HYPERLOOP MANCHESTER

THE STUDENT-LED TRANSPORT REVOLUTION

INTENT TO SHOWCASE

HYPERLOOP MANCHESTER
2020/21

December 2020

Contents

1. Introduction 2

2. General Overview 3

    2.1. Who Are We? 3

    2.2. Team Members 3

    2.3. Values 7

    2.4. Development Environment 7

3. System Overview 8

    3.1. Mechanical 8

        3.1.1. Magnetic Levitation 9

        3.1.2. Propulsion 9

        3.1.3. Suspension 9

        3.1.4. Braking 10

        3.1.5. Emergency Braking 10

        3.1.6. Outer Shell 10

        3.1.7. Chassis Integration 11

    3.2. Electronics and Software 11

        3.2.1. Electronics 12

        3.2.2. Software 14

    3.3. Power 16

4. Safety Compliance with the Rules & Requirements for Showcase 17

1. Introduction

This report aims to give a sufficient overview of Hyperloop Manchester in terms of the internal work structure and the preparations for the EHW showcase so far. In this report, a general overview of the team is given first explaining who we are, team members, values, and development environment of Hyperloop Manchester.

Secondly, the system overview of the pod, that is planned to be showcased in the European Hyperloop Week, is explained in detail depicting the design overview of the main and subsystems of the pod, the progress that has been done by the team so far, and figures that illustrate the explanations in a clear way.

All in all, this report describes individually how the team comply with the safety rules and requirements, included in *Rules and Requirements for Showcase* document.

The *General Overview* section has been written by Hakan Okten. In *System Overview*, the *Mechanical* subsection has been written by Thomas Simpson. The *Electronics and Software* subsection has been written by Hakan Okten. The *Power* section has been written by Hakan Okten. The *Safety Compliance with the Rules and Requirements for the Showcase* has been written by Abraham Levy.

2. General Overview

This section describes Hyperloop Manchester in general, its values, and development environment including research objectives, respectively. In this section, you will have a good understanding of the core of Hyperloop Manchester and team principles.

2.1. Who Are We?

We are Hyperloop Manchester, a student-led team which aims to compete in the Hyperloop competitions organised by the esteemed institutions and to share our knowledge with people around the world. The team was founded in 2019 and it has rapidly recruited a wide range of brilliant-minded members, from engineers to business students. We are gaining recognition globally year by year thanks to our Outreach team. Now, Hyperloop Manchester has around 70 team members and around 50 alumni members from different nationalities and backgrounds.

The team consists of three main divisions: Technical, Research, and Business and Outreach. The Technical team consists of three subdivisions: Mechanical, Electronics and Software, and Power. Team members of the 2020/21 team are listed in the next section.

Hakan Okten will be the representative who will be in correspondence with the EHW committee.
Email: hakan.okten@outlook.com

2.2. Team Members

Committee

Hakan Okten
Co-Founder
Co-President and Electronics Team Advisor

Oliver Laryea
Founding Member
Business and Outreach Director

Abraham Levy
Mechanical Project Director

Hak Jin Sim
Head of Power

Batuhan Gerdan
Co-Founder
Co-President and Mechanical Team Director

Thomas Simpson
Lead Mechanical Engineer

Harry O'Brien
Head of Electronics and Software

Sakircan Beyazit
Head of Research

Members

Mechanical Team:

Propulsion

Nicolo Cortese
Head of Propulsion

Mohammad Umair Syed
Propulsion Engineer

Karim Garada
Propulsion Engineer

Konstantinos Margelos
Propulsion Engineer

Isaac Caletrio Berridge
Propulsion Engineer

Manahil Ullah
Propulsion Engineer

Chassis and Integration

Tina Eslami
Head of Chassis and Integration

James Erwing
Chassis and Integration Engineer

Jared Hassan
Chassis and Integration Engineer

Vlad Popescu
Chassis and Integration Engineer

Philip Rosborough
Chassis and Integration Engineer

Pranav Aggarwal
Chassis and Integration Engineer

Maglev and Emergency Breaking

James Morten
Head of Maglev and Emergency Braking

Mabel Ziman
Maglev and Emergency Braking Engineer

Giulio Stangarone
Maglev and Emergency Braking Engineer

Daniel Rotherham
Maglev and Emergency Braking Engineer

Noim Ahmed
Maglev and Emergency Braking Engineer

Suspension

Furqan Shahzad
Head of Suspension

Charley Jeynes
Suspension Engineer

Benita Benoi
Suspension Engineer

Karolis Gudziunas
Suspension Engineer

David Hajduch
Suspension Engineer

Members

Mechanical Team:

