THE UNIVERSITY
of EDINBURGH

HYPED

Table of contents

Design need

SF – LA = London – Scotland

San Francisco – Los Angeles

Distance
San Francisco – Los Angeles 560 km

Demand (passenger per year)
San Francisco – Los Angeles 2.4M

Scotland– London

Distance	
Edinburgh – London	534 km
Glasgow – London	556 km
Demand (passenger per year)	
Edinburgh – London	3.1M
Glasgow – London	2.3M
TOTAL	**5.4M**

Weaknesses of traditional modes of transportation - luggage restrictions, frequent delays, necessity to commute before flying, long journey times and high ticket prices: all require room for **improvement**. According to Transport Scotland, in 2014: **5.4M** passengers flew from London, Edinburgh and Glasgow combined. This figure highlights the potentially vast target market and market demand. Thus, our aim is to **design and build** a functional half-scale pod capable of travel between San Francisco and Los Angeles or Edinburgh to London. Journey times will reduce with the use of subsonic speeds, coupled with the highest level of safety and unparalleled passenger experience: our business case will justify its entry into service.

Our distinctive features

What makes our design special

1

Provide exceptional passenger experience

A team of designers to guarantee fantastic level of passenger comfort which is a priority for our design. Passenger area designed to give a feeling of spaciousness. Innovative seats to help overcome high acceleration forces.

2

Open, modular structure

Modularity to provide room for developments in the design to fulfill passengers' needs. Versatile structure would give room for expansion to new markets or incorporate more efficient subsystems.

3

Increase the capacity of the system

Exchangeable passenger compartment to considerably reduce turnaround times. Bespoke safety solutions to increase passenger capacity. Detailed business viability study.

Design overview

The pod in a nutshell

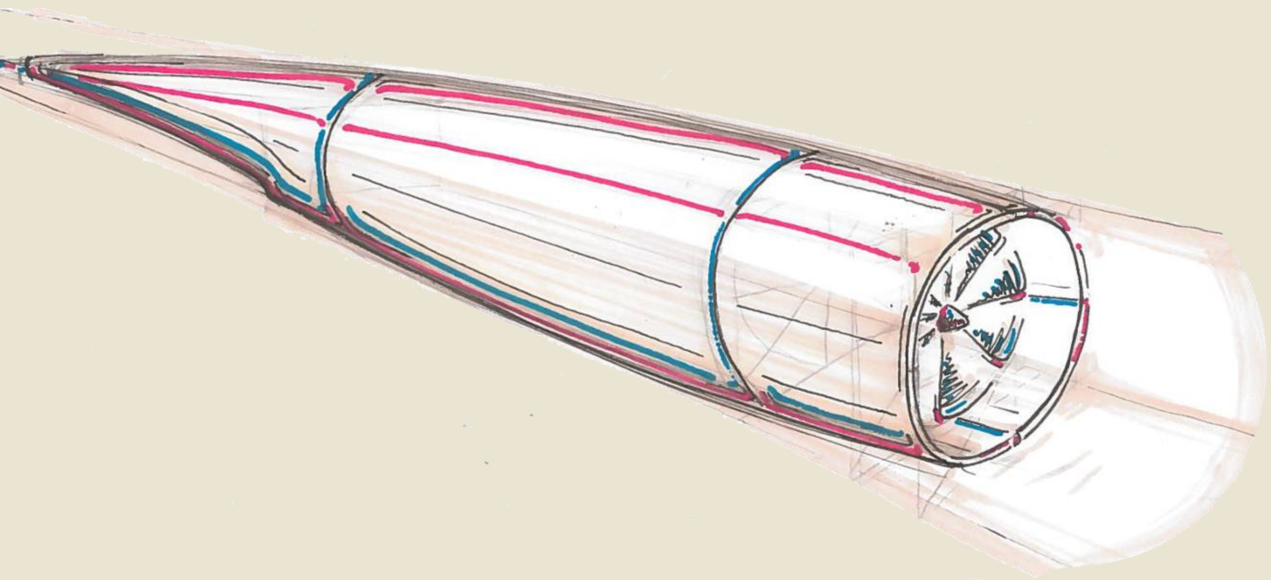
Our aim is to **design** a functional half-scale pod capable of travel between San Francisco and Los Angeles or Edinburgh to London. The competition design, however, will be an adapted half-scale design, optimised for the highest possible performance on the proposed test track.

Dimensions of scaled pod

Length:	6.45 m
Width:	1.10 m
Height:	1.25 m

Specifications by subsystem

Interior	270 kg	3.5 kW
Safety	300 kg	15 kW
Electronics	1100 kg	4 kW
Levitation	425 kg	300 kW
Cooling	350 kg	12 kW
Pressure vessel	370 kg	
Aeroshell	800 kg	
Total	**3,615 kg**	**334.5 kW**



Performance

Operating pressure: 1,000 Pa
Design speed: 1,040 km/h

Capability

Passengers: 10
Payload: 1,500 kg

Technicals

Compressor: axial, 5-stage
Motor: 300 kW
Batteries on board: lithium-ion, 160 kWh
Levitation: hovercraft-like air bearings
Cooling: intercooler

Hazardous materials

Lithium-ion batteries

Stored energy on pod

Lithium-ion batteries
Pressure vessels

Identifying passenger experienc problems

Hyperloop from passengers' perspective

Lack of internal space

What are the minimum internal dimensions of the passenger section?

What is the most effective layout of chairs?

Should we provide a toilet for passengers; this requires a corridor and occupies space?

Passenger comfort

How do we reduce the effects of the acceleration on the body?

How do we reduce feelings of claustrophobia in the pod?

What is the ideal temperature and humidity within the pod?

Boarding the pod

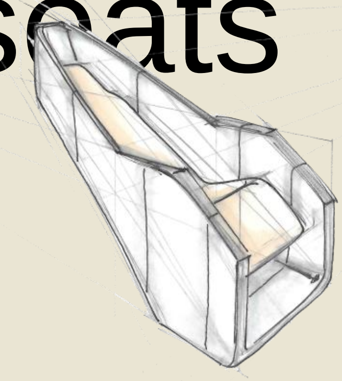
How do passengers access their seat during loading and unloading?

Where is luggage stored?

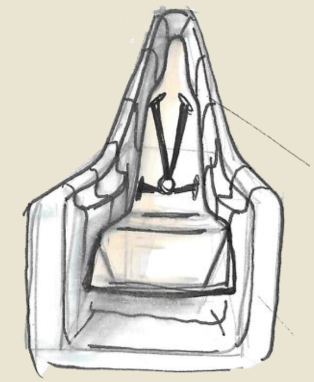
How can we reduce turnover time for pod arrival to pod departure with passenger switchover?

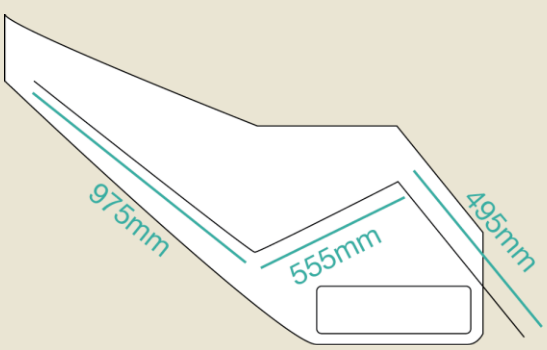
Comfortable bucket seats

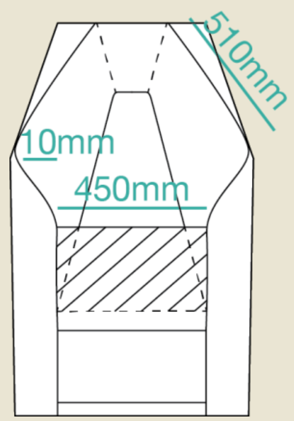
Enjoying your near sonic travel



Monobloc seating that offers structure and support for both a comfortable ride and a sense of safety. The shape of the chairs overlap, partially tessellating to save space along the length of the pod. Luggage space can be provided under each chair. Seats will be angled back to minimise the force acting on the body during acceleration. Outer shell forms a small amount of private space as it rises just over the head of the passenger.







