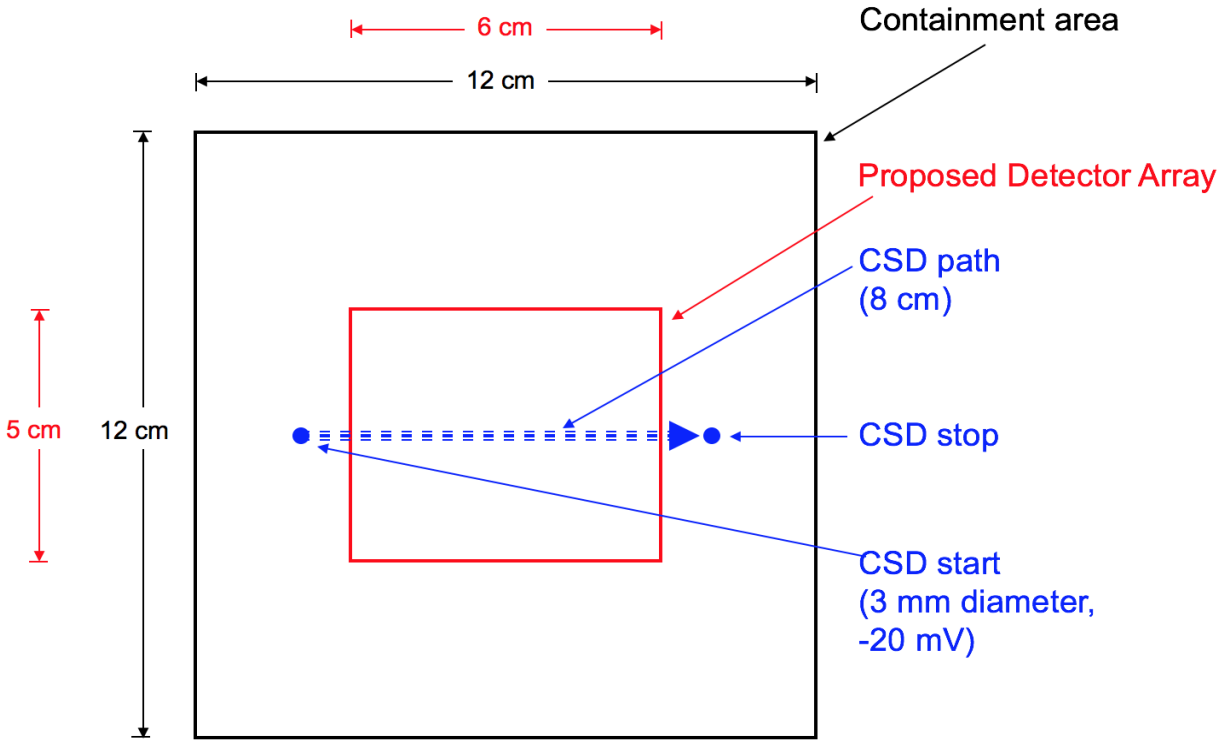
Acknowledgements

- Dr. Winter – course mentor
- Dr. Jones – sponsor
- Ned Uber – technical advisor
- Chris Horowitz – technical advisor
- Sam Hund – technical advisor

