May 2014 Group 9
Variable Coil Helmet System for Transcanial Magnetic Stimulation (TMS)
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

Table of Contents

1 Introduction

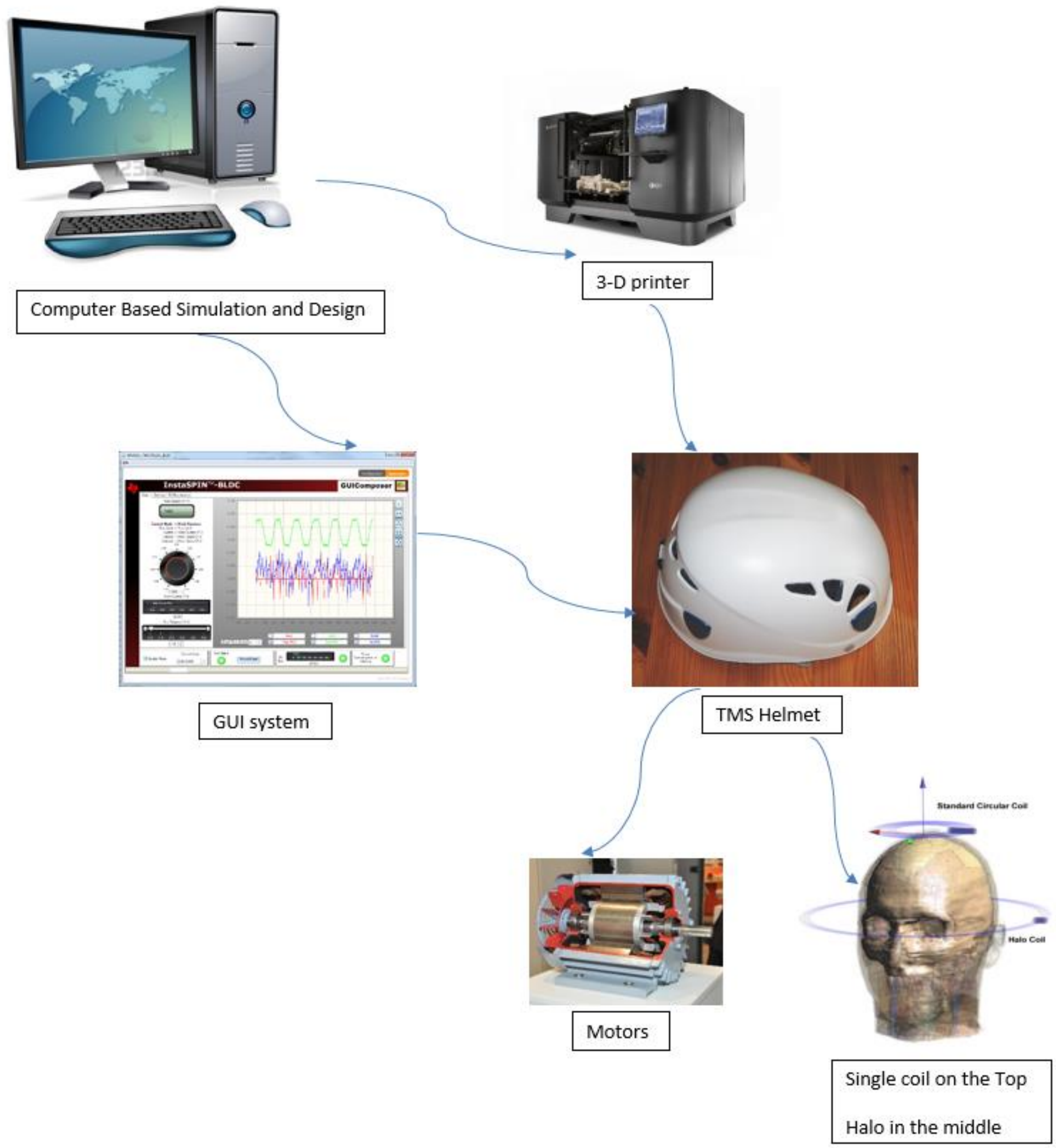
Transcranial Magnetic Stimulation (TMS) is a medical procedure intended to treat various neurological disorders. These disorders include post-traumatic stress disorder, depression, and Parkinson's disease. The procedure involves stimulating different areas of the brain with a magnetic field. The magnetic field then induces an electric field within that area.