To ensure the chairs accommodate the largest number of potential passengers, we followed the guidelines of the ideal chair dimensions for US adults aged 19-65 years using *Body Space: Anthropometry, Ergonomics and Design of Work, Third Edition* (2005) by Stephen Pheasant.

Whilst taking into consideration the 95th percentile of men, the maximum sizes of the chair are as follows:

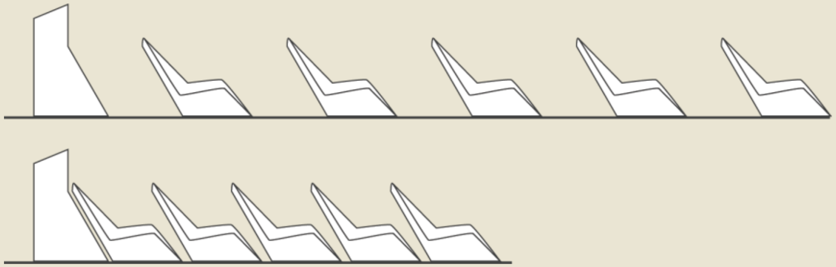
Modular seating and loading the pod

Putting pieces together

Concept inspired by links in the Apple watch bracelet and components of the Blocks Smartwatch to create modular seating that loads and unloads passengers in a comfortable, timely manner. This modularity supports the removal and addition of seat rows with a toilet compartment for longer journeys.

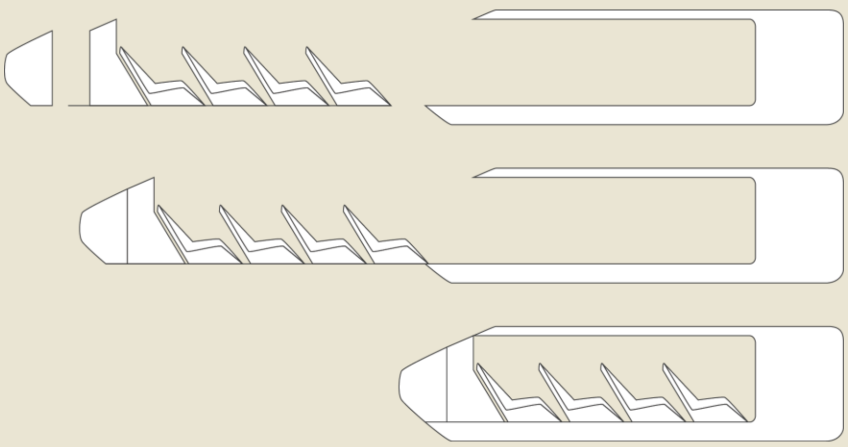
Modular seating

Customizable interior elements (chair configurations, luggage storage, toilets, etc.) fit onto standardized “floor links”. The links are arranged outside of pod by lining up the desired configuration. This means that for changing cargo requirements different interior arrangements can be created and inserted onto the same chassis. For example, seats with space for a corridor can be loaded with a toilet replacing the back unit to create a long haul pod.



Loading/Unloading

The inclusion of doors is problematic for a pressurized pod in a low pressure tube, thus we decided to have a door-less system for loading the pod. Passengers and luggage are loaded into the passenger section floor outside of the pod. The entire passenger section is then transported on rails into the pod. This allows for increased space to move about in before the journey, instead of trying to get comfortable in cramped interior.

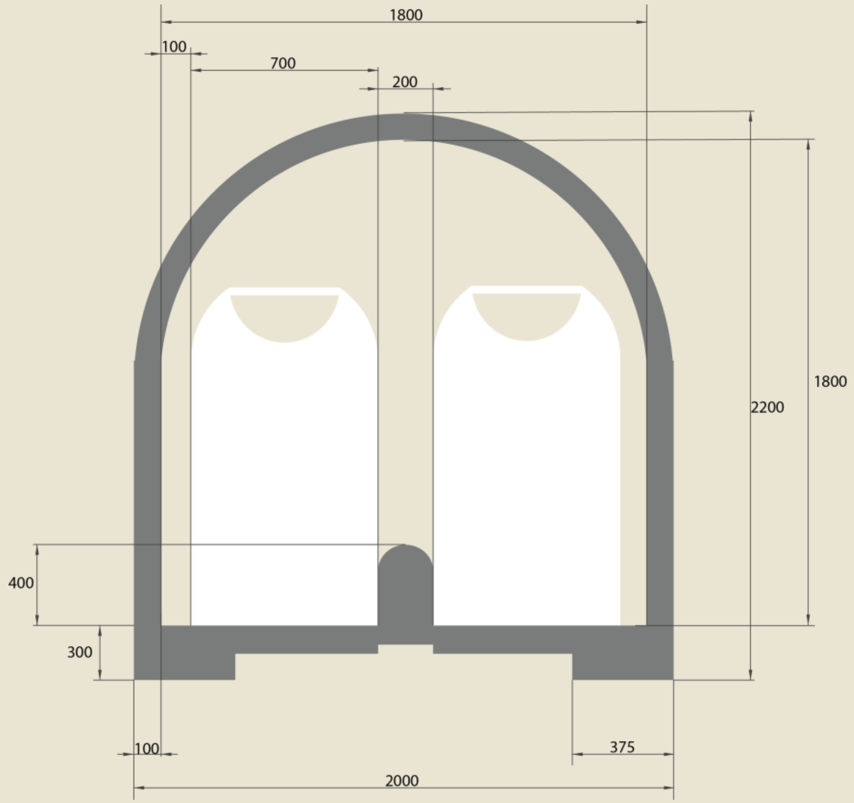


Panel Structure

Two seats abreast formulate one module. Each module joins together once the passengers are seated. When ready, the rear part of the pod containing the batteries connects to the seating compartment, which connects to the outer shell and front section

Cross-sectional dimensions

Plenty space overhead, relax



Internal height of passenger section calculated using the 95th percentile of US male height which is 1800 mm. Passengers will stay seated throughout the journey so there is no need for an aisle. With the modular systems this can be changed to accommodate thinner chairs, a corridor and a toilet for longer journeys. The seats are in rows of two with room for wide arm rests (potentially where oxygen masks are stored) and small gaps between chairs and walls of pod. The floor of the pod protrudes upwards between the chairs to give more room for under floor subsystems.

Relaxing environment inside the pod

Claustrophobia reduction

"I got locked in my car when the key battery was flat. I couldn't get out and I freaked out completely. Couldn't connect to anything or understand what was going on." – (Perry, 2008)

Humidity:

Comfortable range: 30% - 60% relative humidity
Ideal range: 45% - 55% relative humidity

Temperature:

Summertime day: 21.1 °C - 23.9 °C
Summertime night: 18.3 °C - 22.2 °C
Wintertime: 15.5 °C - 18.3 °C

Claustrophobia reduction

To decrease the perception of claustrophobia within the passenger pod, research was undertaken to understand how interiors are made to feel larger. "Less is more when it comes to good interior design". Quoted by Annette Callari from Playing With Blocks online article. The eight building blocks of interior design are line, form, shape, space, light, colour, pattern and texture. Using line, light and reflection to create an illusion that the space is bigger. The images show the work of artist James Turrell who creates sculptural spaces using light, distorting perception of distance.Using entertainment systems can act as a distraction from the surrounding environment. Access to an oxygen mask and air conditioning is important. Reassuring voice explaining process of travel at intervals throughout the journey.