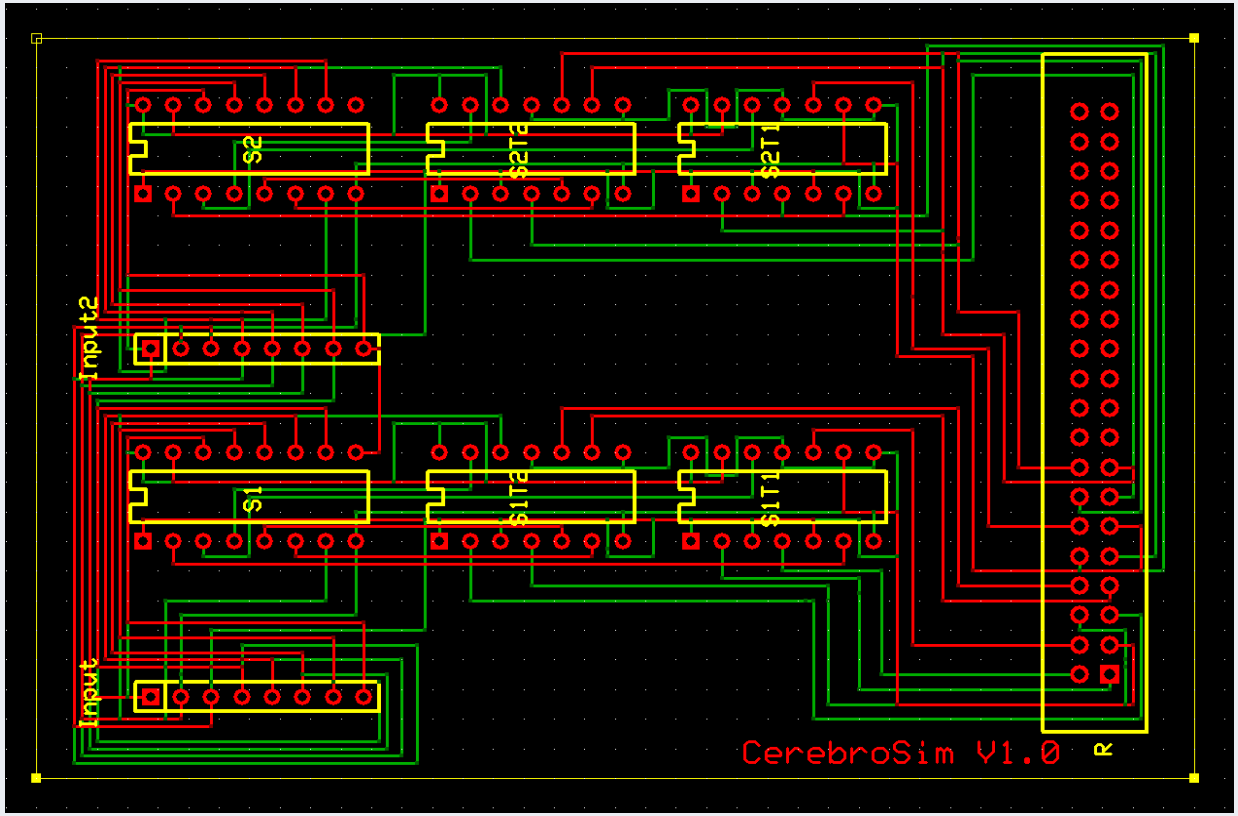
Questions?

