May 2014 group 09
Transcranial Magnetic Stimulation Helmet Design
Project plan

Group Members:
Jialue Fang - jlfang@iastate.edu
Ann Goodyear - ann745@iastate.edu
Yiwen Meng - mengyiw@iastate.edu
Jikang Qu - jqu@iastate.edu
Zhen Xu - xuzhen41@iastate.edu

Client and Advisor:
David Jiles - dcjiles@iastate.edu
Ravi Hadimani - hadimani@iastate.edu

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1 Introduction

Transcranial Magnetic Stimulation (TMS) is a medical procedure intended to treat various neurological disorders. These disorders include post-traumatic stress disorder, depression, and Parkinson's disease. The procedure involves stimulating different areas of the brain with a magnetic field. The magnetic field then induces an electric field within that area. Prior to the halo coil research groups had difficulty stimulating the deeper regions of the brain. The halo coil works by combining with a coil placed on top of the head. The halo coil then goes around the head, like the halo it is named after.

2 Project Summary

For this project we are designing a test fixture for a Halo coil. This test fixture must be capable of moving the Halo coil so it may stimulate different areas of the brain. In order to design our test fixture, we must also understand how the fields of the two coils interact.

3 Concept Sketches

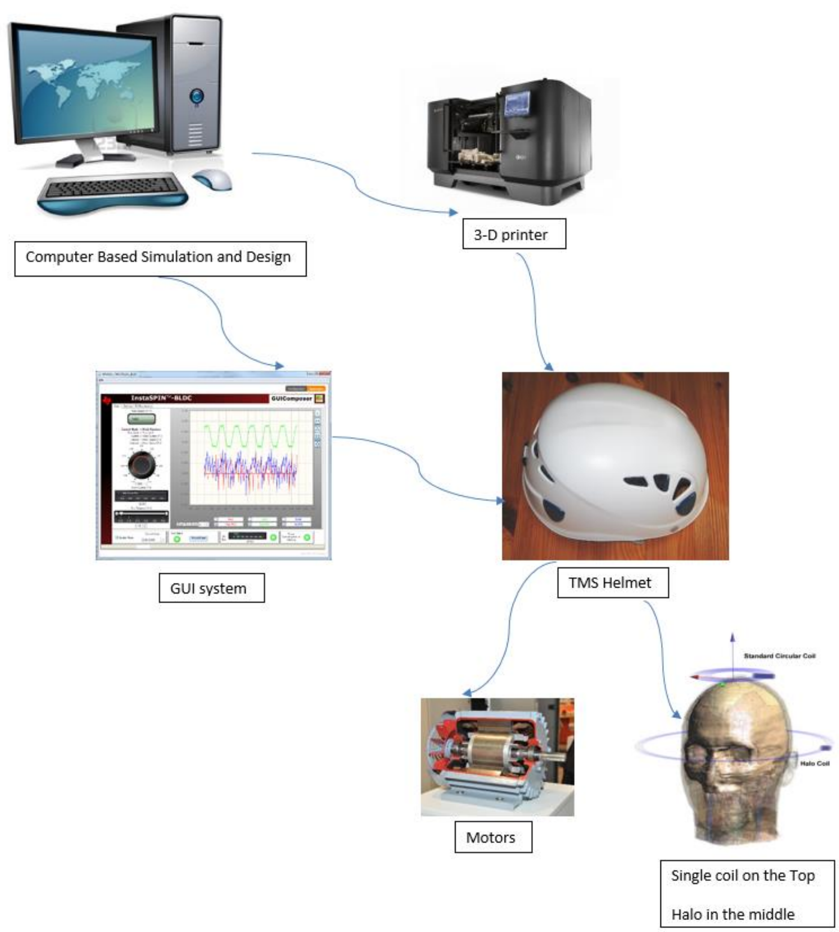
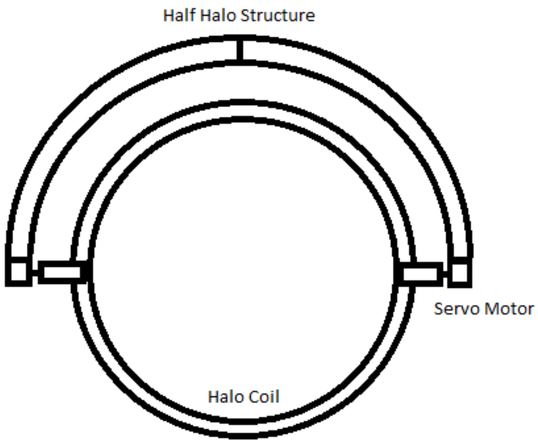


