National Aeronautics and Space Administration

Conceptual Feasibility Study of the Hyperloop for Next-Generation Transport

NASA Glenn Research Center

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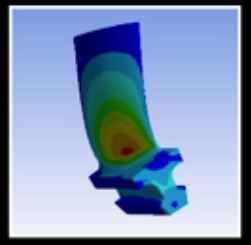
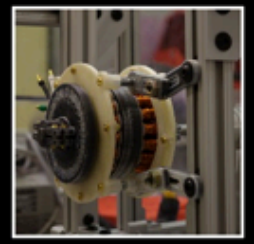
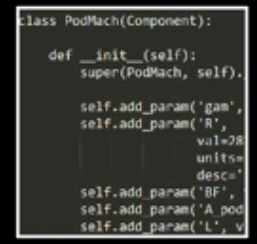
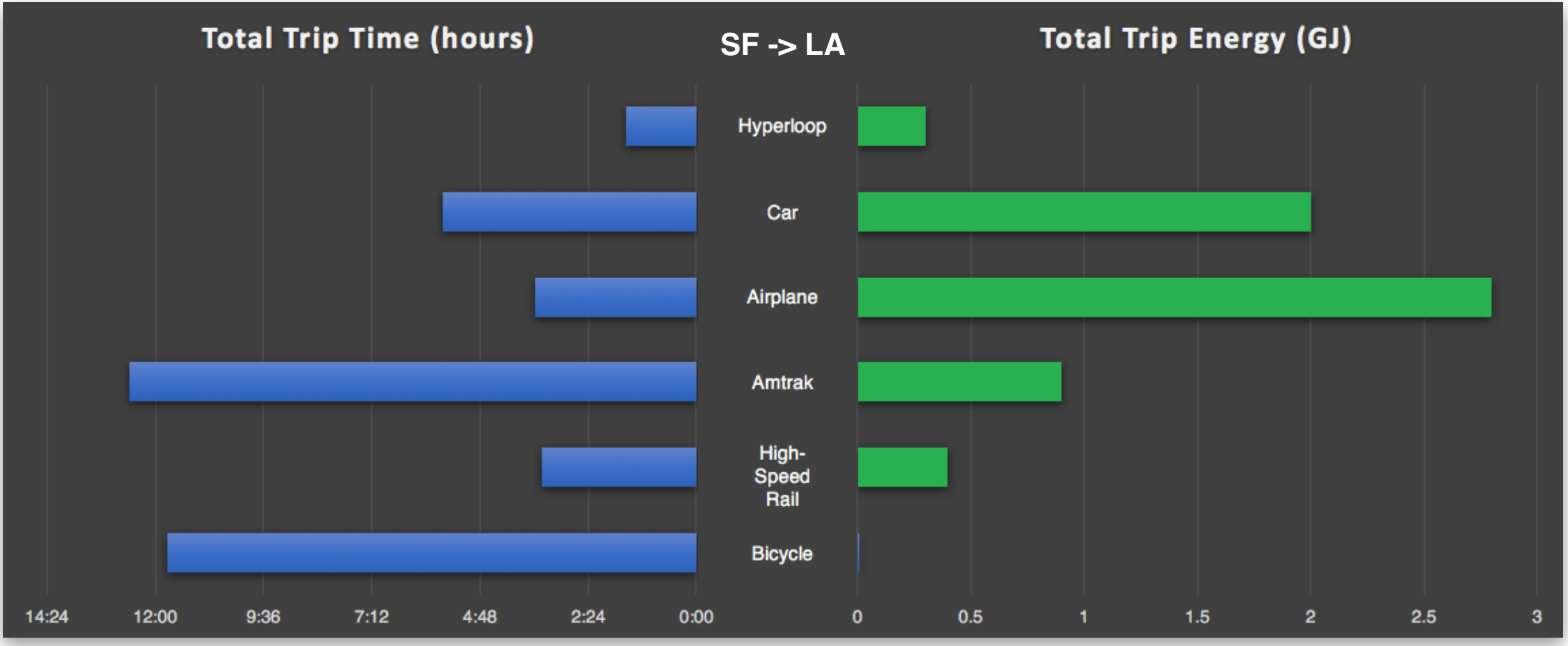






