zürich 2024

FDD Guidelines

European Hyperloop Week

Tech Committee

February 9, 2024

EUROPEAN HYPERLOOP WEEK

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Foreword

Dear Participants,

This document intends to give teams a better understanding of the expected deliverable of the Final Demonstration Documentation (FDD). It is a guide for teams to follow when writing the document so that all required information is present. Following the advice given in this document will facilitate the application process since this contains all the information the jury would like to know from the teams' demonstration. It is therefore strongly advised to follow the structure presented in this document.

Please be mindful that the jury committee is formed by experts of the industry and they already possess knowledge on basic concepts. It is not necessary to explain what a linear motor is, or to justify the formulas used if they are already a standard in the industry. Instead, use your pages wisely to describe why your system is different, what are your design concerns and how have you solved them.

Do not spend a lot of time with subjective prose describing how innovative is your proposal or how many awards have you won at another competition. It is a technical document, not a political speech. Instead, describe your efficiency rates, your specific communication protocols, tolerances, control algorithms, error detection mechanisms, and so on.

Bear in mind that expert jurors on specific topics will review each section independently. So a juror specialized in mechanical engineering will only read the mechanical section, a juror specialized in software will only read the sense and control section, etc. For this reason, in this deliverable, we ask you to include the suspension and safety wheel systems on the mechanical subsection and leave the levitation section for magnetic levitation systems.
Although the FDD will not be used directly to evaluate your presentations at the competitions, it will be used for clarification if something is not shown in the presentation.

To conclude, after a successful FDD submission, each team will have a feedback session with members of the jury and the technical team to discuss their proposal and receive advice or points of improvement.

Best of regards and good luck!

The EHW Technical Team

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Contents

February 9, 2024, the EHW Committee

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1 Cover Page

You shall include the respective application cover page handed with this guidelines at the start of your submission and before your custom submission cover.

For subsystem applications, please fill a single cover page and send a single document that includes all subsystems applied.

2 Introduction

This section should describe the size, philosophy, and objectives of the team. It is important to list all your team members on a readable table or figure. You can also include information like their ongoing studies. You should also describe the details of the development environment, the number of hours per member, and the division of responsibilities. This will give us a good impression of how you are working which will allow us to give you more tailored feedback.

Finally, justify your main sources of financing and the objectives of your research. This should occupy 8 pages maximum.

3 System

For simplicity and ease of reviewing all the documentation, the following structure is recommended for the section:

3.1 System Overview

In this section, you should especially focus on the top-level description and decisions of your system. You should shortly touch on the aspects which your design is revolved around. If available, include the requirements or constraints that have influenced your design the most. Furthermore, include a short budget estimation for the project as well as the following values for your vehicle if possible:

- Render of the vehicle CAD.
- Objectives of the prototype.
- Weight and size.
- Distribution of subsystems inside the prototype.
- Mass distribution of the prototype.
- Acceleration profile of the demonstration.
- Budget divided by subsystems.
- Can the system be scaled for a full-scale model? What adaptations would be necessary? Describe this in general terms, you do not have to go into specifics like the size of the wheels should be bigger.
- If applicable, the same information about the track.

Please include a short description of how the system will be transported to the EHW location. Note that teams applying with a subsystem application will need to describe all the subsystems, even those that will not be evaluated.
Include also the following table, to give an overview of the systems used.

System Overview	
Length [m]	-
Width [m]	-
Height [m]	-
Weight [kg]	-
Vertical levitation method	(e.g. HEMS)
Vertical levitation system max. current [A]	-
Lateral levitation method	(e.g. EMS)
Lateral levitation system max. current [A]	-
Motor concept	(e.g. LIM)
Motor max. current [A]	-
Regenerative braking used	Yes/No
LV system max. voltage [V]	-
HV system max. voltage [V]	-
Braking method	(e.g. Pneumatic activated friction pads)
Pneumatic system max. pressure [bar]	-
Data Log Frequency [Hz]	-
Board communication protocols	(e.g. CAN, Ethernet)

Table 1: System overview methods

This section should occupy a maximum of 15 pages.