Figure 1: System concept sketch



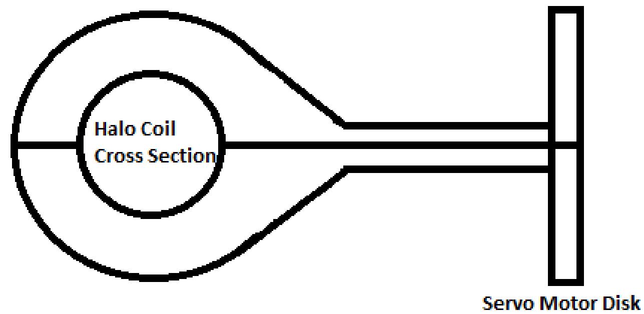
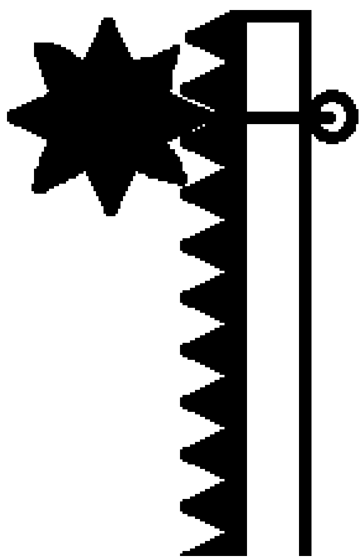