Braking

Louis Gallagher
Head of Braking

Abdoullah Naseer
Braking Engineer

Bassel Ezz
Braking Engineer

Bartozsk Tkaczyk
Braking Engineer

Khalil Hadjam
Braking Engineer

Mert Oktay
Braking Engineer

Outer Shell

Jakub Zemek
Head of Outer Shell

Oguz Tecirlioglu
Outer Shell Engineer

Fin Brown
Outer Shell Engineer

Muhammad Bin Saifullizan
Outer Shell Engineer

Bartek Hasko
Outer Shell Engineer

Electronics and Software Team:

Electronics

Yousef Kloob
Electronics Engineer

Selcuk Saltuk
Electronics Engineer

Mikolaj Lenczewski
Electronics Engineer

Sila Ozer
Electronics Engineer

Ishaan Ghatak
Electronics Engineer

Software

Reean Khan
Software Engineer

Pham Van Vinh
Software Engineer

Members

Research Team:

Amir Kidwai
Research Analyst

Fragkoulis Theodosiou
Research Analyst

Humaid Qasem
Research Analyst

Power Team:

Georgio Bou Younes
Power Engineer

Business and Outreach Team:

Dawood Rubani
Co-Head of Sponsorship

Joel Chan
Co-Head of Sponsorship

Luis Miguel Messias
Treasurer

Hussein Janmohamed
Head of Outreach

Claudia Lee
Head of HR

Boran Engin
Social Media Coordinator

2.3. Values

- **Diversity –** The team consists of around 70 members from multiple nationalities and different backgrounds. Hyperloop Manchester firmly believes that the key to the solution to problems comes from different ideas which constitute diversity.
- **Teamwork –** This is the core of Hyperloop Manchester. Everything in Hyperloop Manchester is done with teams and collaboration. Teamwork along with efficient communication ensures that objectives are defined and reached successfully as we have been doing since the creation of Hyperloop Manchester.
- **Passion –** Everyone in Hyperloop Manchester is allocated in their teams according to their interests and passions. Therefore, every member is passionate about their involvement in the team increasing productivity and sense of accomplishment.
- **Creativity –** Tasks in the team are based on creative ideas and solutions to improve the aspects of the Hyperloop pod.
- **Innovation –** The value that essentially depicts the team is "innovation." Hyperloop Manchester always aims to implement innovative applications in the designed Hyperloop pod and conduct research to continuously improve the Hyperloop structure.

2.4. Development Environment

Due to the global pandemic, Hyperloop Manchester has swiftly and successfully shifted to the digital environment to ensure the safety of all their team members. Our day-to-day tasks include the use of Microsoft Teams to communicate, Google Drive to share files and engineering software environments, such as Autodesk, SolidWorks, and Altium Designer, to work on the design of our pod. Every week, we analyse the work done during that specific week, and we set the workload for the coming week.

Figure 1 – Online Committee Meeting

The development environment created by the members is also the learning environment. The team highly values the knowledge sharing internally and even externally. In the team, whenever the members are done with their main tasks, they are very welcome to develop themselves in the other areas that they are interested in. In doing so, this team spirit gives the members a prominent opportunity to explore their interests whilst they work and improve the pod.

Moreover, the team has an interactive research scheme which is managed by the Research division inside of the development environment. In the research segment, it is aimed to collaborate with the University of Manchester regarding the Hyperloop-related research topics created by Hyperloop Manchester. Currently, the team is in standing communication with a few members of academic staff who are the supervisors of the team. Thanks to the created research topics and support of the team supervisors, the team is developing the pod design and can identify the spots which need to be improved easily. In addition to the scientific institutions of the University of Manchester, the Research division aims to enhance the Hyperloop-related research scope and to reach out to the people in other research institutions across the UK.