3.2 Mechanical

This section provides detailed information regarding the mechanical system. The applicant must demonstrate the safe design and engineering of the system, along with the ability to test and operate it safely. The following should be included, as applicable:

1. Introduction
   (a) Provide a brief overview of the system, outlining the different subsystems and components compromising the mechanical system.

   Each subsystem, such as the wheels, suspension, brakes, and structures should be addressed separately. Each subsection should contain the following information:

2. Overview
   (a) Explain the main requirements and constraints that drive the design.
   (b) Explain the concept of the sub-subsystem. If necessary, explain briefly why the concept was chosen over other possibilities.
   (c) Detail the size, components, and appearance of the sub-subsystem. In a table the choice of material, mass, dimensions, and other relevant factors should be included, an example of a table can be seen in Table 3.

3. Theoretical concepts
   (a) Provide a detailed explanation of the theoretical and physical principles that form the foundation of the desired functionality. Do not explain basic physics (such as the Laws of Newton).
   (b) Use free body diagrams to define load cases for simulations.

4. Design process and appearance
   (a) Present CAD models and technical drawings.
   (b) Present and justify the selection of materials used in the subsystem.
   (c) Provide relevant properties of the materials selected.
   (d) Provide a rationale for why the specific configuration has been chosen.
   (e) Present FEM results, including pictures and obtained values. Simulate the expected worst-case scenario loads.
   (f) Provide reasoning and the necessary calculations to justify the simulated loads.
   (g) Prove details on the type of mesh and the specific boundary conditions used in your simulations

5. Manufacturing process
   (a) Compile a parts list (including dimensions and mass) in tabular format, specifying whether parts are produced in-house or outsourced.
   (b) Describe what efforts have been made so that the designed part is realistically manufacturable. Example: The brackets have no outer circular segments so the part can be milled. Or the part is composed of flat sheets so they can be laser cut, etc.

6. Integration process
   (a) Describe how the parts will be assembled, including integration into subordinate structures/systems if applicable.

   (b) If applicable, explain in detail how the subsystem interacts with the other subsystems.

7. Safety considerations
   (a) Discuss the safety factor applied to structural elements.
   (b) Discuss worst-case scenarios (e.g., worst-case braking deceleration) and what you plan to do to avoid or contain them.

8. FMEA (Failure Mode and Effects Analysis)[1] results in discussion
   (a) What safety factor was applied and have requirements been met?
   (b) Provide evidence of simulations validating theoretical assumptions and analyze results.
   (c) Assess whether the system is structurally designed to withstand impacts.

9. Testing
   (a) Describe the testing procedures to be included in the Safety Procedures Documentation (SPD).
   (b) Provide a preliminary testing plan, including methodology and expected results.

10. Demonstration
    (a) It should be outlined how the system will be demonstrated if it is a standalone system.

11. Additional considerations when writing the document for specific subsystems:
    (a) Braking system
        i. Identify possible failure points.
        ii. In case several braking systems are used, include a thorough description of when each of the braking systems will be used.
        iii. Describe the braking mechanism, including calipers, discs, and any additional components. Provide reasoning for the selection of specific components.
        iv. Explain the method of actuation for the braking system (e.g., hydraulic, pneumatic, electric).
        v. Include details of the braking force distribution and how it ensures stability and control.
    (b) Pneumatic system
        i. Include pneumatic circuit diagrams and specifications.
        ii. Justify the design of the pneumatic circuit. Analyse possible failure points to justify the placements of certain components.
        iii. Provide details on the pneumatic actuators used and their specifications.
        iv. Discuss the pressure requirements and how they are regulated within safe limits.
        v. Outline the control mechanisms for the pneumatic system and how they ensure precise operation.
    (c) Aeroshell
        i. Include CFD analyses for the conditions expected during the demonstration, and their results, covering values such as lift, drag, or moment coefficient.
        ii. If you plan on demonstrating inside a tube, include it in the CFD simulations.
        iii. In case the system uses high voltage, indicate how will the MIDs be shut off when the aeroshell is covering the pod.