Modularity

Engineering approach

Modularity in engineering

Adaptable and expandable

Integration of better components

Increase lifecycle

More sustainable

Capable of performance deficits (mass and space occupation)

Pod as a testing rig for teams only designing sub-systems:

Allow for easy integration of every subsystem.

Build an environment that improves all subsystems and accelerates development of the technologies necessary for the Hyperloop.

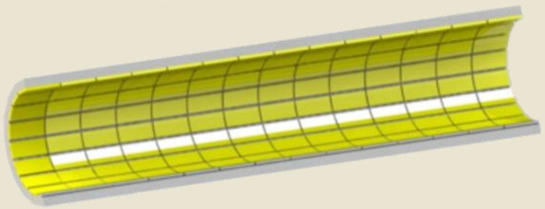
Give teams who designed a single sub system the opportunity to integrate their feature within a pod.

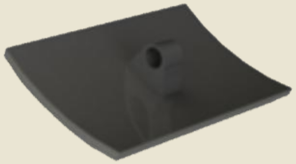
Facilitate communication between teams and create a platform for intellectual exchange that enables the development of technologies for hyperloop within the spaceX competition.

How?

The main component of our pod will be an inner shell with an insert-able platform (with a similar additive structure as our conceptualized pod) such that we can incorporate as many subsystems as possible.

We will be provided a software information hub aiding communication between subsystems.





Modularity features

All subsystems will be entirely or partially replaceable.

The passenger, battery, coolant loading system not only promotes quick boarding, but also separates these systems allowing them to be easily replaced with different components.

Our Li-ion batteries are in modular compartments, allowing them to be assembled flexibly in accordance with the other subsystems (e.g. at the back, or along the base of the pod.)

Panel structure

The panel structure will be incorporated to allow for easy adaptability. Replaceable panels would include a variety of mounting panels, power panels for electricity, and telemetry panels for data logging and communication. New panels can easily be designed and incorporated within the shell structure.

Passenger Safety features

all journeys would be completed as expected from the passenger's perspective

“(…) capsule does not require continuous power to travel. The capsule life support systems will be powered by two or more redundant lithium ion battery packs making it unaffected by a power outage. (…) For additional redundancy, all Hyperloop capsules would be fitted with a mechanical braking system to bring capsules safely to a stop.“– Hyperloop Alpha, Elon Musk

Pod as the safest place to be

In case of an emergency, the pod is supposed to be the safest possible place whilst awaiting help, hence no emergency exits are present. The pod is equipped with HVAC, a fire extinguisher, oxygen masks as well as being isolated by a fireproof layer from the outside.

Oxygen masks

In case of slow pod depressurisation oxygen masks are mounted for passengers when pressure drops below ¾ atm. Chemical reaction uses NaCl + Iron which creates oxygen. The reaction once started cannot be stopped and lasts for 15-20 min. One mask is connected with a couple of others.

Electrochemical storage

Lithium ion batteries - In order to ensure that the environmental conditions within the pod are still suitable, electricity will (at minimum) be needed to light the capsule and power all the essential utilities. For this reason, backup lithium ion batteries are the most practical energy source.

Seatbelts and air cushion

Bucket seats are equipped with seatbelts for acceleration and braking procedure. The wide, vest-style seatbelts are intended to stabilize the person and prevent from injuries. In case of emergency braking with much higher deceleration, complex air cushion system will activate creating a safe bubble around each person.

General safety features

Designing the pod to withstand the worst case scenario

Tube fracture

Competition case
In the result of rapid pressurisation: drag force equates to 11.8 kN resulting in 1.3 MW of heat consumption on the pod shell. Due to high convection heat loss, the outer shell will reach temperatures of 650 °C. However, the resultant high pressure from heat loss will cause sudden deceleration. To remedy this, the emergency brakes must be activated before reaching the maximum temperature.

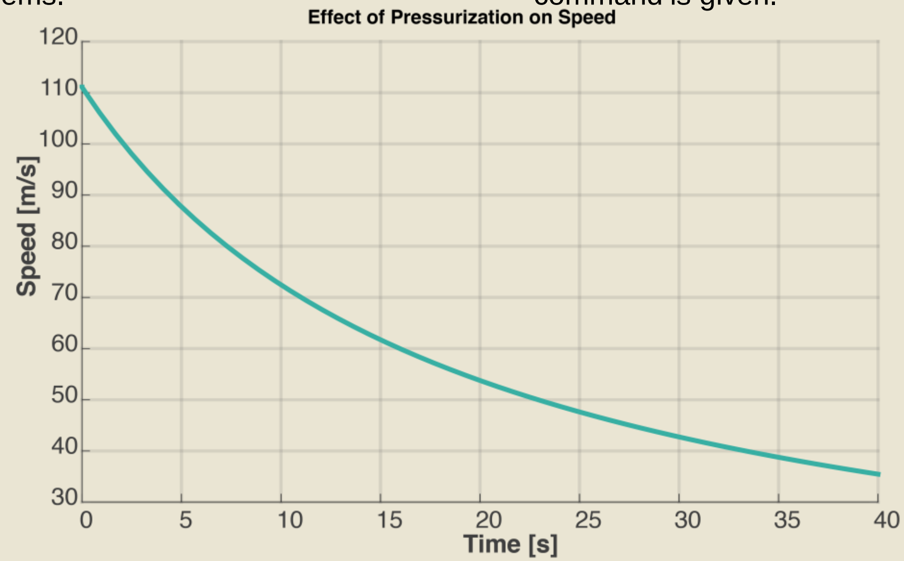
Full scale pod implications
It is important to note: at a speed of 1040 km/h, the friction heat dissipated will equate to roughly 35 MW requiring a temperature difference of more than 2000 °C. Although radiative heat loss will significantly reduce temperature, it is necessary to design the pod with a space grade heat protection shield and install radiator panels to maximise these heat losses.

No single point of failure

Our main design concern is avoiding single point of failure. Thus, our design utilises multiple air bearings, backup battery, a passive braking system and pressure vessel to ensure a safe finish after encountering any problems.