Figure 2 & 3: Halo holder and halo-servo connector



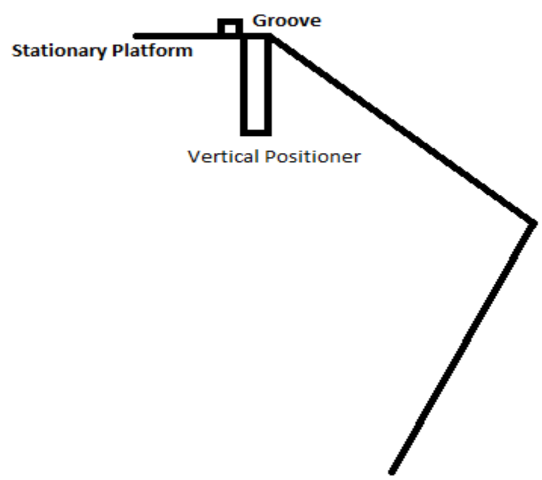


Figure 4 & 5: Vertical positioner and support structure

4 System Block Diagram

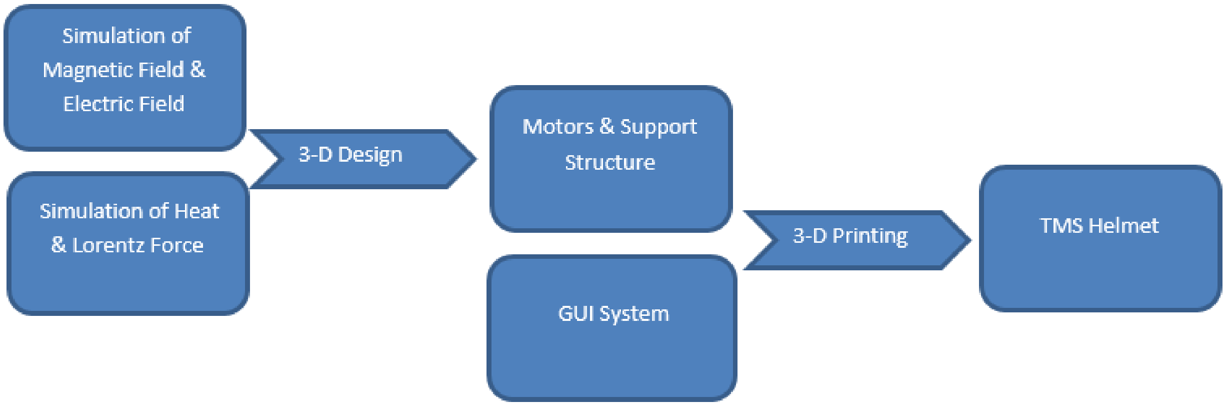


Figure 6: System block diagram

5 Process Description

Simulation

➢ **Electric and Magnetic Field Simulation**

i. Introduction

In order to find how current in the halo coil affects regions of the brain, we need to use SEMCAD to do the simulation and find where the maximum of the electric field occurs when the halo coil is located in different positions.

ii. Methods

First we build the model of the simple head with a halo coil.

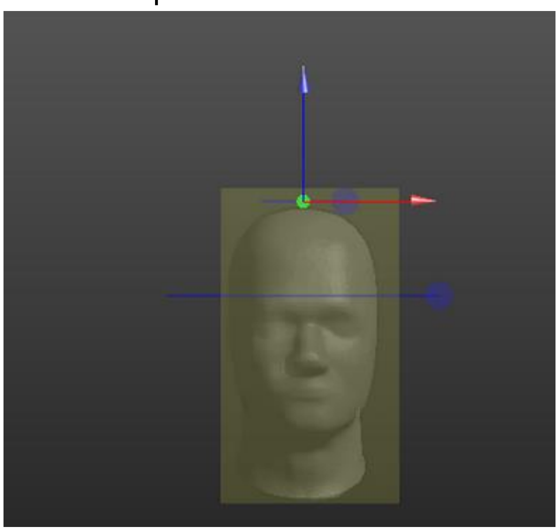


Figure 7: Simple head model

The top coil is the single coil and the lower coil is the halo coil. The diameter of the single coil is 90 mm and it has 14 turns. The diameter of the halo coil is 290 mm and it has 5 turns. The distance between the single coil and the top of the head is 5 mm. The distance between the single coil and the halo coil is 10 cm. During the simulation process, we will rotate the halo coil upward by 30 degrees and downward by 30 degrees by increments of 5 degrees so that we will have 12 data points of where the maximum of the electric field occurs when the halo coil is located in different positions.

- **Electromagnetic Heat Simulation**

i. Introduction

Due to the heat standards of human medical treatment, the surface temperature of coils should not exceed 37°C, the normal body temperature of a human. This is a very important constraint for our design, so in order to find an accurate time limit of the TMS treatment, we will use COMSOL Multiphysics to do the Electromagnetic Heat Simulation.

ii. Methods

In the model library, we select Electromagnetic Heating => Joule Heating Model for the type of simulation. First, we need to build the coil model.