[1] For more information on how to develop an FMEA: https://quality-one.com/fmea/

Address contingency plans for scenarios such as valve failure, loose screws, or worn brake pads.

Custom track	
Length [m]	-
Operating Vehicle Length [m]	-
Width [m]	-
Height [m]	-
Operating pressure [mbar]	-

Table 2: Example of a table

Component	Wheels	Axles	L-bracket 1	L-bracket 2
Number [-]	x8	x8	x16	x8
Mass [kg]	1	0.2	0.1	0.2
Size [mm x mm x mm]	ϕ 100 x 50	ϕ 10 x 90	20x30x50	30x40x60
Material	Polyurethane	Duplex Steel	Aluminium 7075	Aluminium 7075
Manufacturing process	Injection molding	Lathing	Milling	CNC
In-house/outsourced	Outsourced	In-house	In-house	Outsourced

Table 3: Example of parts list

This section should be limited to a maximum of 60 pages and should include pictures of sketches of the design or architecture.

3.3 Infrastructure

In this section, the main components of the infrastructure shall be described as well as their basic functionality. A special focus shall be on how safety mechanisms are implemented in these systems. This section should include, if applicable:

1. Introduction
    (a) Provide some general information and give a brief overview of the system, outlining the different components compromising the infrastructure.
    (b) Detail the type of infrastructure (e.g., external track, tube-like structure...)
    (c) Present and justify the selection of materials used in the infrastructure as well as the material information.
2. Design process and appearance
    (a) Outline the different requirements to be met by the infrastructure.
    (b) Detail the design rationale behind the components of the infrastructure.
    (c) Present CAD models and technical drawings.
    (d) Present FEM results of the worst-case scenarios, including pictures and obtained values.
    (e) Prove details on the type of mesh and the specific boundary conditions used in your simulations. Provide Free Body Diagrams to define load cases.
    (f) Address topics such as thermal expansion, weather resistance, ground anchoring[2], regulation, and electrical grounding to ensure that the infrastructure can withstand different weather conditions safely if necessary.
    (g) Outline ground adaptation methods if applicable.
3. Manufacturing process
    (a) Compile a parts list (including dimensions and mass) in tabular format, specifying whether parts are produced in-house or outsourced.
4. Transport and assembly process
    (a) Describe the transport and lift plan of the infrastructure.
    (b) Describe how the different parts of the infrastructure will be assembled, including integration into subordinate structures/systems if applicable.
    (c) Include a timeline, requested equipment, days and times when a forklift will be required as well as the number of people that will be working on the Custom Test Track simultaneously.
5. Safety considerations
    (a) Discuss the safety factor applied to structural elements.
    (b) Discuss worst-case scenarios (e.g., vehicle stops levitating suddenly) and what you plan to do to avoid or contain them.
    (c) Requirements for transport, storage, and lifting (as defined in Section 9.3, especially TS.4. of the R&R).
    (d) Describe the physical stop designed at the end of the track.
    (e) Show roll-over calculations if applicable.

[2] If you plan on anchoring your track, please provide specific details on how it will be done

(f) Show leak prevention if applicable.

6. FMEA (Failure Mode and Effects Analysis) results in discussion

   (a) Preliminary risk assessment for demonstration, including transport and lifting procedures.
   (b) Detail an FMEA and describe risk mitigation measures for each case.
   (c) Provide evidence of simulations validating theoretical assumptions and analyze results.
   (d) Assess whether the physical stop is structurally designed to withstand impacts.

7. Testing

   (a) Describe the testing procedures to be included in the Safety Procedures Documentation (SPD) if applicable.
   (b) Provide a preliminary testing plan, including methodology and expected results.

8. Demonstration

   (a) It should be outlined how the system will be demonstrated if it is a standalone system.

9. Additional considerations if the custom track includes a tube-like structure:

   (a) Include how vacuum is going to be achieved.
   (b) Detail how sections are going to be joined to prevent leaks.
   (c) Detail roll-over calculations.
   (d) Address contingency plans for different emergency scenarios if anything occurs inside the tube.