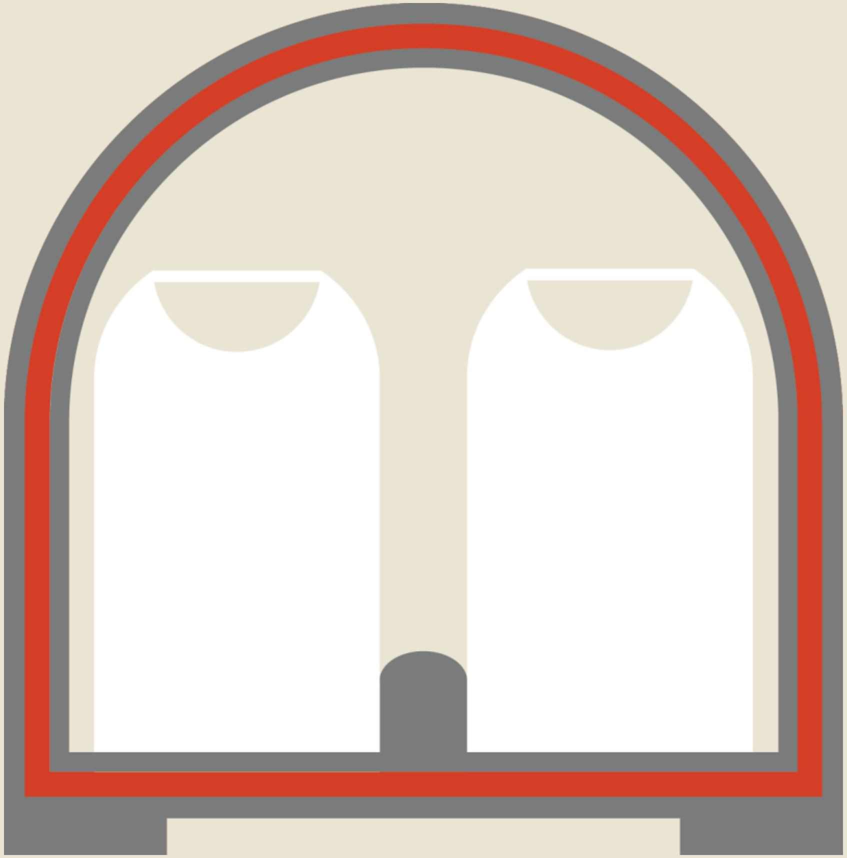
Passive braking system

In order to ensure stopping of the pod in any failure mode, the braking system is fully independent of the electricity. Brakes are activated automatically when electricity is absent or when the appropriate command is given.



Insulation layer

For passengers' safety and comfort



Material choice

The decision was made to use Fiberglass batts insulation layer between the shell and passenger module. Material density is about 16 kg/m^3. With the width of the passenger part being 1 m and the length 4.3 m with a layer thickness of 3 inches, the total amount of material needed is 44.43 kg.

Vibrations

The layer separating the passenger compartment from the rest of the pod will be designed to reduce vibrations which can propagate from the compressor and other electromechanical systems.

Temperature insulation and noise level reduction

The air bearings and compressor are the main source of noise. The pod will use the same technology as the automotive industry: dual purpose noise and temperature isolation foams. The three inch layer thickness is primarily used for noise reduction and should be sufficient for thermal insulation. The outer layer will be in close contact with high temperature parts, so inflammable Fiberglass batts are employed to counter this. Furthermore, batteries are stored outside the passenger capsule so in the event of a fire or system failure: toxic fumes will not affect travellers.

Wheels for service propulsion

In case of total power loss or emergency braking, pod will get you to the safe place

Steel wheels for support

For speeds up to 400 km/h with the aluminum track, steel rail wheels are a valid solution for the braking and service propulsion mechanism. During the journey wheels are hidden: in case of emergency braking, total loss of power or sudden need to transport the pod to a safe place: it would stand on supplied wheels. The number of wheels is dependent on the construction of the chassis and placement of air bearings. Radius of wheel was determined to be 0.20 m which would result in 5300 RPM at 400 km/h speed.

Service propulsion

In case of emergency, wheels are the basis for transporting the pod to a safe place. Front and back wheels are equipped with the 15 hp motors (total power) which supply enough power to transport the pod at speed of 30 km/h. In order to cover 10 km, an independent battery with power of 3.5 kWh is required.

Holding system

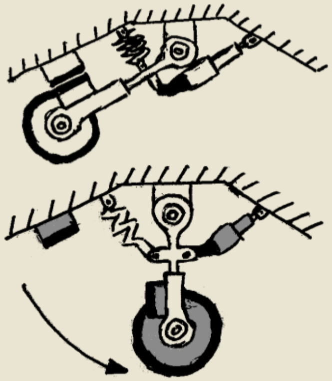
The proposed wheel mechanism relies on a 'holding system' connected to the main power supply. Where the power supply fails the holding systems also stops functioning. It is currently assumed that either interacting electromagnets or a simple actuator-pin system will be used to hold the wheel in place.

Spring and damper

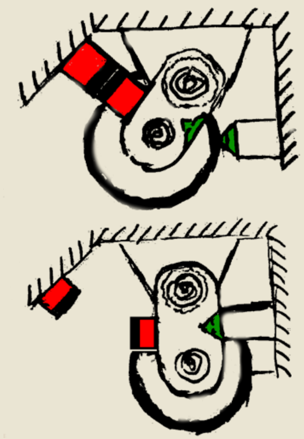
Upon release of the wheel arm from it's initial position, a pre-compressed torsion spring will cause the wheel arm to rotate from its storage position to it's activated position. Some kind of rotational damping device will also be required to prevent it from uncontrollably accelerating/coming to a sudden halt.

Spring loaded clip

Once the wheel arm reaches its final position a spring load clip will lock the wheel in place. This will prevent the wheel arm from moving under the capsules large weight and thus deter grounding from occurring.



Wheel mechanism with spring and damper



Wheel mechanism with holding mechanism and spring loaded clip

Wheels as braking mechanism

Different types of braking combined for energy recovery and reliability

Disk brakes

Conventional disk breaks will be used as the primary breaking system due to their good reliability. Four disk brakes are attached to each wheel and activated once braking procedure is initiated. When braking from a speed of nearly 400 km/h, the required diameter of brakes is 35 cm with a thickness of 50 mm. Assuming the initial brake temperature is 20 °C, disks will reach 577.8 °C to stop the capsule. For speeds above 400 km/h eddy current brakes should be used.

Preventing slip

In order to prevent slip from occurring between the wheels and the tube floor, the wheels will be mechanically accelerated to the required rpm.

Regenerative brakes

In addition to conventional clamp brakes our team will use regenerative brakes with two 60 hp alternators. This will help decrease the power dissipated as heat on the disk brakes which in case of braking from maximum speed would reach a temperature of 638 °C without an alternator.