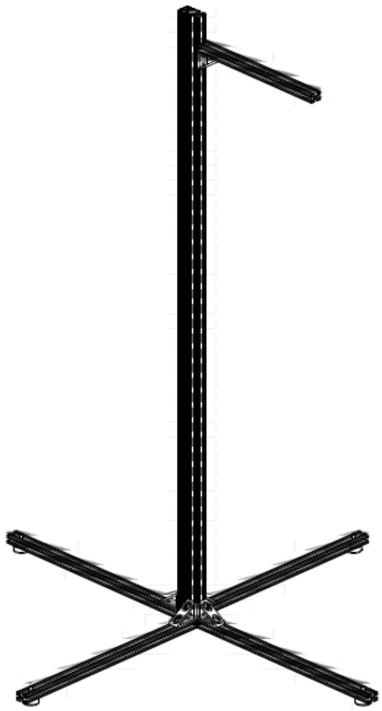
Prior to the halo coil research groups had difficulty stimulating the deeper regions of the brain. The halo coil system consists of two coils. The smaller stationary coil rests on top of the patient's head while the larger halo coil circles the patient's head. In this way the two fields combine and interact in different ways depending on the position of the halo coil.

2 Project Summary

The purpose of the project is to design a test fixture for the halo coil. The test fixture, or helmet, must move the halo coil so that the system generates an electric field within a specific portion of the patient's brain. This will require the helmet to be capable of moving the halo coil vertically as well as tilting the halo coil..

3 Concept Sketches


Computer Based Simulation and Design
3-D printer
InstaSPIN™-BLDC
GUIComposer
GUI system
TMS Helmet
Motors
Standard Circular Coil
Halo Coil
Single coil on the Top
Halo in the middle