Please also include the main characteristics of the infrastructure in a table. The following illustrates an example:

Open		Tube-like Structure	
Length [m]	-	Length [m]	-
Width [m]	-	Width [m]	-
Height [m]	-	Height [m]	-
Weight [kg]	-	Weight [kg]	-
N. of segments [-]	-	N. of segments	-
-	-	Operating pressure [mbar]	-

Table 4: Infrastructure characteristics

Since the infrastructure is highly dependent on each team's scope and its associated risks, the length of this section will not be limited to a certain number of pages. Nevertheless, an estimate of 20-30 pages maximum will be valued.

3.4 Traction

This section provides detailed information regarding the traction system. The applicant must demonstrate the safe design and engineering of the system, along with the ability to test and operate it safely. The following should be included, as applicable:

1. Introduction
   (a) Provide a brief overview of the system, outlining the type of motor, render of the motor and inverter boards, and input/output of the control system.

   If applicable, the following information should be included about the motor:

2. Overview
   (a) Explain the main requirements and constraints that drive the design, such as:
   - Maximum design speed (should be higher than the demonstration one).
   - Average acceleration.
   - Dimensions.
   - Focus (Is it efficiency, power density...).

   (b) Explain the concept of the motor. If necessary, explain briefly why the concept was chosen over other possibilities.
   (c) Detail the size, components, and appearance of the motor. In a table the choice of material, mass, dimensions, and other relevant factors should be included, an example of a table can be seen at the end of this text.
3. Theoretical concepts
   (a) Provide a detailed explanation of the theoretical and physical principles that form the foundation of the desired functionality. Do not explain basic physics (such as the Laws of Newton).
   (b) Explain the interaction between the track and the motor.
   (c) Use free body diagrams to define load cases for simulations.
4. Design process and appearance
   (a) Present CAD models and technical drawings.
   (b) Present and justify the selection of materials used in the subsystem.
   (c) Provide relevant properties of the materials selected.
   (d) Provide a rationale for why the specific configuration has been chosen. Dimensions, number of windings, strength of magnets, air gap, etc.
   (e) Present FEM results, including pictures and obtained values. These must include magnetic and mechanical simulations of the assembly. Magnetic simulations must include forces generated at different air gaps and currents (if applicable).
   (f) Prove details on the type of mesh and the specific boundary conditions used in your simulations.
   (g) Provide calculations on the expected temperature reached by the system. Discuss whether it is necessary to incorporate a cooling system (if you decide you need a cooling system, you can find an explanation in the Levitation section 14(b)). In case the motor method relies on the generation of Eddy currents to generate traction force a thermal simulation must be shown (e.g. Linear Induction Motors).

5. Control system overview
   (a) Provide an overview of the control architecture employed in the traction system to regulate the motion of the pod.
   (b) Describe the control strategy used for the electric motor, such as field-oriented control, direct torque control, or other relevant methods. Justify the choice of a control strategy based on system requirements and performance objectives.
   (c) Detail the sensors utilized for feedback in the control loop, including position sensors, velocity sensors, and any other relevant sensors. Explain how sensor data is processed and used for motor control.
   (d) Discuss the interface with other subsystems, particularly the electric system, detailing how the traction system interacts with these components to ensure coordinated operation.
   (e) Describe any safety features incorporated into the control architecture, such as overcurrent protection, overvoltage protection, and fault detection algorithms.
   (f) Discuss the control strategy for traction force modulation, including acceleration, deceleration, and braking.
   (g) Detail any redundancy or fail-safe mechanisms implemented in the control architecture to mitigate the risk of system failures and ensure safe operation.
   (h) Detail how will regenerative braking, if possible, be achieved with the motor and what mechanisms are in place to guarantee safely recuperating energy.
6. Manufacturing process
   (a) Compile a parts list (including dimensions and mass) in tabular format, specifying whether parts are produced in-house or outsourced.
   (b) Describe what efforts have been made so that the designed part is realistically manufacturable. Example: The brackets have no outer circular segments so the part can be milled. Or the part is composed of flat sheets so they can be laser cut, etc.
7. Integration process
   (a) Describe how the parts will be assembled, including integration into subordinate structures/systems if applicable.
   (b) Explain how the motor interacts with other subsystems. For example:
      i. Sense and control: how is the motor controlled? How are failures in the motor reported to the operator?
      ii. Electrical: How is power being provided to the motor?
      iii. Levitation: Do the magnetic fields of the motor affect the levitation modules, or vice-versa?
      iv. Mechanical: How does the motor interface with the chassis?
8. Safety considerations
   (a) Discuss the safety factor applied to structural elements.
   (b) If applicable, discuss the safety factor applied to the demagnetization of permanent magnets.
   (c) If applicable, discuss high voltage safety considerations for the motor.
   (d) Discuss worst-case scenarios (e.g., worst-case braking deceleration) and what you plan to do to avoid or contain them.
9. FMEA (Failure Mode and Effects Analysis)[3] results in discussion