2016

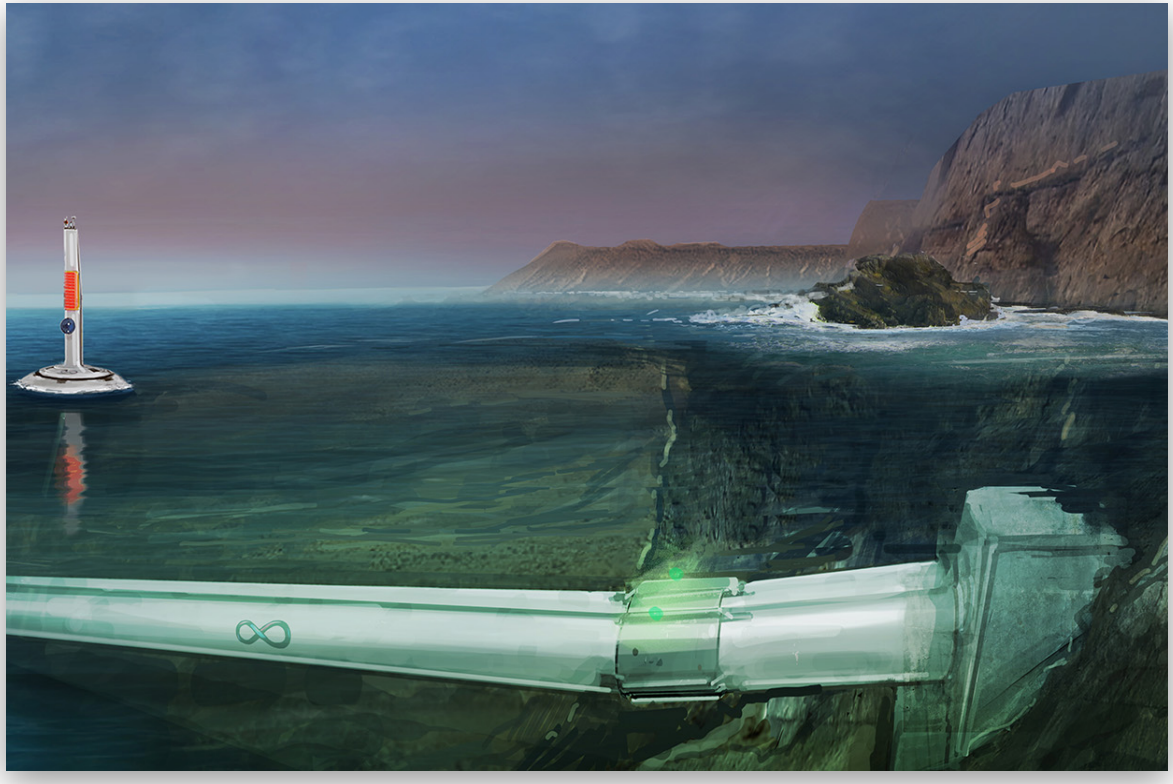
The Hyperloop is a zero-carbon transportation concept promising to be faster and cheaper than existing modes of transportation



[Popular Science 2015]