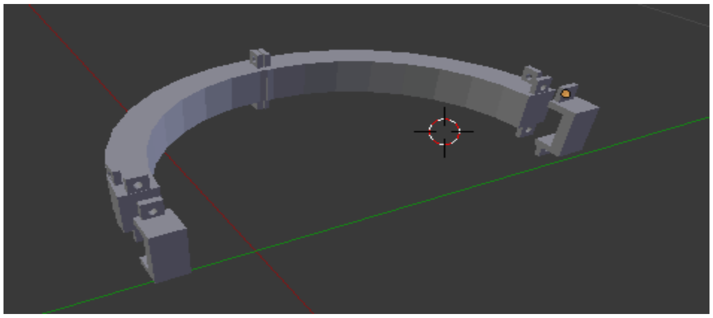


Figure 2: Rotational Structure

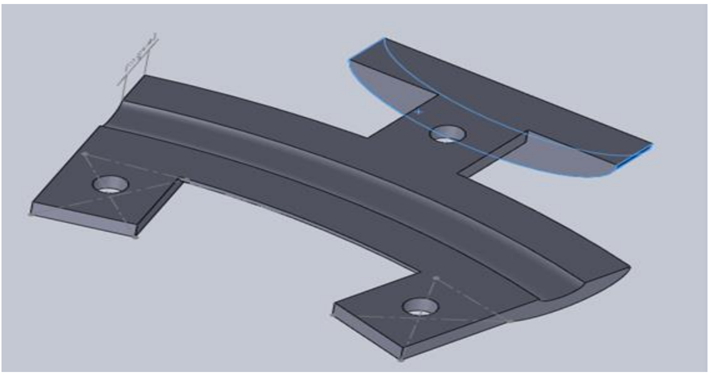


Figure 1: Support structure

Figure 3: Halo holder

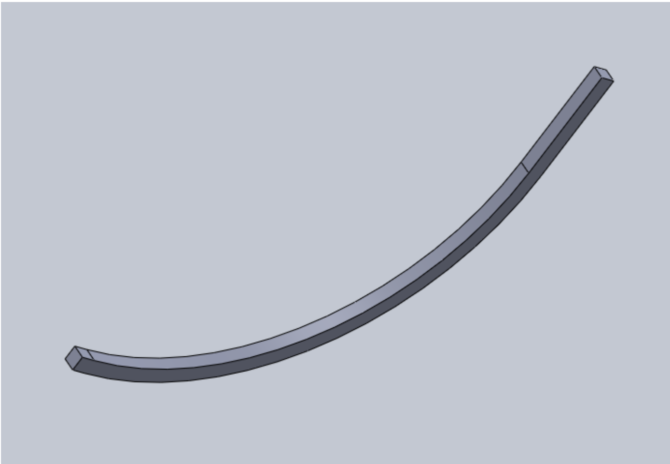
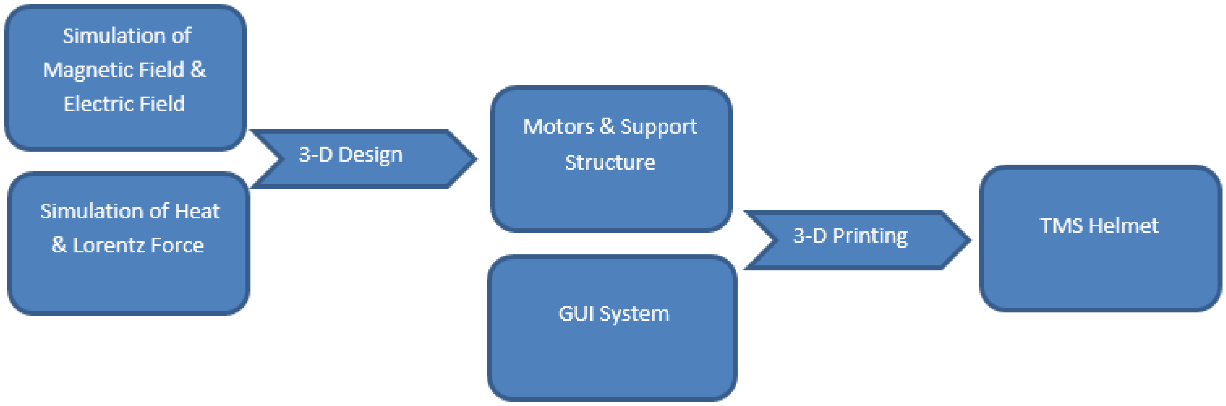


Figure 4: Vertical support

4 System Block Diagram



5 Process Description

Simulation

- **Electric and Magnetic Field SImulation**

i. Introduction

The first part of the project was to prove the principal behind the operation of the halo coil system. A simulation of the magnetic and electric fields using the program SEMCAD must show variation in the fields as the position of the halo coil changes.

ii. Methods

The first step is to build the model of a simple head and a halo coil.

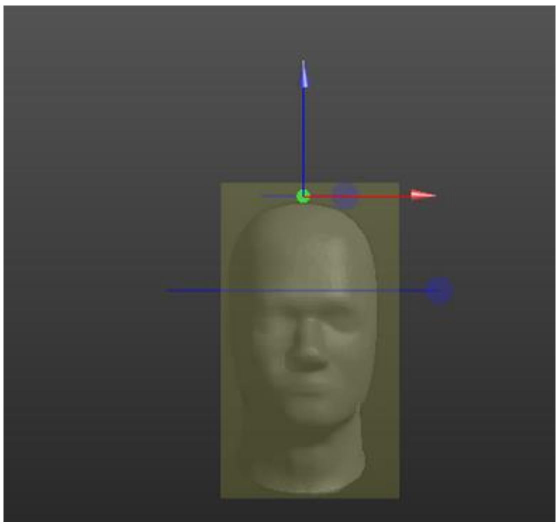


Figure 5: The simple head model

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, the halo coil rotates upward 30 degrees and downward 30 degrees in increments of 5 degrees, generating 12 data points. The halo coil also moves up 5 cm and down 5 cm with a resolution of 1 cm.

- **Electromagnetic Heat Simulation**

i. Introduction

Due to the heat standards of human medical treatment, the surface temperature of the coils should not exceed 37°C. Because of the high current, both of the coils heat up quickly. In order to comply with the medical standards, a COMSOL Multiphysics electromagnetic heat simulation determined the length of time a TMS treatment may last.

ii. Methods

The first step of the simulation process is to build a model of the coils.