[3] For more information on how to develop an FMEA: https://quality-one.com/fmea/

   (a) What safety factor was applied and have requirements been met?
   (b) Provide evidence of simulations validating theoretical assumptions and analyze results.
   (c) Provide an analysis of the risks of the motor.
   (d) Assess whether the system is structurally designed to withstand impacts.

10. Testing
   (a) Describe the testing procedures to be included in the Safety Procedures Documentation (SPD).
   (b) Provide a preliminary testing plan, including methodology and expected results.

11. Demonstration
   (a) Outline how the motor will be demonstrated if it is a standalone system.

12. Full-scale adaptation
   (a) Explain how this subsystem choice is beneficial in a full-scale concept or how it should be adapted for a full-scale hyperloop.

Please also include the main characteristics of this subsystem in a table. The following illustrates an example:

Traction System	
Maximum acceleration [g]	-
Maximum deceleration [g]	-
Operating voltage [V]	-
Nominal current [A]	-
Maximum current [A]	-
Maximum power [kW]	-
Dimensions [m x m x m]	-

Table 5: Traction system characteristics

This section should occupy a maximum of 60 pages. Please include pictures or sketches of the design if available.

3.5 Levitation & Guiding

In this section, the main components of the levitation system shall be described as well as their basic functionality.A special focus shall be placed on how safety mechanisms are implemented in these systems. This section should include, if applicable:

1. Introduction
   (a) Provide a brief overview of the system, outlining the different subsystems and components compromising the levitation/guiding system.

   As described in the foreword, include in this section only the information regarding levitation modules. Include suspension and safety wheel designs in the mechanical section. Each sub-subsystem, such as the lateral or vertical levitation systems should be addressed separately. They will be referred to in this section as levitation modules. Each subsection should contain the following information:

2. Overview
   (a) Explain the concept and design requirements or constraints, such as:
      - Nominal levitation air gap.
      - Maximum and minimum levitation air gap.
      - Dimensions.
      - Focus (efficiency, stability, etc).
      - Expected loads.

   (b) Explain the concept of the motor. If necessary, explain briefly why the concept was chosen over other possibilities.
   (c) Detail the size, components, and appearance of the motor. In a table the choice of material, mass, dimensions, and other relevant factors should be included, an example of a table can be seen at the end of this text.

3. Theoretical concepts
   - Provide a detailed explanation of the theoretical and physical principles that form the foundation of the desired functionality. Do not explain basic physics (such as the Laws of Newton).
   - Use free body diagrams to define load cases for simulations.

4. Design process and appearance
   (a) Present CAD models and technical drawings.
   (b) Present FEM results including pictures and obtained values. These must include magnetic and mechanical simulations of the assembly. Magnetic simulations must include forces generated at different air gaps and currents (if applicable).
   (c) Provide a rationale for why the specific configuration has been chosen. Dimensions, number of windings, strength of magnets, air gap, current, voltage, etc.
   (d) Prove details on the type of mesh and the specific boundary conditions used in your simulations.
   (e) Provide calculations on the expected temperature reached by the system. Explain whether it is necessary to incorporate a cooling system (further explanation in 14-b). In case the levitation method relies on the generation of Eddy currents (rotating permanent magnet disks or Halbach arrays) a thermal simulation must be shown.