3. System Overview

This section aims to give an overview of the pod system which consists of Mechanical, Electronics and Power systems mainly. Each system has a different role in the pod and is being implemented in a tuneable way with the other systems. Now, the report delves into the details of each system.

3.1. Mechanical

The mechanical system is responsible for the majority of the physical components that make up the Hyperloop Manchester pod, and it produces the progressive motion that makes Hyperloop a unique and innovative method of transportation. The mechanical system is very closely linked to both the Electronics and Software systems for an integrated and coordinated pod design.

The first prototype pod design, named Hyperman I, is the first manifestation of the progress of Hyperloop Manchester team in designing and building a state-of-the-art Hyperloop pod. However, the team managed to get a better outer shell structure after the first design of the prototype. The latest concept of pod is shown in Figure 2.

Figure 2 – Latest concept of the pod

The mechanical system is itself composed of seven subsystems briefly discussed below. Hyperloop Manchester plans to bring laptops to the site in order to show the mechanical system designs on the screen.

3.1.1. Magnetic Levitation:

Magnetic levitation will be achieved by utilising the special properties of a Halbach magnet array. This array is unusual in that it has a directional magnetic field – the arrangement of the magnets allows for a very high flux density on one side, whilst the other side experiences a flux density that is close to zero. The intensity of the high strength magnetic field will allow this sub-system to produce levitation for the entire pod and suspend it above the track.

3.1.2. Propulsion:

The propulsion system will use AC induction motors to produce the high-speed forward motion of the pod. This subsystem is the subject of extensive research to develop a highly functioning and easily controllable setup with a high maximum speed. At low speeds, the forward motion will be produced using guide wheels that rest on the track.

The specifications of the motor specified so far are as follows. The motor covered in this report is being planned and designed to operate at around 500 km/h. It is estimated that it will weigh around 80 kg. The motor is also being planned to be mounted on a prototype testing Pod. The weigh of the pod is not certain yet and subject to further research. The voltage estimated for the motor is supplied by 705.6V battery pack which consists of two batteries, explained in the Power section in detail. The entire motor design is aimed to be done by the end of January.

3.1.3. Suspension:

The suspension system is designed to provide both vertical and lateral stability to Hyperman I to allow for smooth and reliable locomotion. The vertical control will be performed using a spring and damper system, whilst horizontal control is produced using lateral control modules (LCM).

3.1.4. Braking:

Braking will slow the pod down as required when it reaches the end of the track. The choice of braking mechanism will be eddy currents. These were chosen in preference to friction braking due to their superior properties and performance. Research is ongoing into the magnetic arrays and mechanical positioning system that will be used to move the magnets.

3.1.5. Emergency Braking:

Emergency braking is a sub-system that is intended for use as a backup method of stopping the pod, in case of a fault elsewhere in the mechanical system. The extension of the brake pads is controlled by an electromagnet.

3.1.6. Outer Shell:

Outer shell designs have been developed and simulated using ANSYS in order to consider their efficacy in minimising the coefficient of drag (C_D). Despite the production of the first prototype in the form of Hyperman I, research into more effective shell designs is ongoing in the interests of optimising the degree of streamlining the pod. Multiple designs are being simulated to determine their C_D, and the prototype pod shell will be adjusted accordingly.

Based on these simulations, a unique pod shape has been put forward for use, as shown. The conceptual dimensions of the pod are $2.00 \times 0.68 \times 0.45 \pm 0.05m$ ($length \times width \times height$).