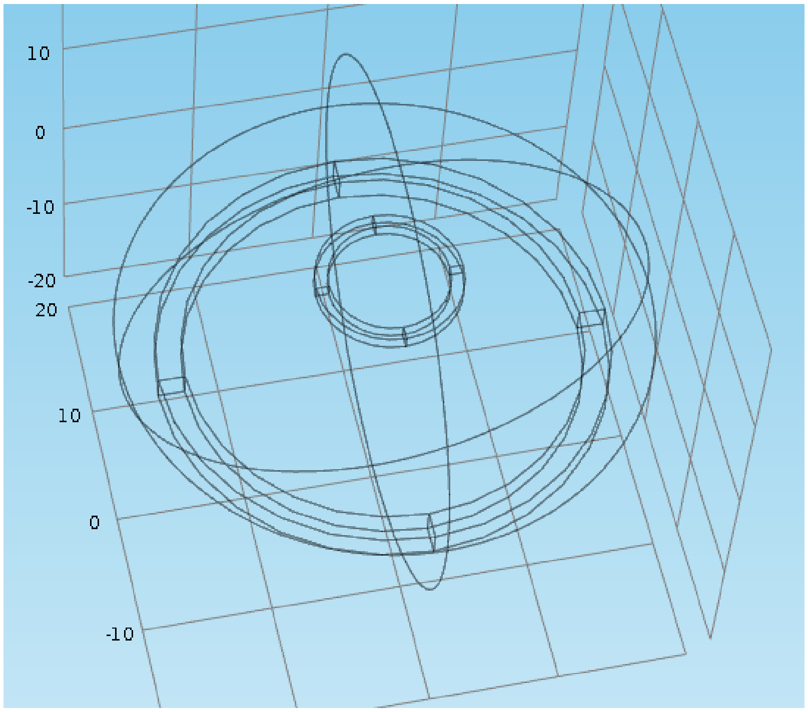


Figure 8: Coil model in COMSOL heat simulation. The small circle on the top is the single coil, and the coil below is the halo coil.

The signal from the biophasic stimulator is a sinusoidal wave with a frequency of 2.5K Hz, and a magnitude of 5000 A. We first calculate the power for the two coils and do the Frequency-Transient analysis to figure out the time when coils would reach 37 °C.

- **Electromagnetic Lorentz Force Simulation**

i. Introduction

Any metal in the magnetic field can generate Lorentz force, which is another hazard for our design, especially since we are using two coils in the design. We need to figure out the minimum distance between two coils to make sure the whole helmet is balanced during the treatment. Beside this, we also need to find the safe distance between the Halo coil and the servo motors because we use motors to move the Halo coil and we must guarantee that the whole structure is absolutely stable.

ii. Methods

In the model library, we select Electromagnetic Force model for the type of simulation, and we use the same coil model and input current as the heat simulation. We have to change the distance between two coils to find the minimum.

Helmet Design

For the helmet design we will take into account the simulation results and coil dimensions to create a general design. This design will include a support structure, a stationary platform for the single coil, and a positioning system capable of moving the halo coil. We will use the modeling program Blender to create a 3D printing file of the helmet design. We will then send this file to the 3D printers to implement our design. We will implement the design piece by piece so that we may determine the weight. Because we are using the 3D printers, the helmet will be made of thermoplastics. After implementing and testing our design, we will re-design as necessary.

Programming

There are mainly two parts, GUI and Arduino programming. The first part is the GUI which will provide a user interface to the user, showing the current position of the coils and the peak E field. This interface also allows the user to move the coil. This task depends on the data from the simulation group. The second part is the Arduino programming which plays the role of a driver. The Arduino takes a signal from the PC via a USB port, interprets the signal, and drives the servo to the right positions.