CONCEPTUAL FEASIBILITY STUDY OF THE HYPERLOOP VEHICLE FOR NEXT-GENERATION TRANSPORT

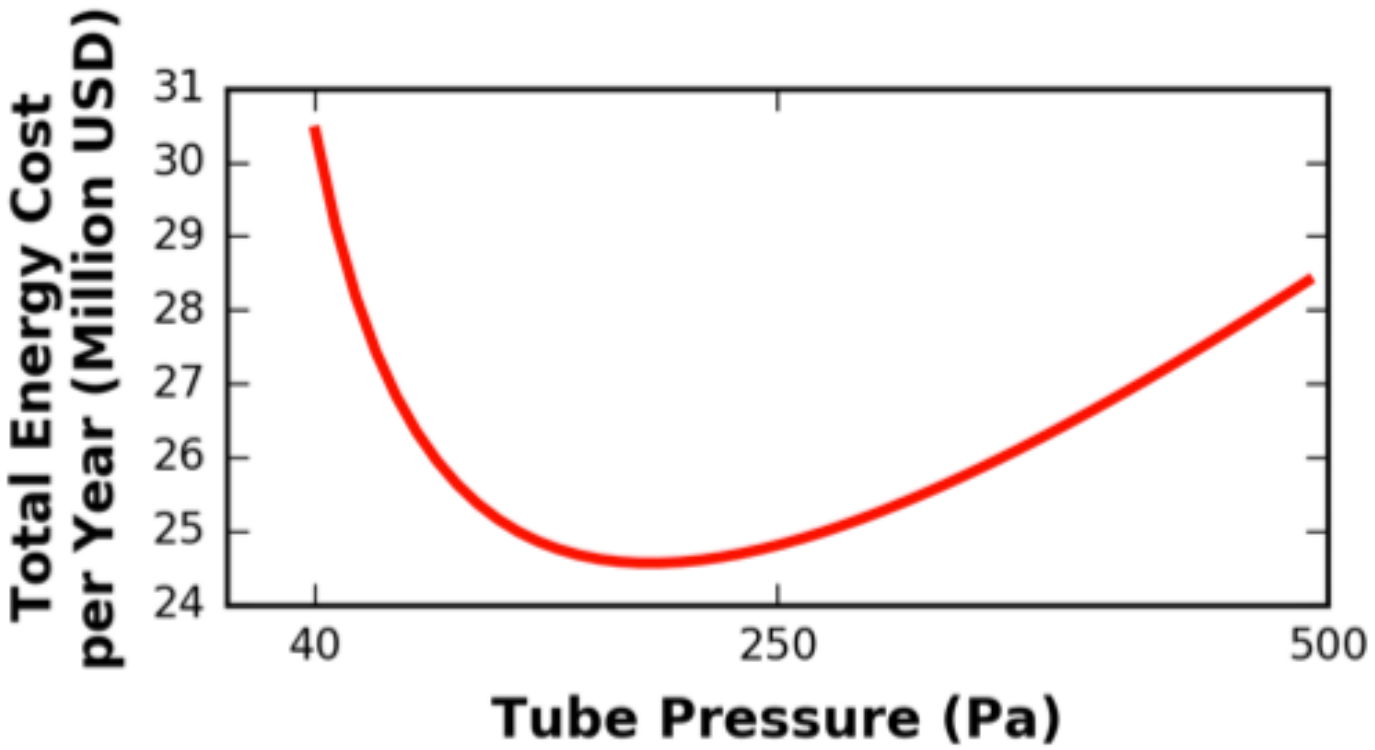
Underwater routes show some potential structural advantages when compared to over-land routes



[Hyperloop One 2016]

[Popular Science 2015]

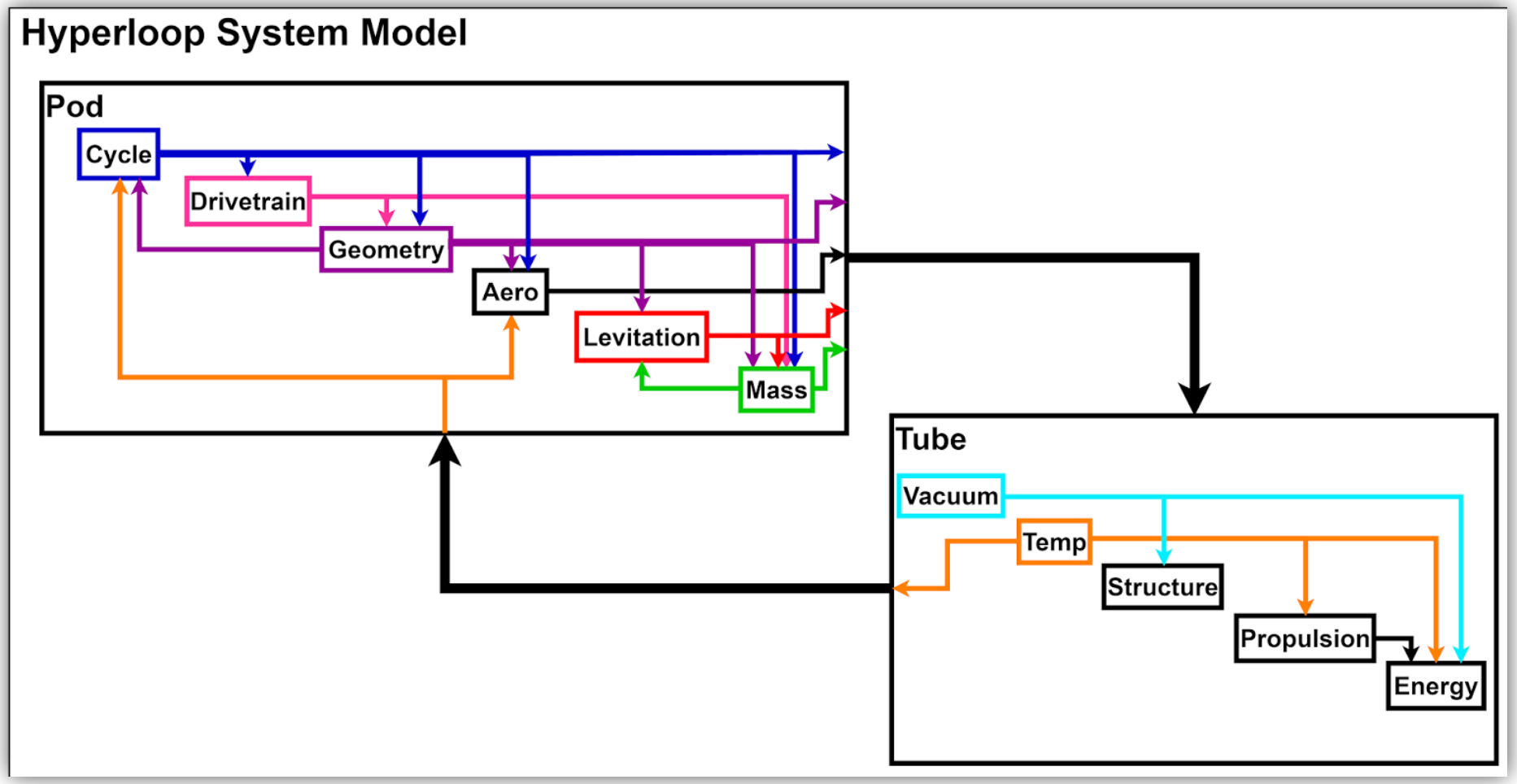
There is an optimal operating pressure for the tube that minimizes net energy usage