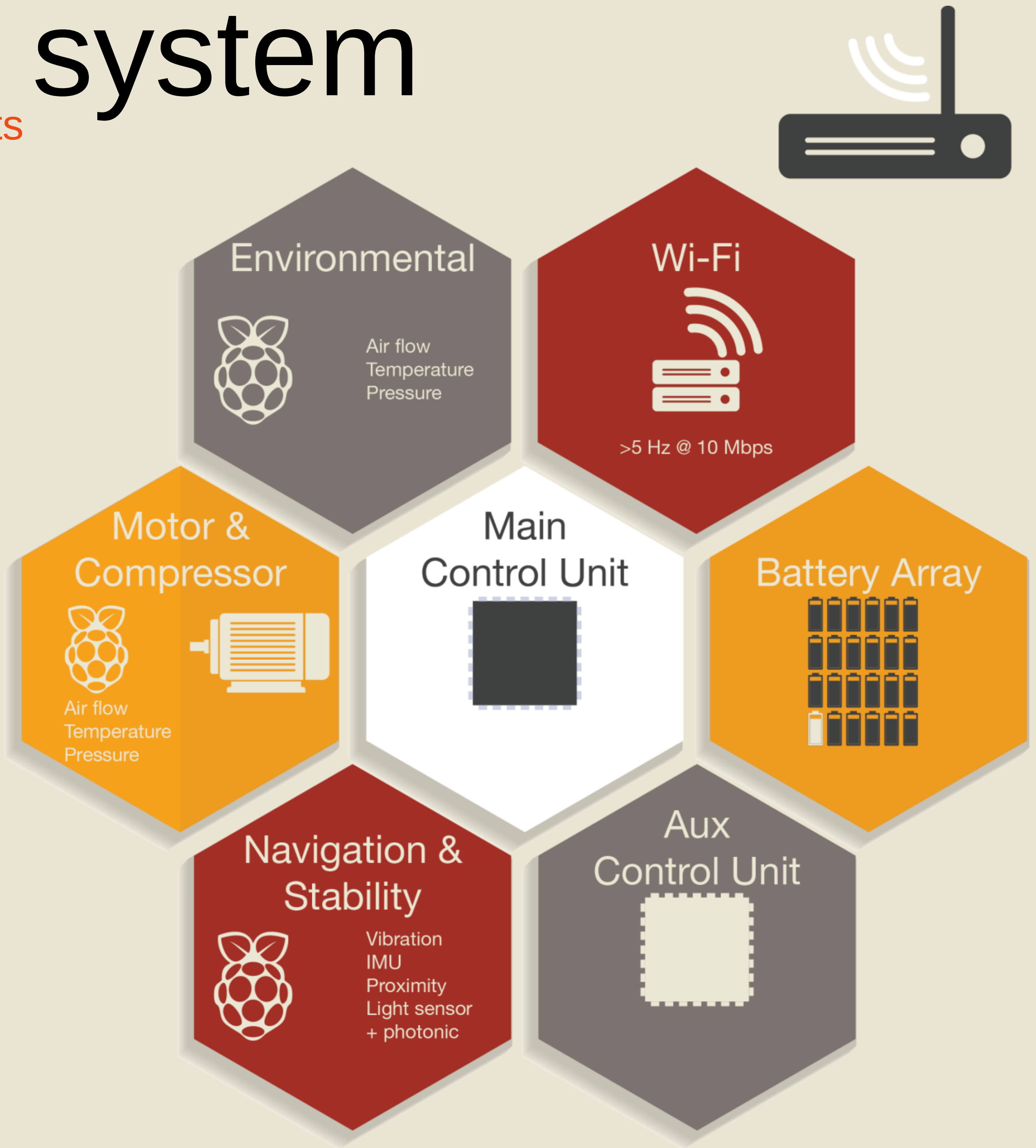
Eddy current linear brakes

Quiet, frictionless, wear-free, and require little or no maintenance, braking force is directly proportional to speed, heat dissipated through the large surface area of the rail and not concentrated on disk rotors. These brakes would also be enclosed in protective cages in order to minimize the interference between the electromagnetic field generated while braking and sensors/communication operation. During the competition we don't expect to reach speed above 400 km/h, however we propose this solution to be utilized in the full scale pod, for slowing down from maximum to medium speeds, then the wheel brakes would take over.

Electrical system

Layout of main components

An overview of the electrical system, all the essential performance and environmental data will be read in with microprocessors such as Raspberry Pi, which is then sent to the main control unit. After handling the data, it then sends the stream through Wi-Fi to the control centre to be further manipulated. Battery array will provide DC power, which is converted to AC, and supply the whole electrical system. An auxiliary unit will be separated from both the control unit and battery, which will switch on in case of emergency to maintain basic functionality.



Control

Control system hierarchy and main concepts

Sensors report to Raspberry Pi's, which send the data to main Intel i7 processor based unit. Finally, data is then sent to the control centre through Wi-Fi (>5 Hz @ 10 Mbps).

Algorithm

PID Negative feedback: the main proximity unit will assure stability from IMU and proximity sensors by using the aluminium rail and track as a referencing point. Sensor readings are constantly monitored and PID (Proportional Integral Derivative) control loop is carried out for each subsystem. This loop ensures the active parts of the subsystem get triggered in time.

AUX

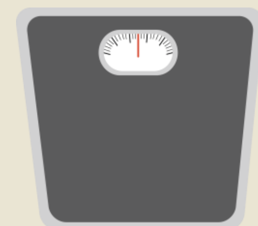
The auxiliary unit will be activated in case of main unit failure, which controls the service propulsion and essential communications.

Navigation

The reflective tape lines on the ceiling of the tube provide a reliable method of measuring both the speed of the pod and determining its location within the tube. This approach is achieved by shining red LED's up to the ceiling: catching reflections and observing their amplitude. In the full scale design, if the tube utilizes multiple Wi-Fi access points, a more accurate location of the Pod could be determined using Wi-Fi triangulation.

Power

Battery specification and usage



Batteries

Lithium-ion battery @ ~240 Wh/kg (technology trusted by Tesla). They will be arrayed at the rear end of the pod. 95% of power will be allocated to the main batteries, 5% will be used as a backup and isolated for emergency.

Power path

Power comes from the battery in form of DC, then it is branched out into two separate sets of power converters – DC to AC converter provides AC power to main motors, whereas the DC to DC step down converters supply all the remaining devices, such as the processing units, interior comfort systems etc.

Batteries size

Maximum of 30 min service time requires around 160 kWh, resulting in a battery pack (cells, coolant and circuitry) weighing around 1100 kg, with estimated volume of about 2 m^3.

Levitation system

Options, evaluation, Choice

We evaluated the three most popular types of contact with ground for operational propulsion and found that the air bearings will be the best and the most economical solution if our design should scale up to full size and subsonic speeds.

Air Bearings

No friction/contact
Minimal wear, relatively simple technology
Good stiffness and damping
Large are needed to lower compression rate
Incorporation into shell possible
Air flow makes aerodynamics more complex

Wheels

Tried and trusted
Rotation speed need large wheel diameter
Stiff, but can't absorb damping
Safe method
Negative effect on aerodynamics

Mag-Lev

No friction/contact
Propelling potential, but complex
Good stiffness and damping
High cost and lower efficiency
Easier than air bearings, can be incorporated well into design

Flat Plate

Precise, simple design
Very small air gap [µm]
Increasing gap = higher flow rate or less loading
µm air gap

Porous Surface

Graphite; long life time
No hole clogging
Needs clean & dry air

Very small air gap µm

Micro Nozzles

Precise machining
Hole clogging
Clean & dry air

Very small air gap in µm

Air Caster

Hovercraft type
"Dead volume"
More complex

Greater air gap

Conclusions

The above methods have been tested at high accelerations, such as fast moving machinery, but rarely exceed velocities of 50 m/s. The necessity for a very flat surface is a need for all types of air bearings, less for air casters as they can adapt with their air cushion. Especially the first 3 devices have a high stiffness. However, it is unclear in this early stage if a sudden bump would lead to the surfaces touching leading to catastrophic failure, the same accounts for the air caster. However, the skirt would deform and minimal wear would ensure from surface changes.

Air bearings in more detail

Our levitation system

Hovercraft-type air bearings

Our design utilises hovercraft-type air bearings as they offer low friction, little wear and good stiffness/damping whilst being a highly innovative design. The issue is to maintain the air flow at a reasonable air pressure in a low pressure tube at low speeds. In case of loss of pressure from the compressor, air bearings will use a backup air tank which can provide air for 60 seconds of operation (until wheels are deployed). A flow rate at 0.14 m^3/s at a pressure of 20 kPa maintains levitation of the pod at mass of 3000 kg. The total mass of the air bearings is 75 kg.

Custom air bearings

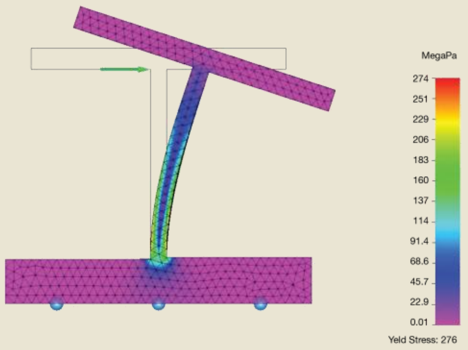
We would like to design custom air bearings which can withstand higher stress and temperatures. Since the technology is well established, we will draw heavily from existing technologies (Airfloat, Air Caster Corp, Aero Go, Hovair, Solving, Vertex & Aerofilm Systems) and will adjust the design to our needs (i.e. increasing skirt temperature resistance to use of special elastomers by DuPont).