Appendices

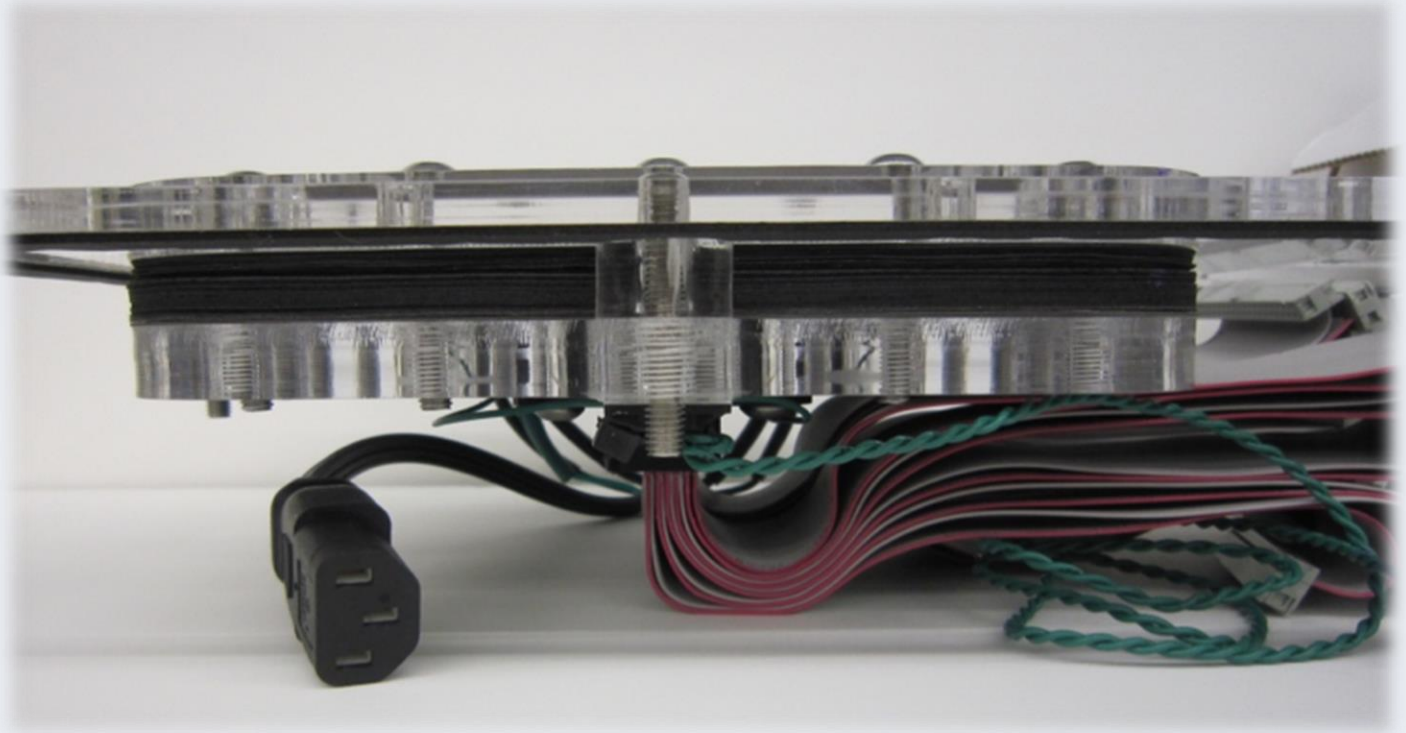
Proposed Schema for CSD Simulator for CerebroScope, 24-Feb-16