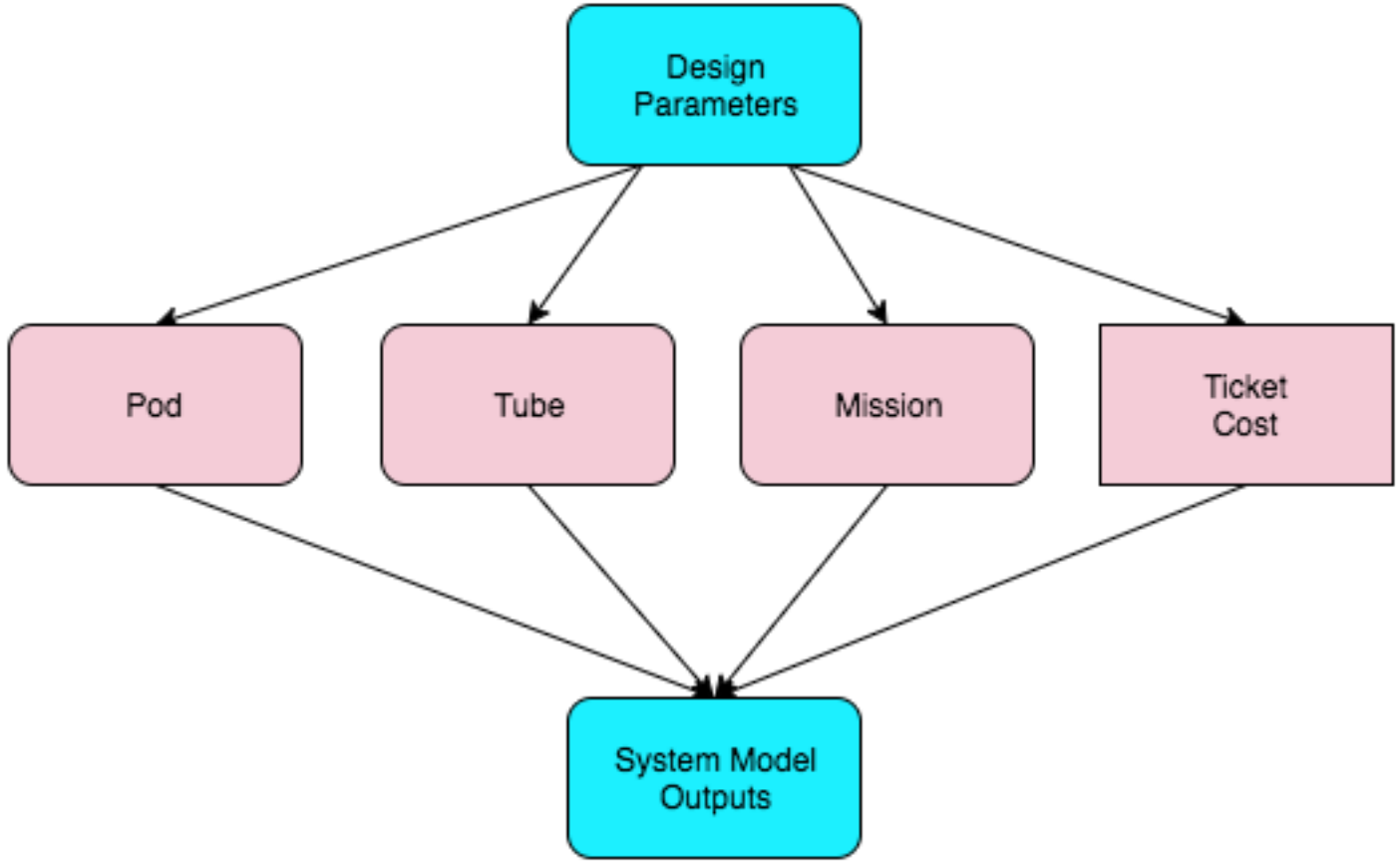
Overview

- **System Model**
- Trade Studies
- Looking Forward

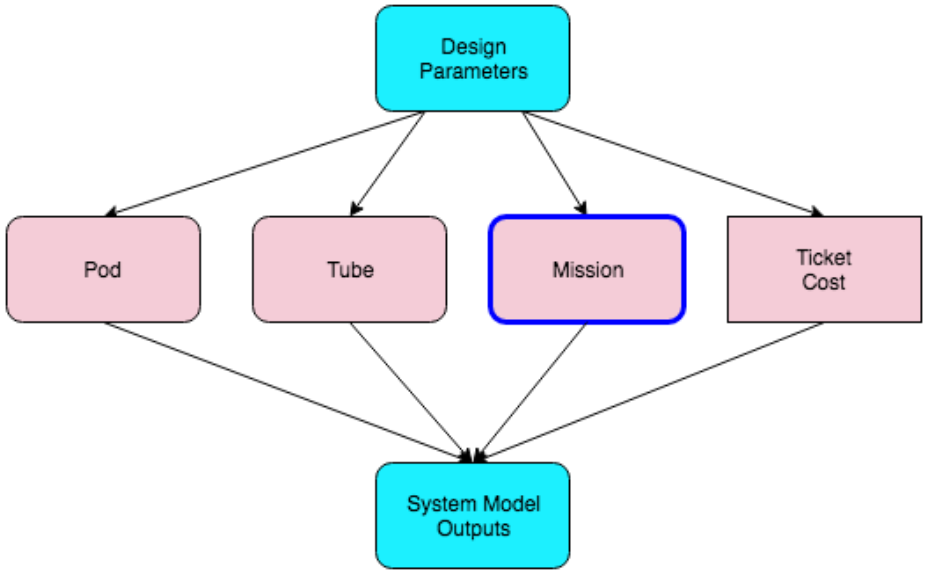
Using a system analysis model to conduct trade