Suspension system

Suspension system will be based on air bearings grouped in assemblies of four, each with a load carrying air cushion and set of dampers. The air cushion can potentially tilt the body in order to keep the accelerations acting on passengers smaller.

Floor plan

Rail Guidance and stability

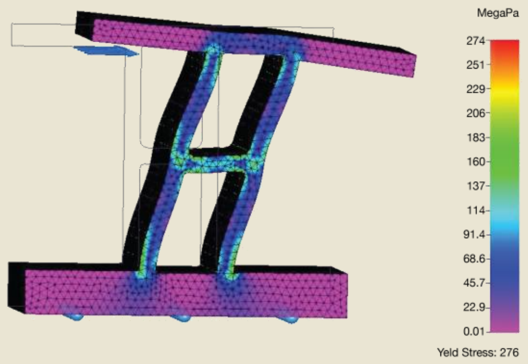


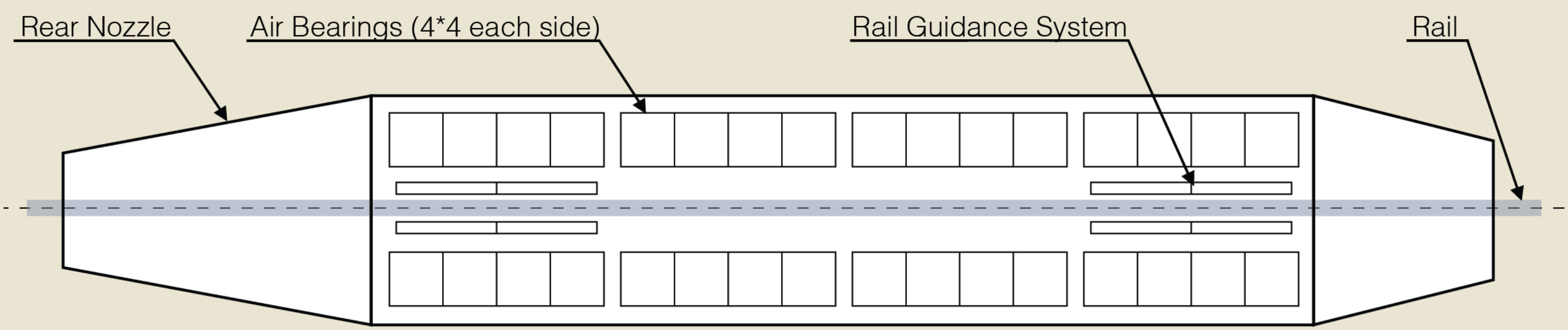
Rear nozzle as a stability mechanism

The rear nozzle does not generate enough force to aid steering of the pod, but the mechanisms success lies in dampening vibrations. The rear nozzle will be controlled via PWM signals and is active in both vertical and horizontal directions, thus counteracting pod displacement in any direction. Mode of operation is very similar to a rudder in a ship and force is generated from changing the directional flow of air.

Rail guidance system

Having run simple FEA test on the rail provided, we developed a steering system that requires no active parts as it’s based on the pod being guided by the rail with a reinforced profile (yielded maximum force of 9 kN and 42 kN respectively), the latter being sufficient to support the pod cornering at high speeds.



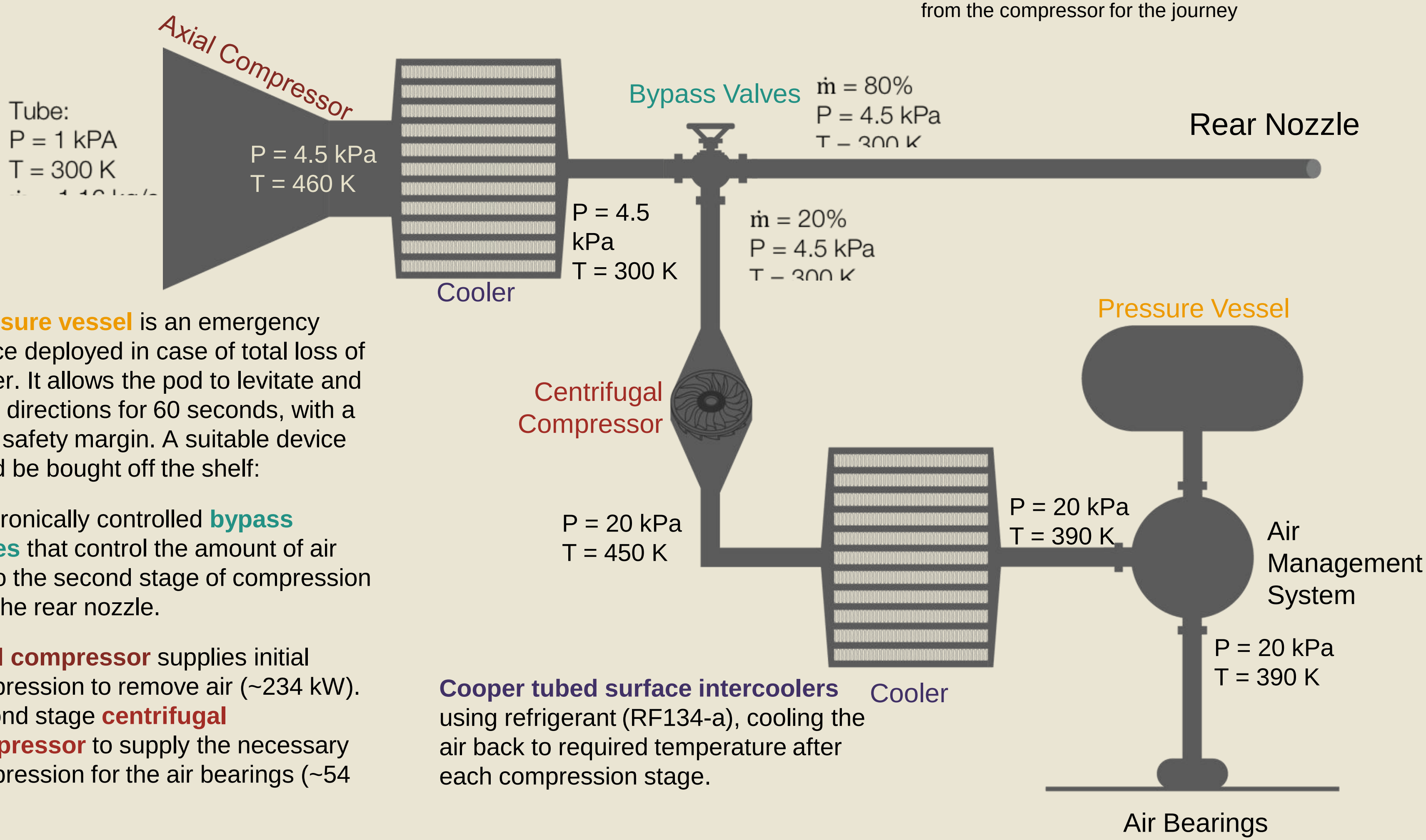


Air system outline

Flow management

Assumptions:

Ambient pressure 1 kPa
Ambient temperature of 300 K
Axial compressor efficiency: 0.8
Centrifugal compressor efficiency: 0.7
80% of the air is bypassed
Isentropic behaviour of air in the compressors
Coolers cool the air to 300 K/390 K
The pressure vessel acts as emergency reservoir
Passenger compartment will not need an air supply from the compressor for the journey



Pressure vessel is an emergency device deployed in case of total loss of power. It allows the pod to levitate and keep directions for 60 seconds, with a 50% safety margin. A suitable device could be bought off the shelf:

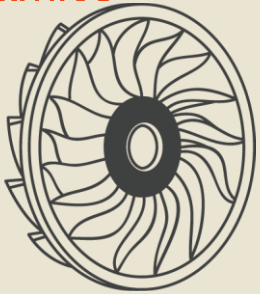
Electronically controlled **bypass valves** that control the amount of air fed to the second stage of compression and the rear nozzle.