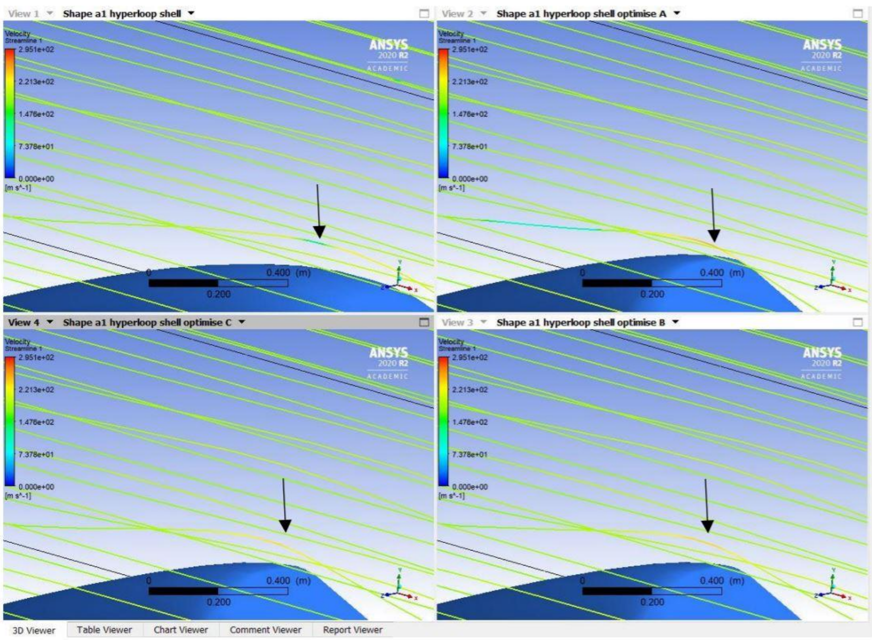

Figure 3 – Shell simulation

3.1.7. Chassis Integration:

Chassis integration is responsible for the assembly of all other subsystems onto the pod and is concerned with the optimal design of the chassis structure. The chassis is to be manufactured out of a carbon fibre skin with a honeycomb aluminium structure sandwiched in between the skins. The high stiffness and durability of this structure, combined with its very low weight, makes it an advantageous choice for the chassis. Attachments to the chassis will be made using aluminium where necessary. Two chassis designs which will be considered further are shown below.

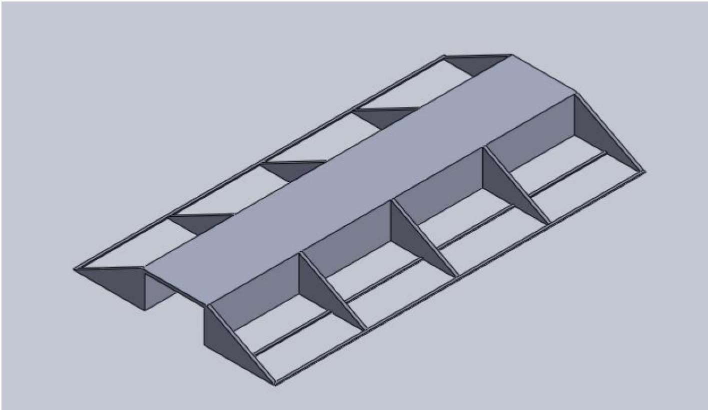

Figure 4(a) – Chassis Design Concept 1

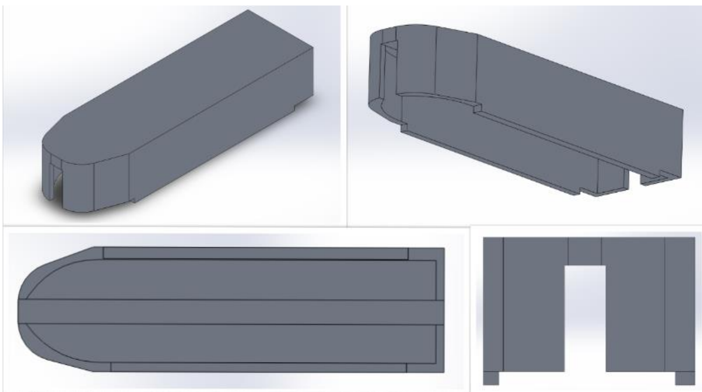

Figure 4(b) – Chassis Design Concept 2

3.2. Electronics and Software

This segment of the pod system is essentially the brain of the components inside. Electronics create the hardware environment, and software implements the behaviour of each hardware system located in the system. This segment of the pod system has two main systems inside which are discussed in detail below.

3.2.1. Electronics:

Electronics segment is generally responsible for creating an efficient hardware environment for the pod management system. The hardware design is so crucial since even the distance between the connections affects the performance and noise severity. The electronics system of the pod consists of multiple modules. Each electronics module has a different responsibility and effect on the pod components. The module designs currently in the process are a battery management system, motor controller system and planned to start shortly are a brake controller system and door controller. The electronics module structure is shown in Figure 5 below.