studies, we demonstrated the Hyperloop's technical and business feasibility



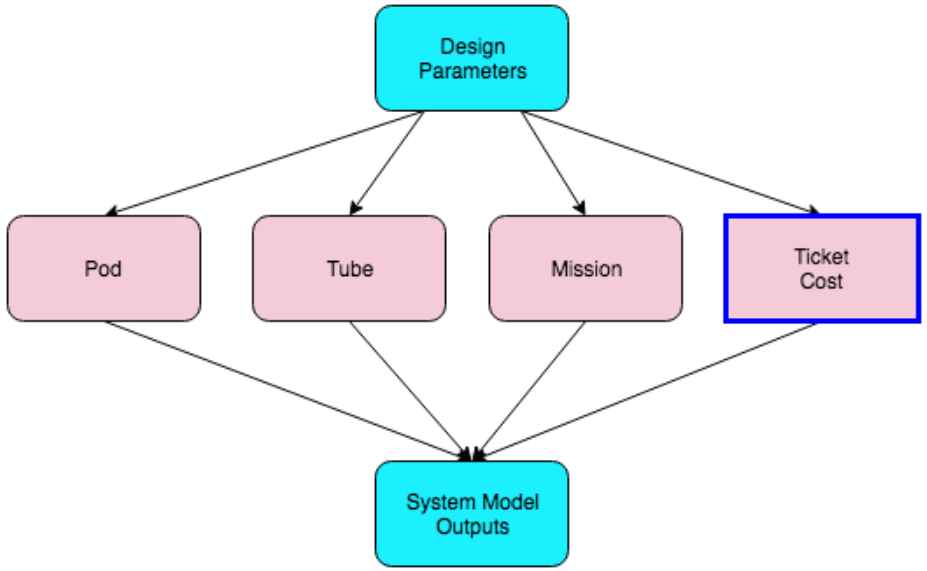
The full system model is broken down into 4 primary sub-disciplines