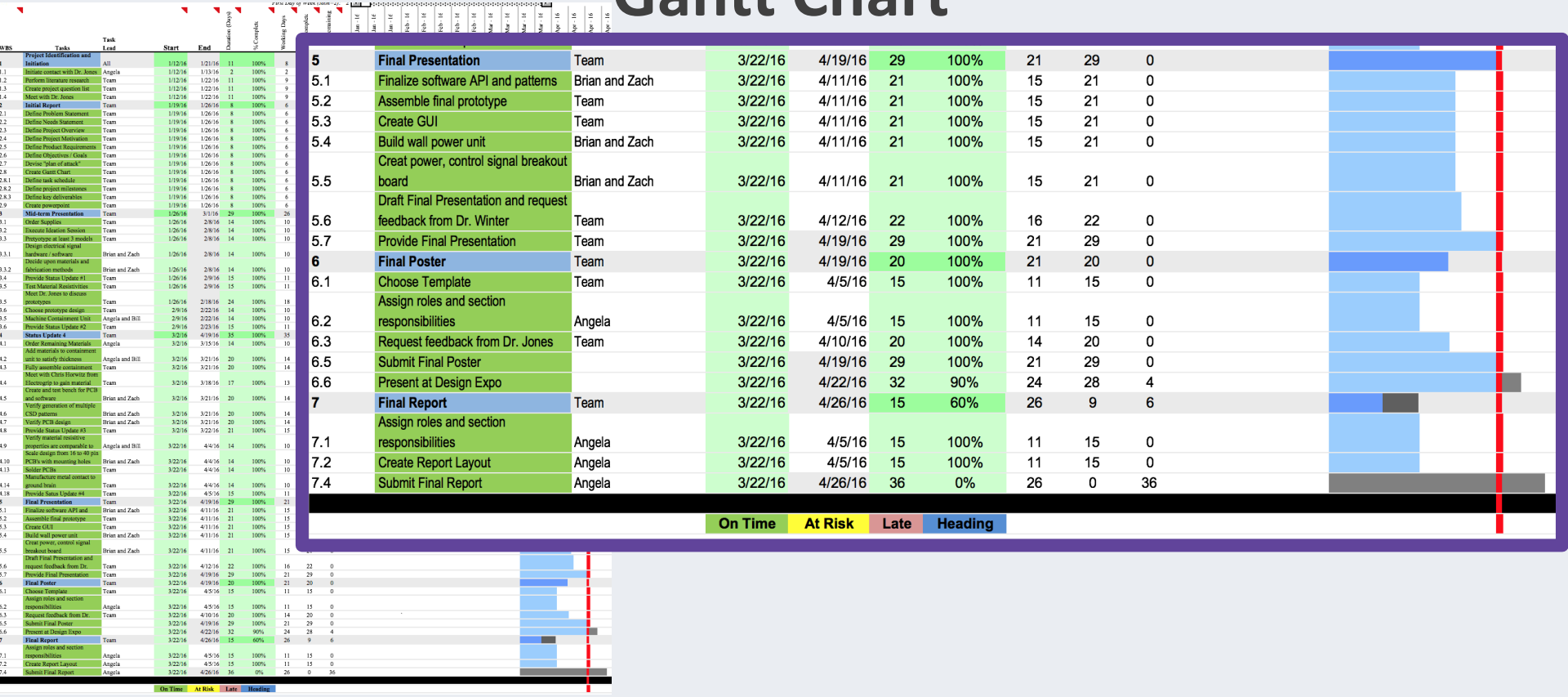
PCB Schematic



Material Bed



Gantt Chart



WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Completed	Days Remaining	Jan - 16	Jan - 16	Jan - 16	Feb - 16	Feb - 16	Feb - 16	Feb - 16	Feb - 16	Mar - 16	Mar - 16	Mar - 16	Mar - 16	Apr - 16	Apr - 16	Apr - 16
1	Project Identification and Initiation	All	1/12/16	1/21/16	11	100%	8																	
1.1	Initiate contact with Dr. Jones	Angela	1/12/16	1/13/16	2	100%	2																	
1.2	Perform literature research	Team	1/12/16	1/22/16	11	100%	9																	
1.3	Create project question list	Team	1/12/16	1/22/16	11	100%	9																	
1.4	Meet with Dr. Jones	Team	1/12/16	1/22/16	11	100%	9																	
2	Initial Report	Team	1/19/16	1/26/16	8	100%	6																	
2.1	Define Problem Statement	Team	1/19/16	1/26/16	8	100%	6																	
2.2	Define Needs Statement	Team	1/19/16	1/26/16	8	100%	6																	
2.3	Define Project Overview	Team	1/19/16	1/26/16	8	100%	6																	
2.4	Define Project Motivation	Team	1/19/16	1/26/16	8	100%	6																	
2.5	Define Product Requirements	Team	1/19/16	1/26/16	8	100%	6																	
2.6	Define Objectives / Goals	Team	1/19/16	1/26/16	8	100%	6																	
2.7	Devise "plan of attack"	Team	1/19/16	1/26/16	8	100%	6																	
2.8	Create Gantt Chart	Team	1/19/16	1/26/16	8	100%	6																	
2.8.1	Define task schedule	Team	1/19/16	1/26/16	8	100%	6																	
2.8.2	Define project milestones	Team	1/19/16	1/26/16	8	100%	6																	
2.8.3	Define key deliverables	Team	1/19/16	1/26/16	8	100%	6																	
2.9	Create powerpoint	Team	1/19/16	1/26/16	8	100%	6																	
3	Mid-term Presentation	Team	1/26/16	3/1/16	29	100%	26																	
3.1	Order Supplies	Team	1/26/16	2/8/16	14	100%	10																	
3.2	Execute Ideation Session	Team	1/26/16	2/8/16	14	100%	10																	
3.3	Prototype at least 3 models	Team	1/26/16	2/8/16	14	100%	10																	
3.3.1	Design electrical signal hardware / software	Brian and Zach	1/26/16	2/8/16	14	100%	10																	
3.3.2	Decide upon materials and fabrication methods	Brian and Zach	1/26/16	2/8/16	14	100%	10																	
3.4	Provide Status Update #1	Team	1/26/16	2/9/16	15	100%	11																	
3.5	Test Material Resistivities	Team	1/26/16	2/9/16	15	100%	11																	
3.5	Meet Dr. Jones to discuss prototypes	Team	1/26/16	2/18/16	24	100%	18																	
3.6	Choose prototype design	Team	2/9/16	2/22/16	14	100%	10																	
3.5	Machine Containment Unit	Angela and Bill	2/9/16	2/22/16	14	100%	10																	
3.6	Provide Status Update #2	Team	2/9/16	2/23/16	15	100%	11																	
4	Status Update 4	Team	3/2/16	4/19/16	35	100%	35																	