5. Control architecture
   (a) Include a description of the control mechanism in place to control the air gap.
   (b) Provide calculations necessary to guarantee the stability of the system (or a description of the plan to tune the control system).
   (c) Describe the control algorithms used, whether they are PID controllers, state feedback controllers, or any other control strategy. Explain why the chosen control method is suitable for the levitation/guiding system.
   (d) Discuss the sensors used for feedback in the control loop and how their output is utilized to regulate the levitation air gap.
   (e) Explain the interface with other subsystems, particularly the motor and powertrain, detailing how the control system interacts with these components to ensure coordinated operation.
   (f) Describe how errors in the levitation system are detected and handled, including fault detection and isolation strategies.
   (g) Discuss any redundancy or fail-safe mechanisms implemented in the control architecture to enhance system reliability and safety.
6. Material choice
   (a) Present and justify the selection of materials used in the sub-system.
7. Manufacturing process
   (a) Compile a parts list (including dimensions and mass) in a tabular format specifying whether parts are produced in-house or outsourced.
   (b) Describe what efforts have been made so that the designed part is realistically manufacturable. Example: The brackets have no outer circular segments so the part can be milled. The length of the coil windings is limited due to the maximum length of the winding machine.
8. Integration process
   (a) Describe how the parts will be assembled, including integration into subordinate structures/systems if applicable.
   (b) Describe in detail how the subsystem interacts with the other subsystems.
      i. Sense and control: how is the control or data from the levitation system integrated into the GUI? What errors can come from the levitation system, and how are these errors handled?
      ii. Electrical: How is power being delivered to the levitation modules? What happens if power is cut?
      iii. Traction: Do the magnetic fields of the levitation system affect the motor, or vice-versa? Is the levitation system able to handle the loads expected from the motor?
      iv. Mechanical: How do the levitation modules interface with the chassis? At what distance are the safety wheels placed? How is this distance determined?
9. Safety considerations
   (a) Discuss the safety factor applied to structural elements.
   (b) Discuss the safety factor applied to the demagnetization of permanent magnets.
   (c) If applicable, discuss safety considerations taken to handle permanent or electromagnets.

(d) Discuss worst-case scenarios (e.g., worst-case drop of the pod) and what you plan to do to avoid or contain them.

(e) Explain how permanent magnets will be covered to satisfy the 1mT requirement on the outer perimeter of the cover box.

10. FMEA (Failure Mode and Effects Analysis)[4] results in discussion

    (a) What safety factor was applied and have requirements been met?

    (b) Include an analysis of the risks of the subsystem.

    (c) Provide evidence of simulations validating theoretical assumptions and analyze results.

    (d) Assess whether the system is structurally designed to withstand impacts.

11. Testing

    (a) Describe the testing procedures to be included in the Safety Procedures Documentation (SPD).

    (b) Provide a preliminary testing plan, including methodology and expected results.

12. Demonstration

    (a) It should be outlined how the system will be demonstrated if it is a standalone system.

13. Full-scale adaptation

    (a) Explain how this subsystem choice is beneficial in a full-scale concept or how it should be adapted for a full-scale hyperloop.

14. Additional considerations when writing the document for specific subsystems:

    (a) Rotating permanent magnet disk
        i. Identify possible failure points.
        ii. Explain how the spinning wheel and motor assembly will be balanced to minimize possible vibrations.
        iii. Thermal simulations of energy transferred between magnets and track, particularly looking at the temperature components reach.
        iv. The system must be checked by an external company for balancing after their transport to Zürich (The EHW will not provide this option, teams have to find it).
        v. Provide an analysis of what would happen if 1 or more of these rotating disk assemblies would fail.
        vi. Include a mechanism to guarantee stabilization of the rotating disk in the direction of motion.