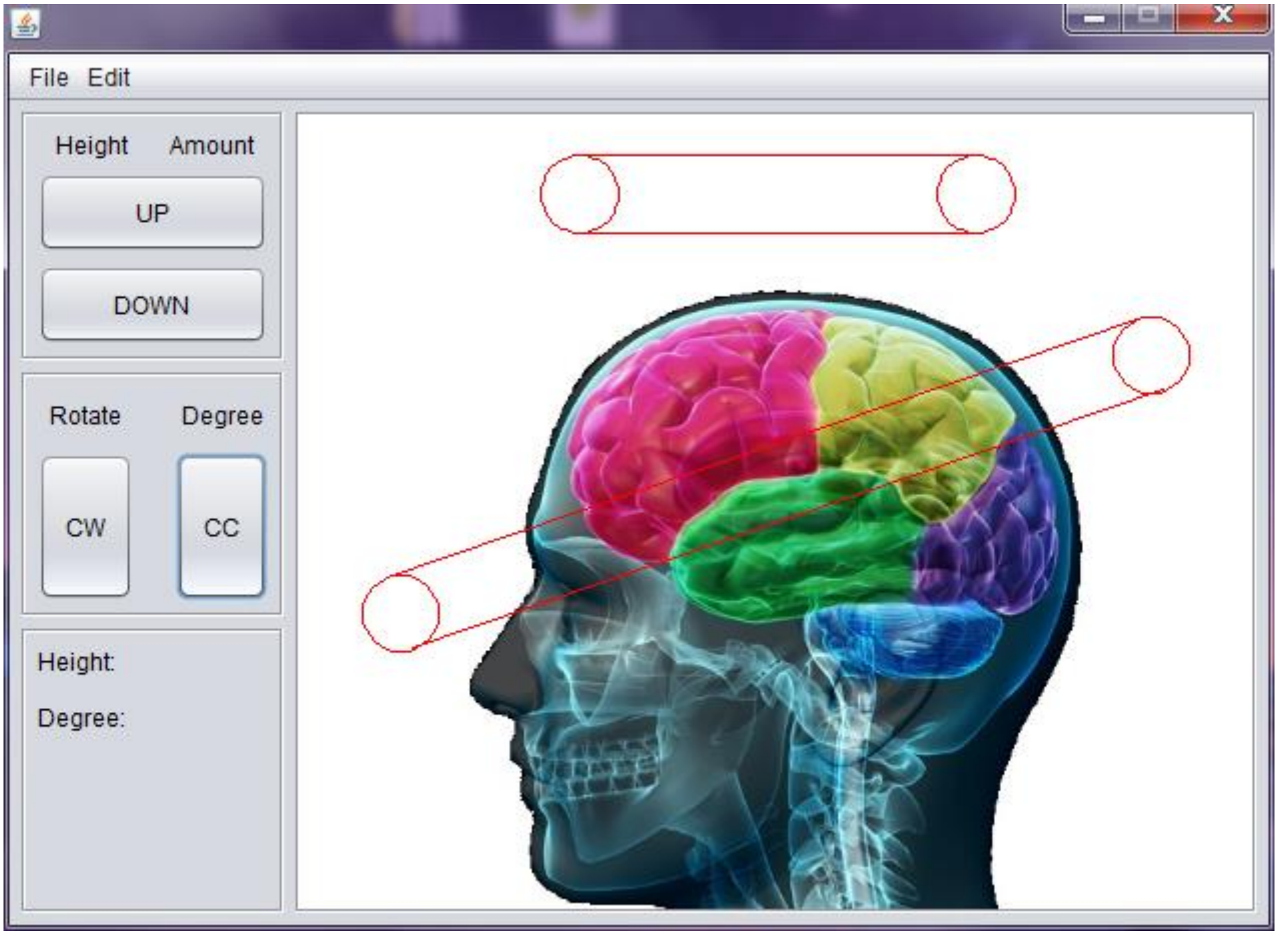


Figure 9: User interface

6 Operating Environment

Our system is intended for operation in a hospital setting. Before it reaches a hospital, it will be operated in a laboratory setting for human testing. As both of these environments are controlled environments there should be little difference in the operating environment when it is transitioned. It is meant to be operated by trained hospital workers. These workers will have a strong understanding of human biology, but less understanding of electric and magnetic fields. The user interface will be designed with this in mind. It will also be designed to make the positioning of the halo coil easy and consistent for ease of use. The system will require access to power for the stimulator and a computer for the user interface.

7 Functional Specifications

- **Clinic medical standard-** Since our helmet design will be used in the clinical treatment of human brain disorders, we must first meet medical requirements. Most importantly, the temperature of the surface of coil cannot go beyond 37 °C, which is the normal human body temperature. We have to figure out the time when the surface of the coils would reach 37 °C, and we have to stop the treatment at that time to avoid heat stress.

- **Lorentz force-** There are two coils in the helmet design and they can be moved intentionally to do the treatment. Since they would generate Lorentz force in between, we have to figure out the minimum distance for them to make sure the whole structure is definitely stable.

- **Generating required Electromagnetic field-** We should set the intensity of the stimulator at 100% to generate the magnetic field of 2 Tesla at the surface of the coil. This injects a current between neurons that makes the action potential 200 mV to achieve the treatment.

- **Vertical movement and rotation of Halo coil-** The vertical movement of Halo coil has a range of 7 cm and a resolution of 1cm. The rotation is between +30 and -30 degrees with a resolution of 5 degrees. It can be easily moved by the GUI interface which connects to the motors.

8 Non-Functional Requirements

- **Accuracy** - Must provide consistent results
- **Comfort** - Must account for the patient's comfort
- **Variability** - Must be capable of fitting many different head sizes and different heights
- **Extensibility** - Source code for UI should be written in a way that functions can be easily added or deleted.