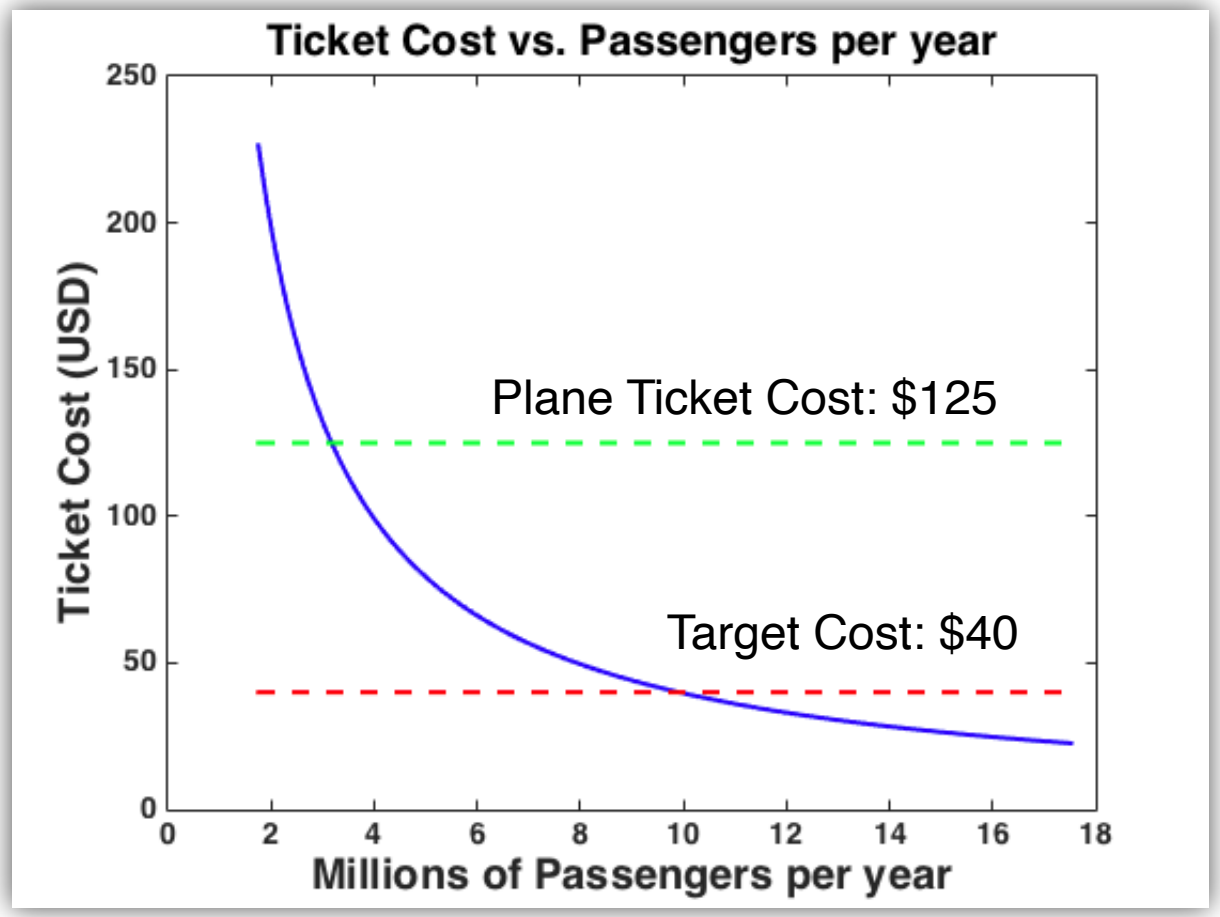
Mission: an explicit time integration of the pod traveling from SF to LA