4.1	Order Remaining Materials	Angela	3/2/16	3/15/16	14	100%	10																	
4.2	Add materials to containment unit to satisfy thickness	Angela and Bill	3/2/16	3/21/16	20	100%	14																	
4.3	Fully assemble containment	Team	3/2/16	3/21/16	20	100%	14																	
4.4	Meet with Chris Horwitz from Electrogrip to gain material	Team	3/2/16	3/18/16	17	100%	13																	
4.5	Create and test bench for PCB and software	Brian and Zach	3/2/16	3/21/16	20	100%	14																	
4.6	Verify generation of multiple CSD patterns	Brian and Zach	3/2/16	3/21/16	20	100%	14																	
4.7	Verify PCB design	Brian and Zach	3/2/16	3/21/16	20	100%	14																	
4.8	Provide Status Update #3	Team	3/2/16	3/22/16	21	100%	15																	
4.9	Verify material resistive properties are comparable to	Angela and Bill	3/22/16	4/4/16	14	100%	10																	
4.10	Scale design from 16 to 40 pin PCB's with mounting holes	Brian and Zach	3/22/16	4/4/16	14	100%	10																	
4.13	Solder PCBs	Team	3/22/16	4/4/16	14	100%	10																	
4.14	Manufacture metal contact to ground brain	Team	3/22/16	4/4/16	14	100%	10																	
4.18	Provide Satus Update #4	Team	3/22/16	4/5/16	15	100%	11																	
5	Final Presentation	Team	3/22/16	4/19/16	29	100%	21																	
5.1	Finalize software API and	Brian and Zach	3/22/16	4/11/16	21	100%	15																	
5.2	Assemble final prototype	Team	3/22/16	4/11/16	21	100%	15																	
5.3	Create GUI	Team	3/22/16	4/11/16	21	100%	15																	
5.4	Build wall power unit	Brian and Zach	3/22/16	4/11/16	21	100%	15																	
5.5	Creat power, control signal breakout board	Brian and Zach	3/22/16	4/11/16	21	100%	15																	
5.6	Draft Final Presentation and request feedback from Dr.	Team	3/22/16	4/12/16	22	100%	16	22	0															
5.7	Provide Final Presentation	Team	3/22/16	4/19/16	29	100%	21	29	0															
6	Final Poster	Team	3/22/16	4/19/16	20	100%	21	20	0															
6.1	Choose Template	Team	3/22/16	4/5/16	15	100%	11	15	0															
6.2	Assign roles and section responsibilities	Angela	3/22/16	4/5/16	15	100%	11	15	0															
6.3	Request feedback from Dr. Jones	Team	3/22/16	4/10/16	20	100%	14	20	0															
6.5	Submit Final Poster		3/22/16	4/19/16	29	100%	21	29	0															
6.6	Present at Design Expo		3/22/16	4/22/16	32	90%	24	28	4															
7	Final Report	Team	3/22/16	4/26/16	15	60%	26	9	6															
7.1	Assign roles and section responsibilities	Angela	3/22/16	4/5/16	15	100%	11	15	0															
7.2	Create Report Layout	Angela	3/22/16	4/5/16	15	100%	11	15	0															
7.4	Submit Final Report	Angela	3/22/16	4/26/16	36	0%	26	0	36															

On Time | At Risk | Late | Heading

CerebroSim Milestone Trend Analysis