9 Deliverables

- **First semester-** A prototype helmet positioning system with attached servos and required software, simulation results, support structure design, and user interface design
- **Second semester-** The tested helmet with associated support structure and user interface

10 Work Plan

Resources Required

- 3D printer
- Gaussmeter (provided by client)
- Plastic nuts and bolts
- Servo motors

❖ Simulation software-SEMCAD and COMSOL (provided by client)

Timeline

❖ Fall Semester

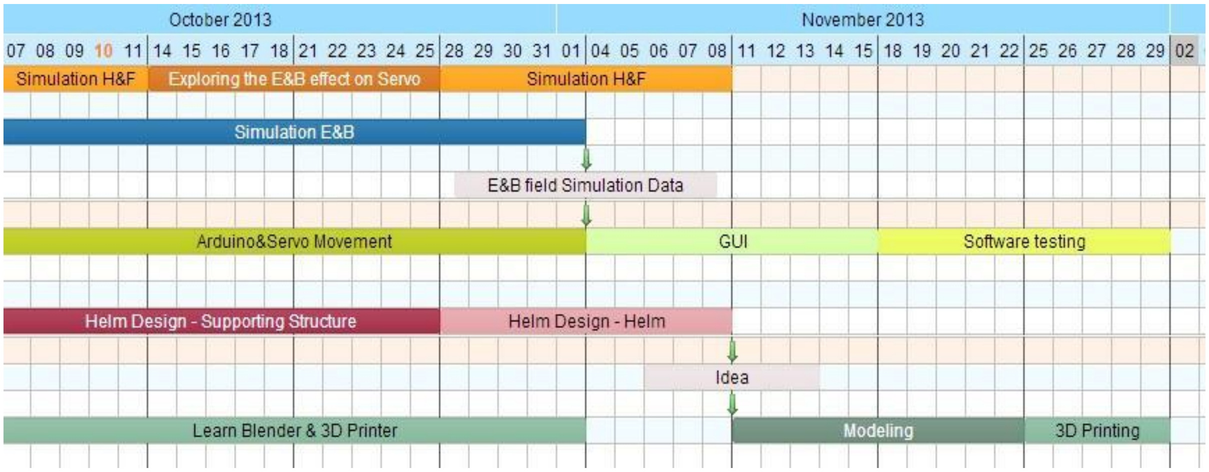


Figure 10: Gant chart for fall semester

❖ Spring Semester

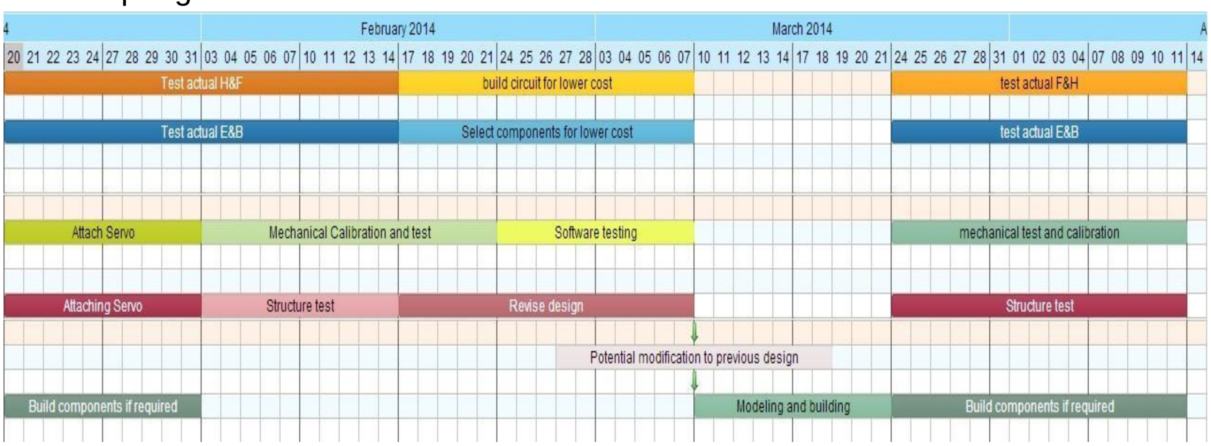


Figure 11: Gant chart for spring semester

Work Breakdown Structure

	Task Name	Start Date	End Date	Assigned To	Duration(Day)
	Simulation	**13-10-07**	**14-04-11**		**135**
	Heat and force simulation	13-10-07	13-11-08	Yiwen Meng	25
	Electronic field and magnetic field simulation	13-10-07	13-11-01	Jikang Qu	20
	Exploring the electronic filed and magnetic field on servo	13-10-14	13-10-25	Jikang Qu	10
	Electronic field and magnetic field simulation data deliver	13-11-01	13-11-01	Jikang Qu	1
	Test actual Heat and force on 1st prototype	14-01-20	14-02-14	Yiwen Meng	20
	Test actual electronic field and magnetic field on 1st prototype	14-01-20	14-02-14	Jikang Qu	20
	Test actual Heat and force on 2nd prototype	14-03-21	14-04-11	Yiwen Meng	16
	Test actual electronic field and magnetic field on 2nd prototype	14-03-21	14-04-11	Jikang Qu	16
	Helmet Design	**13-10-07**	**14-04-11**		**135**
	Learn Blender 3D modeling software	13-10-07	13-11-01	Jialue Fang	20
	Helmet Design	13-10-07	13-11-08		25
	Supporting structure design	13-10-07	13-10-25	Ann Goodyear	15
	Helmet Design	13-10-26	13-11-08	Ann Goodyear	11
	Final Design for 1st prototype	13-11-09	13-11-14	Ann Goodyear	5
	Build circuit for lower cost	14-02-15	14-03-07	Ann Goodyear	16
	Select components for lower cost	14-02-15	14-03-07	Ann Goodyear	16
	1st Structure test	14-02-03	14-02-14	Ann Goodyear	10
	Design Revision	14-02-15	14-03-07	Ann Goodyear	16