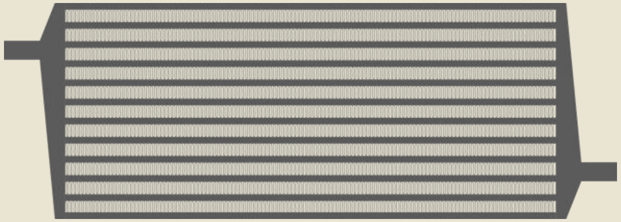
Axial compressor supplies initial compression to remove air (~234 kW). Second stage **centrifugal compressor** to supply the necessary compression for the air bearings (~54 kW).

Cooper tubed surface intercoolers using refrigerant (RF134-a), cooling the air back to required temperature after each compression stage.

Compression and cooling

Air thermodynamics





Compressor

The thermodynamic calculations are based on the model pod and according to our desired tube conditions 20 kPa is required for the hovercraft air bearings. The compression achieved from the axial compressor can be increased by adding more rotary stages. Higher pressure is needed to obtain the necessary scaling for the full sized passenger pod. The axial and centrifugal compressor possess the same pressure ratio as the system is cooled back to inlet temperature before entering the second compressor.

The compressor is crucial for the full sized pod to remove air from the front of the pod at near sonic velocities. Yet using a compressor in our model pod is unfeasible. Thus it is placed in a model and operational during the competition for demonstration purposes. The emergency air storage tank installed in our pod will be sufficient for such small distance (competition flight will last less than 1 minute).

Intercooler

The system requires two intercoolers to reduce the air temperature leaving the compressor. Both will be built using the same technology (surface intercooler, concurrent flow, pipes with fenders) and use refrigerant R134a as a working fluid (heating up from -50 ºC to 0 ºC). The anticipated required mass flow rate of refrigerant is 0.65 kg/s (total) and the mass is expected to be 294 kg and 34 kg. The second intercooler is required solely to reduce the temperature to 120 ºC, as the air bearings will be designed to be operational at these temperatures; small mass flow rate at higher temperature should not affect the overall temperature in the tube.

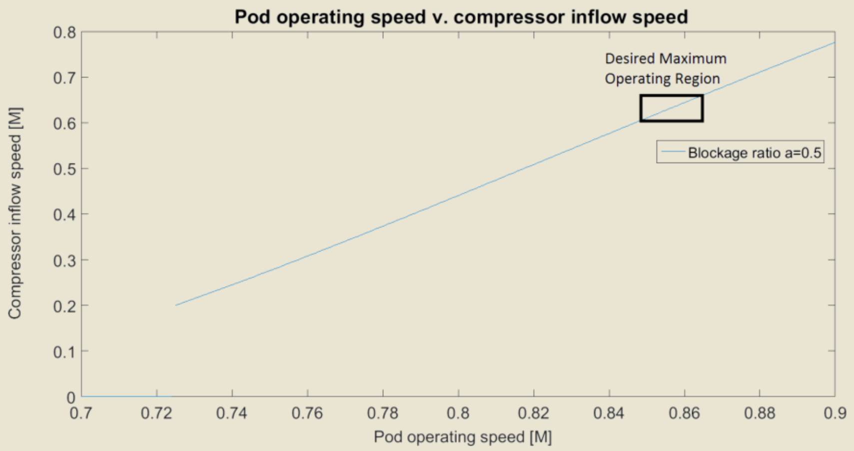
The low temperature R134a as the primary cooling system provides an added incentive which can be used to cool down the passenger cabin and other subsystems if required. Used up refrigerant will be stored in the back of the pod and removed at the station.

Cooling down the system by direct water injection was taken into account as steam at low pressure in the tube will never condense.

Shape optimization and air flow model

Design of aesthetically pleasing shape that ensures the fastest possible operational speed

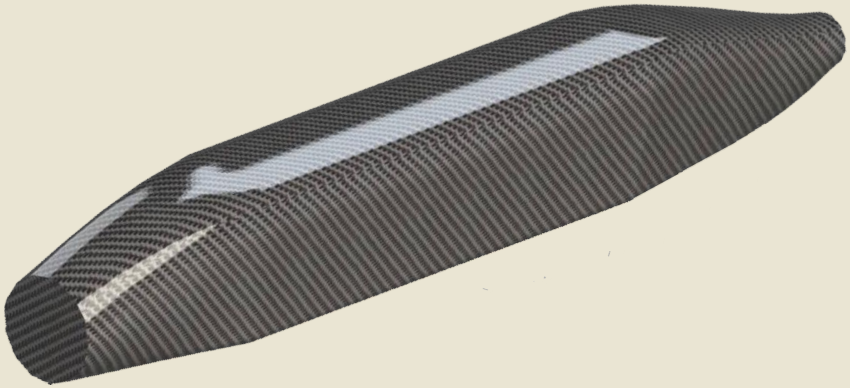
Kantrowitz limit problem is encountered at a much higher pod speed for a given blockage ratio if a compressor system is mounted in front of the pod, allowing some of the air to pass through it. This idea essentially finds an alternative solution to the Kantrowitz limit problem. Compressor system on the pod is similar to an aircraft engine compressor as they both operate at higher Mach numbers and in low-pressure conditions. For jet engines, the air incoming to the compressor must be subsonic as supersonic inflow would cause shockwaves and very large pressure fluctuations on the blades. The aim of the inflow velocity to the compressor should be below M=0.65. This can be achieved by adding a diffuser in front of the compressor. The interdependence of various areas, travel speed, bypass speed and compressor incoming speed then becomes complex, leaving space for major optimisation. The air flow model that we created addresses this problem. Below is a graph displaying the interdependence of the pod operating speed and compressor inflow speed for a designed blockage ratio of 0.5. The maximum operating speed of the pod was optimised to be M=0.85 reflecting in compressor inflow velocity of M=0.61



shell shape and Materials

Hyperloop skin

The choice of main structural materials was governed by a number of requirements. These include but are not limited to: great rigidity and tensile strength, fatigue resistance, fire resistance, low weight and low coefficient of thermal expansion. A material excelling in all above requirements is carbon-fibre reinforced polymer (CFRP). Other materials, mainly composite materials, will be used in the structural design, but it is currently approximated that up to 70% of the structure will be built using CFRP. Additional analysis of material suitability needs to be performed. The mass of the pod shell and truss structure is currently approximated to be around 800 kg.