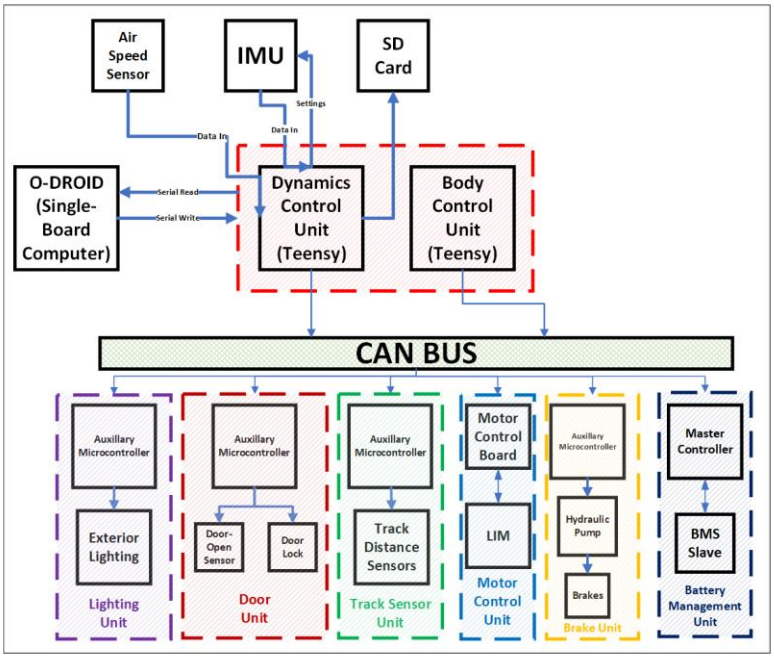

Figure 5 – Electronics system structure

The lighting-control board will connect a small microcontroller to a series of relays in order to turn on and off lights in the pod. The designed lighting system consists of five lights. In addition to this, the microcontroller will connect to a CAN interface chip in order to communicate with the rest of the pod. A small board is required to encompass all of this. The circuit of the lighting-control board has been sketched and is waiting to be implemented on Altium.

The door-control board will connect a small microcontroller to a maglock via an isolated relay, to lock the door, and a small switch, in order to sense if the door is open or not. In addition to this, the microcontroller will connect to a CAN interface chip to communicate with the rest of the pod. A small board is required to encompass all of this. The circuit of the door-control board has been sketched and is waiting to be implemented on Altium.

The track sensor unit is the board containing a Teensy 4.0 that is able to collate sensor information coming from two high-accuracy distance sensors and then transmit this information over CAN. Therefore, we must break out connectors for both the laser sensor and the CAN bus. To keep track of the system stability, we should also be taking temperature measurements regularly, so temperature sensors should also be integrated with the necessary breakout pins.

The motor controller is the speed controller board which is used to control the speed of the AC linear induction motor that the pod contains. With the speed controller board which can be seen in Figure 6, we aim to enhance the process control and to save the energy.

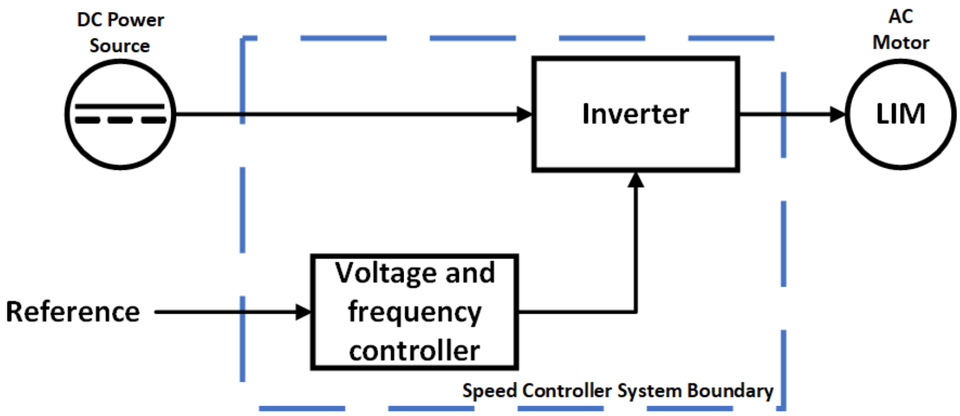

Figure 6 – High-Level Speed Controller Block Diagram

The common brake interface is the circuitry that will interact with the eddy current brakes - these will be in use during normal operation. The emergency brake interface is the circuitry that will interact with the emergency brakes - used in fail-safe operations. The electronics designs of braking and emergency braking are different since the braking types are not the same. The braking electronics system is pending to be designed.