	2nd Structure test	14-03-22	14-04-11	Jialue Fang	16
	Programming	**13-10-07**	**14-04-11**		**135**
	Arduino and servo movement	13-10-07	13-11-01	Zhen Xu	20
	GUI	13-11-01	13-11-15	Zhen Xu	11
	1st Software testing	13-11-15	13-11-29	Zhen Xu	11
	Attach servo	14-01-20	14-01-31	Zhen Xu	10
	1st Mechanical Calibration and test	14-02-01	14-02-21	Zhen Xu	16
	2nd Software testing	14-02-22	14-03-07	Zhen Xu	11
	2nd mechanical test and calibration	14-03-21	14-04-11	Zhen Xu	16
	Prototyping	**13-11-11**	**14-04-11**		**110**
	1st Modeling	13-11-11	13-11-22	Jialue Fang	10
	1st 3D Printing	13-11-23	13-11-29	Jialue Fang	6
	1st prototype deliver	13-11-30	13-11-30	Jialue Fang	1
	Modeling after revived feedback about 1st prototype	14-03-08	14-03-21	Jialue Fang	11
	2nd 3D Printing	14-03-22	14-04-01	Jialue Fang	8
	Integration testing	14-04-02	14-04-10	Jialue Fang	7
	2nd prototype deliver	14-04-11	14-04-11	Jialue Fang	1

Table 1: Work breakdown

Risks and Mitigation Strategies

Risk	Risk factor (0-10)	Criticality (0 - 10)	Mitigation Strategy
Materials for the helmet are a very important part of this project. We have to find out what materials will not affect the magnetic field, will not change during certain ranges of temperatures, etc… If any of these condition are failed, the performance of the TMS helmet will be affected seriously.	6	7	We will do research about the materials and test them before using them as the materials for the helmet.
In this project, we have to learn many new software, write many design documents, build the 3D model, etc… So we need a great deal of time working on it.	6	6	We will strictly follow the schedule and try to finish each task on time.
In this project, we have to use the 3D printer to build our final product. So learning 3D modeling software is quite important. So it is risky if we cannot fully understand this software and use it properly.	5	7	We will set a very detailed schedule for software learning. Each week we will meet and discuss any problems met and come up with the solutions together.

Table 2: Risks and Mitigations