    (b) Cooling system (If this was explained in another subsystem, please refer to it and explain shortly the adaptation of the cooling system to this specific subsystem).
        i. Explain how the cooling system works.
        ii. Explain how the cooling system interfaces with the levitation modules. Include CAD pictures.
        iii. Explain how the cooling system has been designed to keep the temperature within acceptable values.
        iv. Explain how the cooling system will be prevented from leaking.

[4] For more information on how to develop an FMEA: https://quality-one.com/fmea/

v. Provide the necessary calculations or simulations to prove the efficacy of the cooling system.

Please also include the main characteristics of this subsystem in a table. The following illustrates an example:

Vertical Levitation		Lateral Levitation	
Levitation method	(e.g. HEMS)	Levitation method	(e.g. EMS)
Nominal air gap [mm]	-	Capacity [Ah]	-
Maximum air gap [mm]	-	Maximum air gap [mm]	-
Minimum air gap [mm]	-	Minimum air gap [mm]	-
Operating voltage [V]	-	Operating voltage [V]	-
Nominal current [A]	-	Nominal current [A]	-
Maximum current [A]	-	Maximum current [A]	-
Maximum power [kW]	-	Maximum power [kW]	-
Dimensions [m x m x m]	-	Dimensions [m x m x m]	-

Table 6: Levitation and Guiding system characteristics

This section should occupy a maximum of 60 pages. Please include pictures or sketches of the design or architecture if available.

3.6 Electrical

In this section, the components of the electrical systems shall be described. A special focus shall be put on how safety mechanisms are implemented in these systems. The mechanical aspects of used structural parts should be discussed as well. This section should include, if applicable:

1. Introduction
    (a) Brief overview with the main points of the HV and LV systems.
    (b) List of all discrete electrical subsystems
    (c) Wiring diagram of the HV system

    If applicable, the following information should be included for each sub-subsystem, such as the wiring system, high and low voltage batteries, power boards for levitation and propulsion, or onboard chargers.
2. Overview
    (a) Explain the main requirements and constraints that drive the design.
3. Electrical and mechanical design process:
    (a) Present Schematics or logic diagrams of the boards.
    (b) Present temperature simulations for vacuum conditions.
4. Description of subsystem control.
    (a) Briefly reference the control systems of the boards, which should be explained in the levitation or propulsion section respectively.
5. Interfaces with other systems.
    (a) Briefly reference the communication protocols or control mechanisms of the boards, which should be explained in the respective Sense & Control section.
6. Table similar to Table 7
7. Final system description
8. Manufacturing process
    (a) Compile a parts list (including dimensions and mass) in a tabular format specifying whether parts are produced in-house or outsourced.
    (b) Describe what efforts have been made so that the designed part is realistically manufacturable.
9. Testing
    (a) Describe the testing procedures to be included in the Safety Procedures Documentation (SPD).
    (b) Provide a preliminary testing plan, including methodology and expected results.
10. FMEA (Failure Mode and Effects Analysis)[5]
    (a) Describe the main hazards and the measures and methodologies taken to prevent them.

[5]For more information on how to develop an FMEA: https://quality-one.com/fmea/

(b) Assess whether the system is designed to withstand the intended current, voltages, and temperatures.

(c) Assess whether the system is designed to withstand the expected impacts.

11. Additional considerations when writing the document for specific subsystems:

(a) High voltage batteries

i. Provide details on the design or choice of an IMD (Insulation Monitoring Device) and how it will be implemented in the vehicle.
ii. Provide details on how the MID's are integrated and prove their accessibility.
iii. Prove how the motor and braking systems are physically prevented from being actuated at the same time.
iv. Explain how your system meets all Rules and Regulations applicable to high voltage systems.