The battery management system (BMS) is the group of battery controller boards which are the slave boards connected to the master controller. Five measurement algorithms will be implemented in the battery management system. These measurement algorithms are state of charge, state of health, thermal management, limit estimation, and cell balancing. In terms of cell balancing, passive cell balancing will be implemented in the battery management system. The designed battery management system structure can be seen in Figure 7.

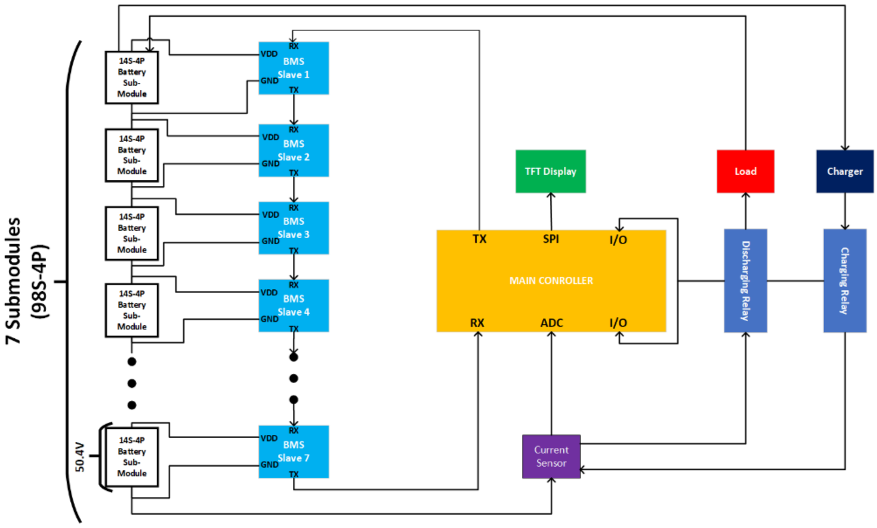

Figure 7 – BMS Structure Diagram

Finally, the BMS slave module has been designed and put into the connection diagram as can be seen below in Figure 8.

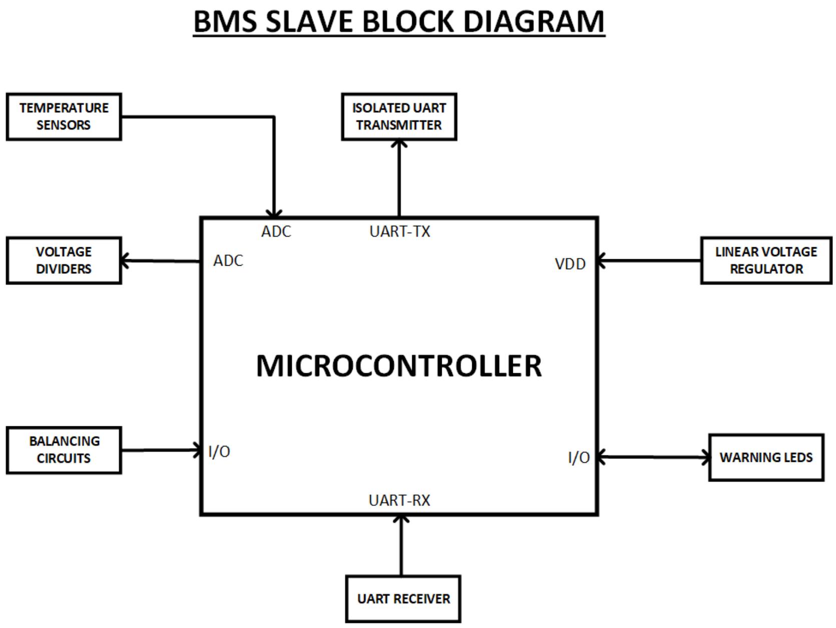

Figure 8 – BMS Slave Module Diagram

To prove the functionality of the aforementioned electronics systems, some of them integrated with the mechanical systems, Hyperloop Manchester plans to record a video and show on the screen, possibly on a laptop.