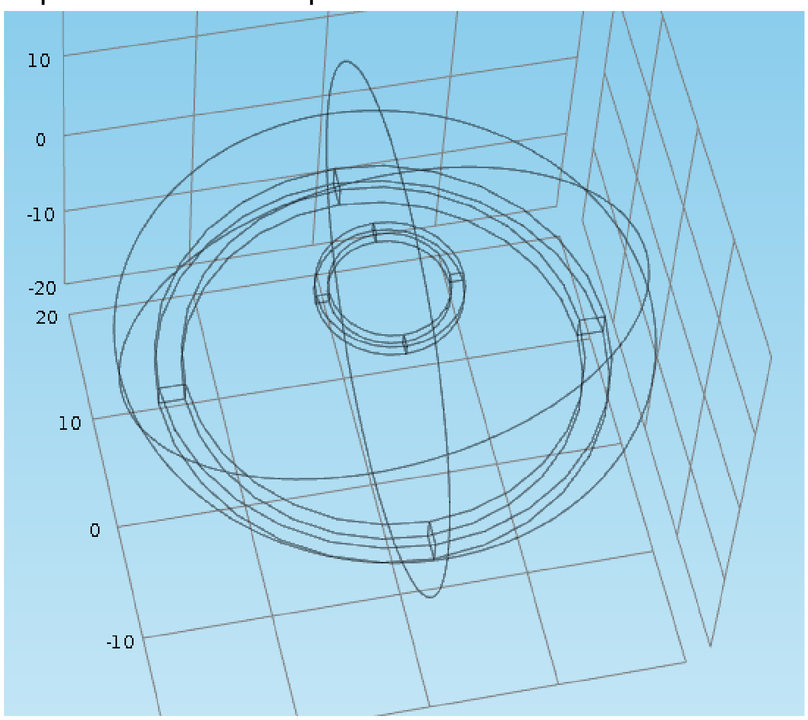


Figure 6: Coil model in COMSOL heat simulation with the smaller single coil and the larger halo coil

The signal from the biophasic stimulator is a sinusoidal wave with a frequency of 2.5 kHz, and a magnitude of 5000 A. A COMSOL Frequency-Transient analysis uses the calculated power to figure out the time needed for the coils to reach 37 °C.

- **Electromagnetic Lorentz Force Simulation**

i. Introduction

Any metal in a magnetic field generates Lorentz force, which can have an effect on the stability of the various components of the design. The two coils increase the effects of the force and also experience the force. A simulation will show the size and direction of the force as the halo coil changes position. The force must not exceed the yield strength of the involved components, thus limiting how close the two coils may come.

The design also includes servo motors containing metal parts. These metal parts need to be far enough away from the magnetic field that they do not experience a significant force.

ii. Methods

The simulation is an electromagnetic force simulation with the same coil model and the same input current as the heat simulation. The distance between the two coils changes throughout the course of the simulation in order to determine the minimum safe distance.

The test for the minimum distance between the servo motor and the halo coil involved setting the stimulator to 100 % and holding the servo a distance from the coil. If the servo moved, it was too close to the coil.

Helmet Design

The helmet design will take into account the simulation results and coil dimensions to create a general design. This design will include a support structure and a positioning system capable of moving the halo coil. The 3D model is created using the modeling software Solidworks. The rotational positioning system will be 3D printed and made of thermoplastics. The rest of the structure will be shaped aluminum in order to prevent interference with the magnetic field.

Programming

There are two parts: the GUI and the Arduino program. The first part is the GUI which will show the current position of the halo coil and the location of the maximum electric field. This interface also allows the user to move the halo 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 motors to the right positions.