(b) Supercapacitors

i. Explain how they will be discharged in case of failure of failsafe mechanisms.
ii. What voltage levels can your supercapacitors reach? What extra protections are there in order to guarantee the safety of such high voltages?
iii. If they will be placed in a vacuum environment. You must detail the design of a box protecting them from vacuum.
iv. Briefly explain what would happen if one supercap blows up (they contain acid inside and can damage the pod and the infrastructure).

This section should occupy a maximum of 60 pages. Please include pictures, sketches and tables (e.g. Table 7) abundantly to depict the design or architecture.

LV Battery		HV Battery	
Battery Type	(e.g. LiPo)	Battery Type	(e.g. LiPo)
Capacity [Ah]	-	Capacity [Ah]	-
Nominal Voltage [V]	-	Nominal Voltage [V]	-
Cell configuration	(e.g. 2S6P)	Cell configuration	(e.g. 2S10P)
Maximum expected current [A]	-	Max. levitation current [A]	-
=	-	Max. motor current [A]	-
Weight [kg]	-	Weight [kg]	-
Dimensions [m x m x m]	-	Dimensions [m x m x m]	-

Table 7: Electrical system characteristics

3.7 Sense & Control

In this section, the main components of the sensor network and software architecture shall be described as well as their basic functionality. A special focus shall be made on how safety mechanisms are implemented in these systems. Extensive design descriptions are expected of, if applicable:

1. Control boards.
2. Communication network.
3. Graphical User Interface (GUI).

This section can be structured in the following way:

1. Introduction
   (a) Brief overview of all control boards.
   (b) Diagram with the connection of all boards with NAP and control station.
   (c) Brief description of communication protocols used (1 page maximum).
2. State Machine of the vehicle:
   (a) Describe the general state machine.
   (b) Describe every transition and the case of use of every transition.
   (c) Describe particularly how the different braking scenarios are handled.
3. Brief description of code architecture and class diagram (3 pages maximum).
4. For every control board/unit in the vehicle, if applicable:
   (a) Requirements of the board.
   (b) Hardware Rationale (HW design and concerns).
   (c) Firmware Rationale (Internal State machine and design concerns).
   (d) Testing and validation plan.
5. Communication and navigation:
   (a) Design Requirements.
   (b) Network Diagram.
   (c) Diagram of all sub-networks (track, vehicle, and spectators).
   (d) For every GUI (demonstration, testing...):
      i. Picture of every tab or layer (try to keep it at 1 tab for easier visualization during the demonstration).
      ii. Design Rationale of the GUI.
      iii. Testing and validation plan.

Please also include the main characteristics of this subsystem in a table. The following illustrates an example:

Sense&Control System	
Data log Frequency [Hz]	-
Board Communication protocols	(e.g. CAN, Ethernet)
Board Communication rate[Mb/s]	-

Table 8: Sense and control system characteristics

This section should occupy a maximum of 60 pages. Please include pictures or sketches of the design or architecture if available.

4 Safety

Hazardous situations and the solution proposal must be extensively explained in this section. A separate section allows for better visibility and referencing in feedback documents.

If applicable, the following hazards should be addressed:

- Pneumatic Systems
- Vacuum
- Levitation units
- Permanent magnets
- Heavy systems
- Cooling systems
- High voltage Batteries and protections
- Thermal management of the motor, levitation units

For every safety hazard in every subsystem, if applicable:

1. Overview of the hazard
2. Link to the FMEA (Failure Mode & Effects Analysis).
3. Description of critical FMEA (score above 25-30).

This section should occupy a maximum of 30 pages if done separately, or fit the corresponding maximum of the subsystem if inside the subsystem section.

For more information on how to develop an FMEA: https://quality-one.com/fmea/

5 Style

- The document shall be delivered in A4 vertical format.
- Pt11-12 font size must be used for plain text.
- We recommend using standard fonts and LaTex for document layout.
- Feel free to use this template for your FDD submission
- Do not place watermarks as the background of your page.
- Include a list of symbols at the beginning of the document.

6 Contact details

As for any other questions regarding the EHW, if you have any questions regarding the FDD submissions, please send an email to technical@hyperloopweek.com with 'FDD Submission Question' as the subject.