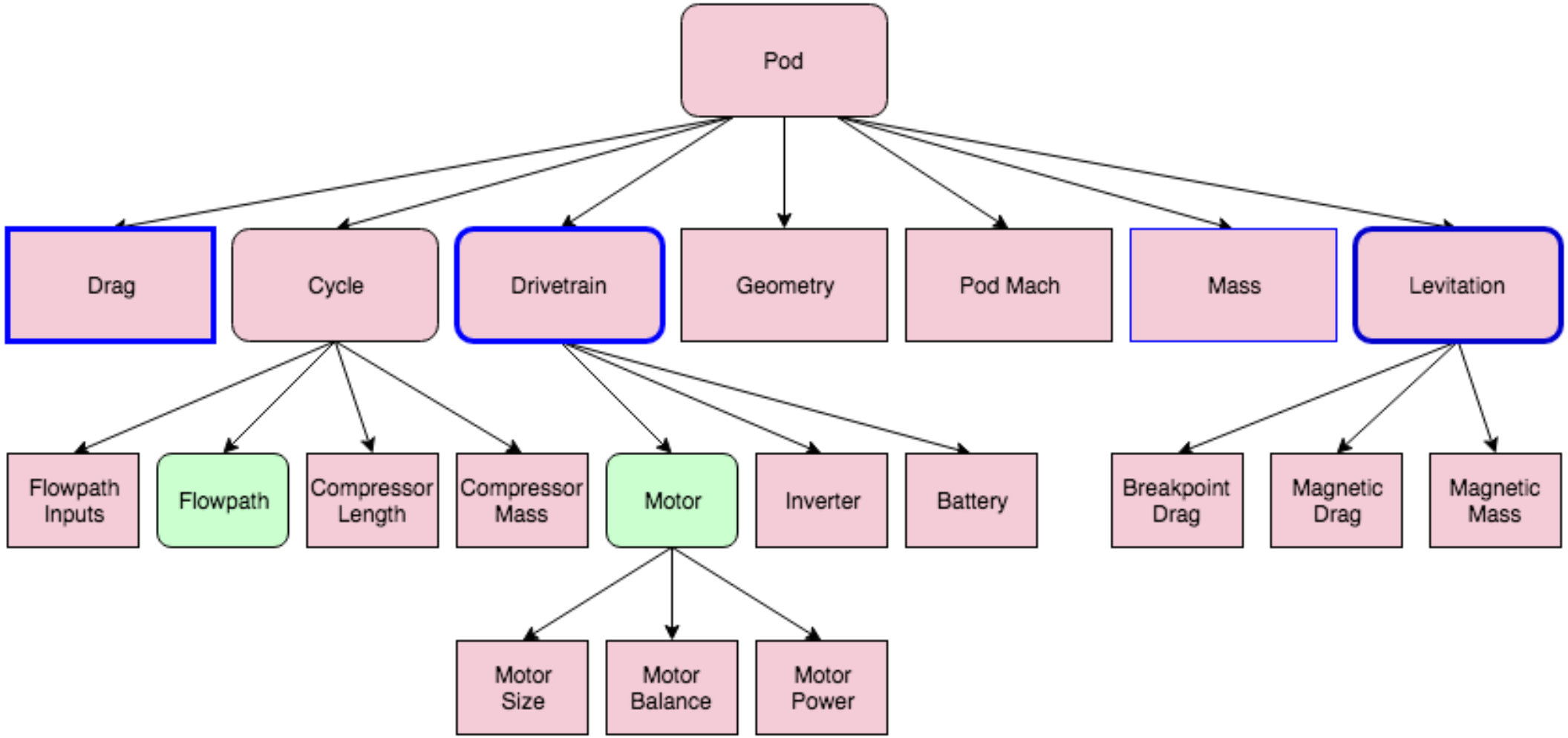
Ticket Cost: an empirical model that captures the relative effects of capital cost energy usage on ticket price



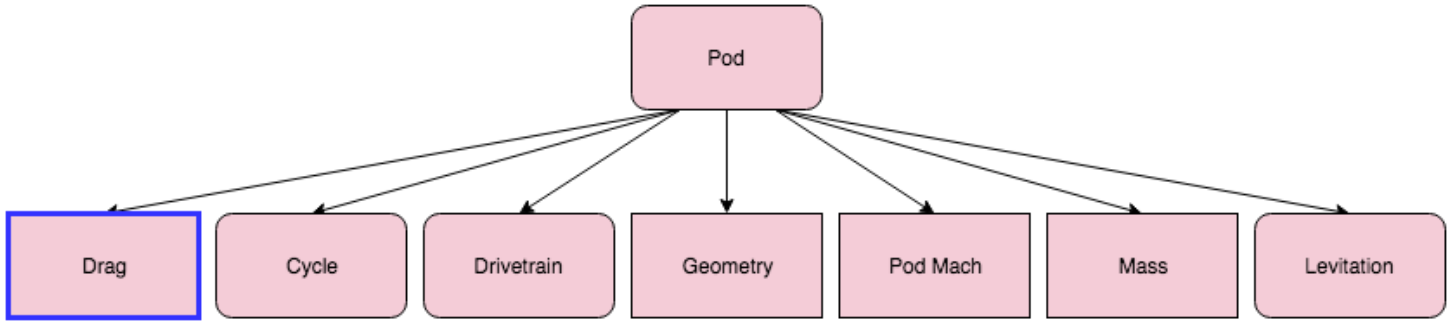
- The DOT predicts that at least 18 million passengers per year would use LA-SF transport