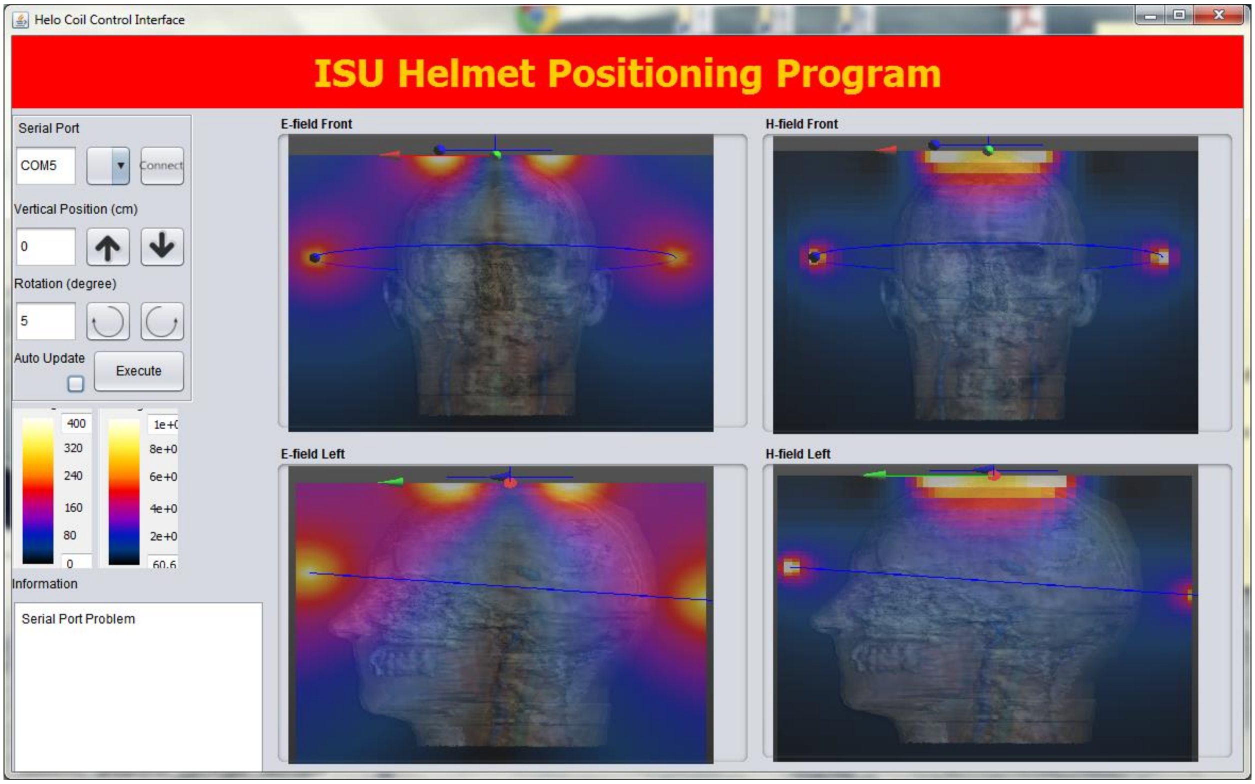


Figure 7: GUI interface

6 Operating Environment

The system is intended for operation in a hospital setting. Before it reaches a hospital, it will be operated in a laboratory setting. 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 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 Requirements

Description	Inputs	Behavior	Outputs
Generate a 2 T magnetic field at the desired location	Command from PC interface	Generate a 2 T magnetic field at the desired location	The magnetic field should display on the PC interface.
Place the helmet easily via machine	Command from the PC interface	Move the helmet to the required place	The movement of the helmet and its final position should display on the PC interface

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

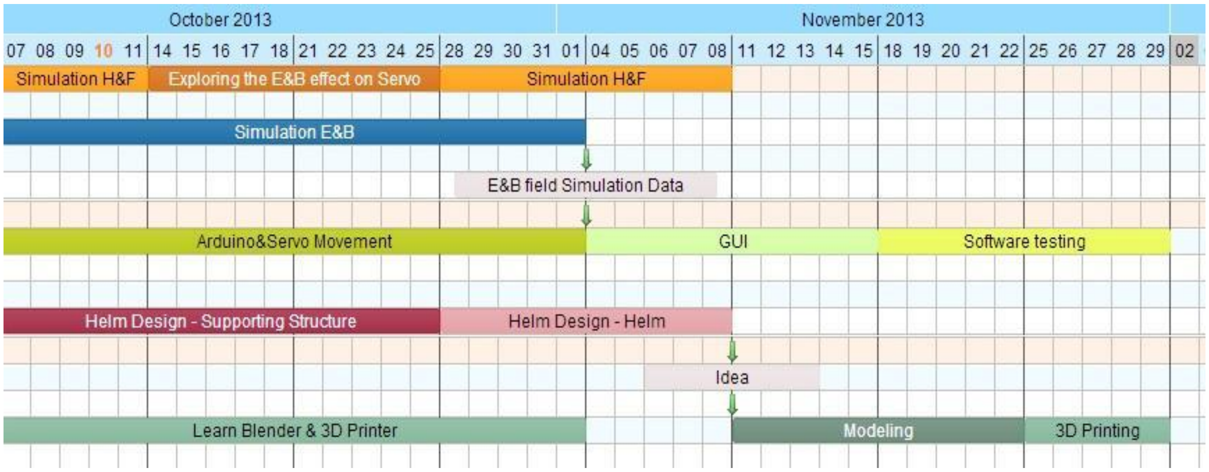
10 Work Plan

Resources Required

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

Timeline

- Fall 13 Semester



- ❖ Spring 14 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

Risks and Mitigation Strategies

Risk	Risk factor (0-10)	Criticality(0 - 10)	Mitigation Strategy
Materials for the helmet is a very important part in this project, we have to found out a materials that will not affect the magnetic field, will not change during certain range of temperatures, etc… if any of this condition failed, the	6	7	We will do research about the materials and test it before use it as the materials for the helmet.

performance of the TMS helmet will be affect seriously.			
In this project, we have to learn many new software, write many design documents, build the 3D model, etc… So we need much time working on it and we might finally run out of time.	6	6	we will strictly follow the schedule and try to finish each task on time.
In this project, we have to use 3D printer to build our final product. So learning 3D modeling software is quite important. So it is kind risky if we can not 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 the problem they met and come up with the solution together.