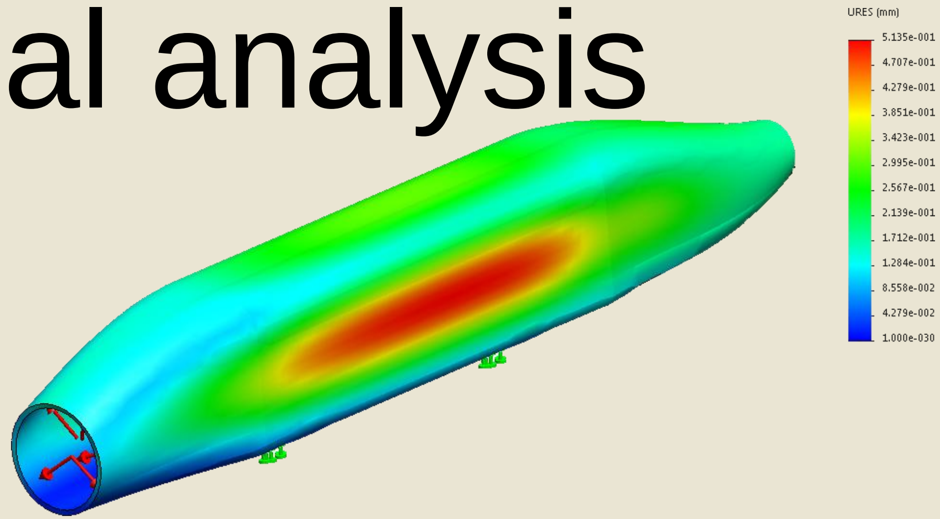


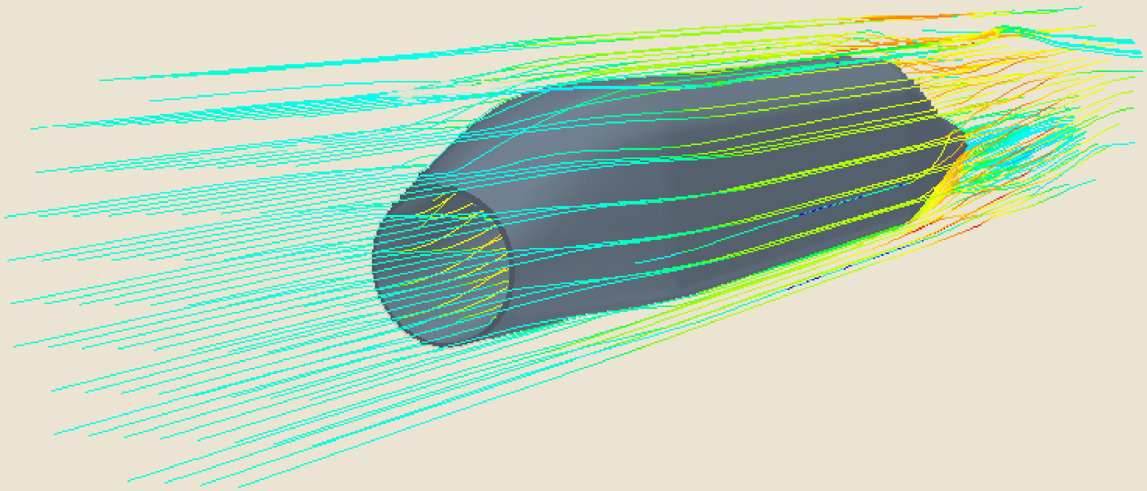
The aerodynamic drag of a train in a tunnel can be substantially larger than that of a train travelling in the open air. With regards to Hyperloop, tunnel aerodynamics is of a lot more importance than open air aerodynamics. Additionally, it is crucially important to understand the coupling between the pod dimensions and possible operating speeds, for a given tube size. Streamlined shape of the pod will significantly contribute to a reduction in aerodynamic drag.

Computational analysis

Crafting the shape

Finite element analysis was performed on the outer pod structure to visualise its behaviour in the given conditions. Pod was analysed as a pressure vessel due to the fact that pressure inside is greater than outside. Results showed how design could be optimised to withstand the loads and decrease the overall weight. Further improvements on outer shell shape are being investigated.





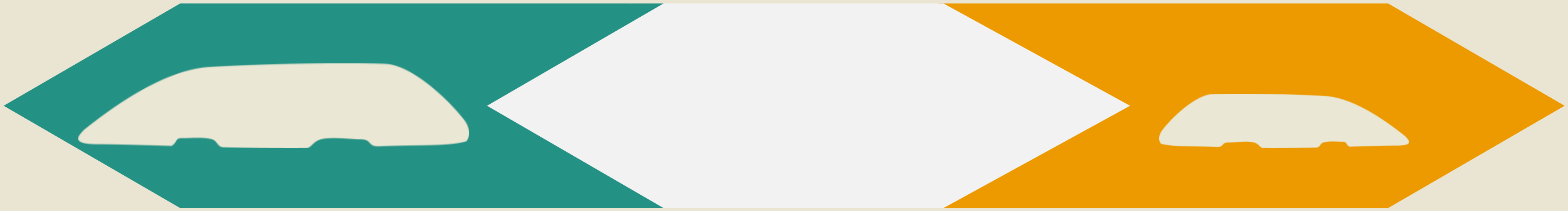
Preliminary CFD analysis was carried out for the designed shape and blockage ratio. To date, not all of the tube-specific conditions have been taken into consideration, resulting in high airflow velocities around the pod. The simulation will be improved to verify the assumptions based on the theoretical models.

Summary

Mass	800 kg
M_{bypass_max}	0.98
M_{pod_max}	0.85
$M_{comp\_inflow\_max}$	0.61
Blockage ratio	0.5

Design development

From blueprints to competition



Full scale

Our design, based around passenger experience and commercial introduction, allows **for easy scalability** into a complete full-size pod. Larger size increases space management efficiency, the wheels, air bearings, suspension, and passenger section walls **will not require increase in size**. A study on stretching the pod fuselage to **increase passenger capacity and per-passenger efficiency** is currently being conducted.

Competition

The competition design will be an adapted half-scale design, optimised for the highest possible performance on the test track. **Mass will be reduced to 1300 – 1700 kg** due to savings in the size of batteries and non-pressurisation of the passenger area. Pod will have no on-board propulsion as the team intends to utilize the pusher provided by SpaceX. Pod will be levitating on hovercraft-like air bearings, wheels used for service propulsion only. Non-pressurised passenger section will remain on the pod to **demonstrate payload capacity**. Structure will remain modular, allowing teams wishing to construct single pod components only to test their solutions on our **highly versatile platform** with the spirit of inter-team cooperation.

About us

We intend to attend the Design Weekend and build a pod for the competition

We are an interdisciplinary team from the University of Edinburgh combining the skills sets of the Engineering school with the School of Design.

THE UNIVERSITY of EDINBURGH

Past university experience:

Edinburgh Napier University, UK
Lund University, Sweden
McGill University, Canada
Nanjing University of Aeronautics and Astronautics, China
South China University of Technology, China
Technical University of Cartagena, Spain
University of California, Berkley, USA
University of California, Davis, USA
University of Pennsylvania, USA
University of Texas, Austin, USA

Our team members have successfully set up their own start-ups and worked in a range of industries for prestigious companies, such as Jaguar, Lotus F1 Team, National Bank of Poland, Diageo, Cirrus Logic, STMicroelectronics. Collectively we speak 14 languages. We are a group of passionate individuals working together to embrace this extraordinary engineering and design challenge.

Advisors:

Dr Don Glass
Dr Timm Krueger
Dr Frank Mill
Prof. Chris Speed
Mr Stephen Warrington

Team members:

Hirsh Agarwal
Matei Alexandru
Ion Antonakis
Adam Anyszewski
Ellie Carr-Smith
Gabrielis Cerniauskas
Jiamin Chen
Christopher Chong
James Davidson
Christophe Floreani
Jan Jaroszuk
Adam Kijowski
Bartosz Krol
Qingbiao Li
Ke Shin Lim
Katy Lobban
Inaki Baca Lopez
Justas Lukosiunas
Miguel Pozuelo Monfort
Lukasz Leszek Pietrasik
Poppy Pippin
Tim Putzien
Joseph Revans
Pawel Safuryn
Peter Vaculciak
Shuai Zeng
Christian Zeppetzauer

Summary

We are hyped, are you?