3.2.2. Software:

The software aspect of the project simply implements the functions of the electronics subsystems mentioned above. The software implementation is prominent since the use of electronics design highly depends on how efficient the software is applied in the pod. The software segment has subsystems specified in accordance with the designed electronics structure. This is because each created electronics needs an algorithm inside to perform the related responsibilities in the pod. The team uses C++ programming language for software applications. The software stack is illustrated in Figure 9 below.

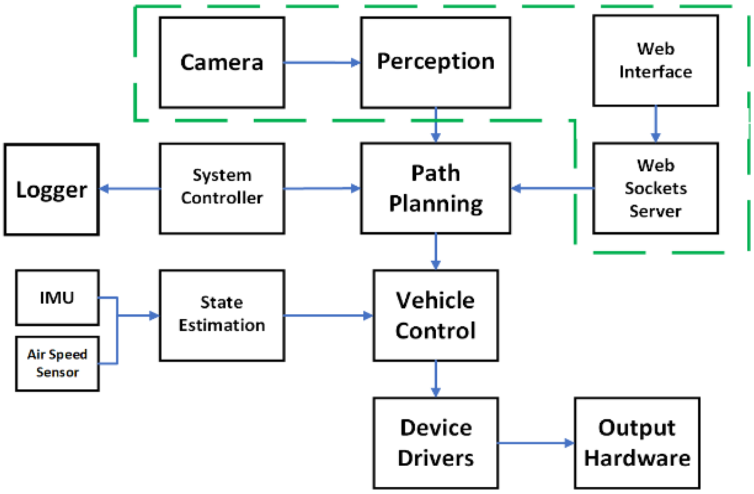

Figure 9 – Software Stack Diagram

The software of the door unit simply creates a door lock with a password. Accessing via CAN bus, an online web environment has been created to enter the password to unlock and/or lock the door. In this way, anyone in the team can have access to the password system.

The software implementation of the lighting subsystem simply turns the light on and/or off and manages five lights used on the pod. Again, this embedded firmware interacts with the pod lighting via CAN bus.

The software design for the brake unit allows the brake electronics to perform its responsibility. The software designs of braking and emergency braking are different since the electronics designs are not the same. As mentioned previously, the reason is the fact that braking will be eddy current braking, and the emergency braking will be friction braking.

As for the control software, there are two applications designed for the pod: dynamic and motor controls. Dynamic control software creates the control functionality of the entire pod including movement and safety measures. On the other hand, the software application of the motor control unit implements the algorithms needed for the motor control design and aimed functionalities, such as speed control. This embedded firmware again allows the interaction between the motor control board and the dynamic pod control unit over the CAN bus.

After finishing the coding part, to test the written codes, we have created hardware mocks on GitHub which check if the written code is valid for the specific module or not.

3.3. Power

This division of the pod system focuses on the powertrain. The power is an important factor of the pod since it powers up the pod. Unless it is designed carefully, it may cause some serious problems including injuries, explosions, and more. In this segment, the type of the cells in the battery pack of AC induction motor has been chosen to be a Li-Ion 18650 cell, which is specifically Panasonic NCR18650B. The mentioned Li-Ion cell has a nominal voltage of 3.6 V and a typical nominal capacity of 3350 mAh.

The battery structure for the AC induction motor has been designed in collaboration with the electronics team. The current battery structure plan consists of two batteries. Each battery has a 98S-4P configuration. The battery structure, created by Electronics and Power divisions, is shown below in Figure 10.

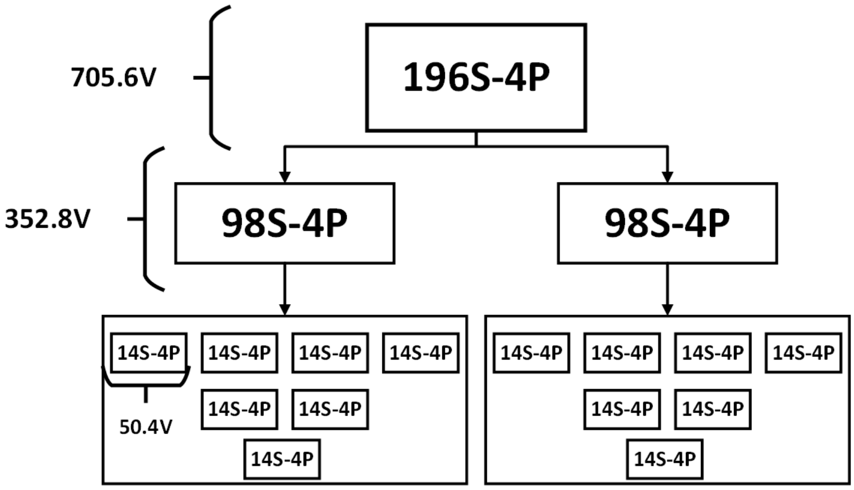

Figure 10 – Battery Structure

Furthermore, the battery connection structure has been designed along with the electronics and mechanical segments. The Mechanical segment specified the power requirements of the motor. Afterwards, the Electronics division designed the battery wiring structure in order to fulfil the motor power requirements.

To demonstrate the power system, Hyperloop Manchester plans to record the video and display the demonstration videos on the screen, possibly on a laptop.

4. Safety Compliance with the Rules & Requirements for Showcase

For the sake of complying with the Rules & Requirements for Showcases established by the European Hyperloop Week group (henceforth, EHW), below are described the measures taken to fulfil the demands. Furthermore, showcasing will only involve the presentation of the Conceptual Design of the Hyperloop Pod (henceforth, Pod) made by the Hyperloop Manchester team.

- In accordance with the provisions of the rule **SC 1** that can be found in section 5.1 of *Rules & Requirements for Showcase*, Hyperloop Manchester takes responsibility and declares the inexistence of any means of power generation systems in the Pod to be showcased at the EHW**.** To comply with this rule, we will not implement the power source in the pod during the showcase.

- In accordance with the provisions of the rule **SC 2** that can be found in section 5.1 of *Rules & Requirements for Showcase*, Hyperloop Manchester takes responsibility and declares the inexistence of any means of energy (this includes potential, kinetic, chemical, and electromagnetic energy) storing units, batteries or systems in the Pod to be showcased at the EHW. To comply with this rule, any energy stored component will not be brought to the EHW site. The reason why the power system is mentioned in this report is that Hyperloop Manchester asked if the battery and power system could be mentioned in the report to give a more sufficient overview of electrical design and got permission to mention it in this report from the EHW.

- In accordance with the provisions of the rule **SC 3** that can be found in section 5.1 of *Rules & Requirements for Showcase*, Hyperloop Manchester agrees to sign the agreement in which they take full responsibility for any damage, incident or accident caused to or by their Pod.

- In accordance with the provisions of the rule **SC 4** that can be found in section 5.1 of *Rules & Requirements for Showcase*, Hyperloop Manchester commits on presenting a full and detailed list of the, if any, low power devices or appliances that are not part of the Pod and only intended for visual display or presentation purposes (i.e., LEDs, light, monitors). If any low power devices or appliances that are not part of the Pod are used, Hyperloop Manchester will solely use them if they have been previously approved by the EHW committee. The predefined low power devices planned to be used so far on the site of EHW 2021 are mentioned in this report in related sections.

- In accordance with the provisions of the rule **SC 5** that can be found in section 5.1 of *Rules & Requirements for Showcase*, Hyperloop Manchester agrees and is liable of complying with all the requirements listed in section 8.4 *Transport, Storage and Lifting Requirements*. To do this, Hyperloop Manchester will tell and show the guidelines one by one to the transportation firm which Hyperloop Manchester will work with.

Hereby, Hyperloop Manchester certifies that it has read and understood the Safety compliance with the Rules & Requirements for Showcase set by the EHW and is responsible for any failed attempt to attain concurrence of the rules stated above.

Hyperloop Manchester Team 2020/21
Saturday, December 12, 2020