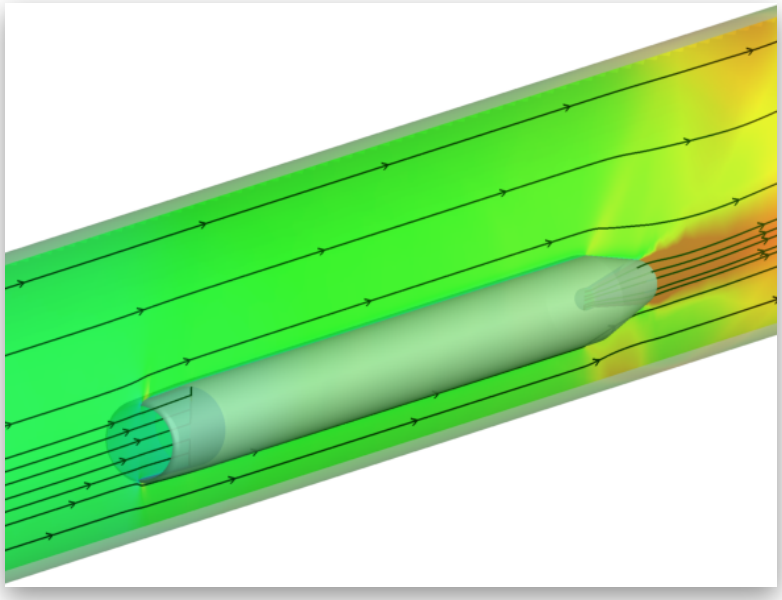


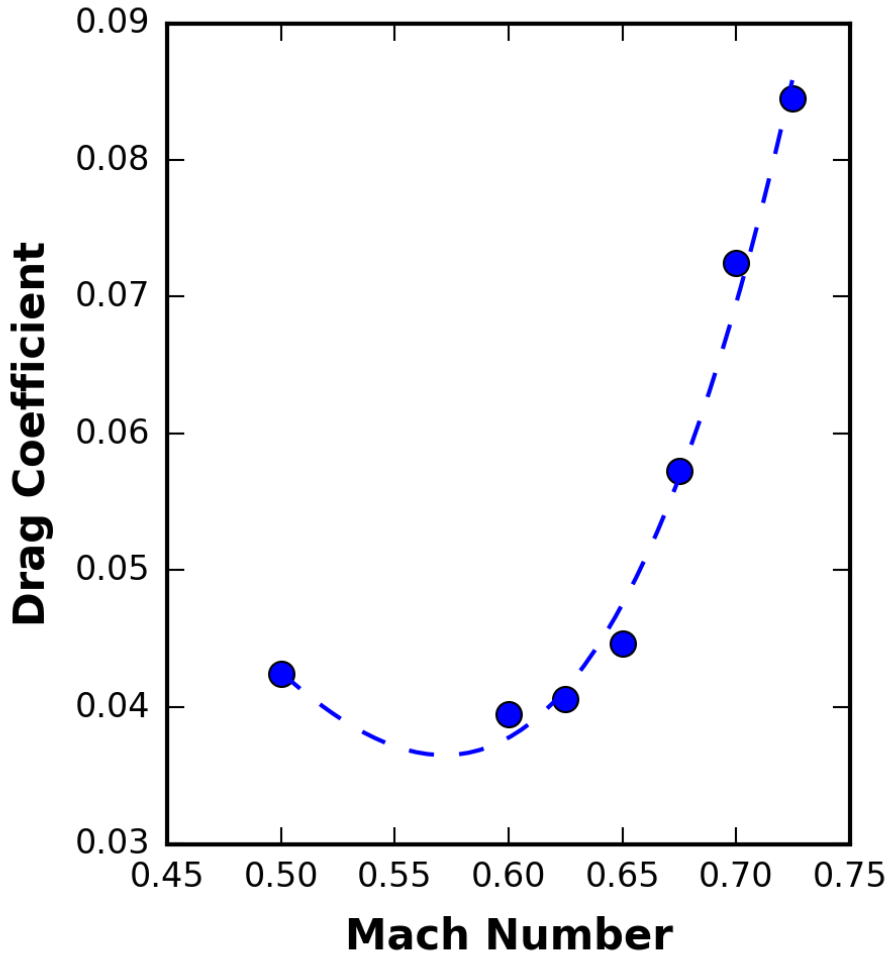
Pod: models subsystems associated with the passenger pod



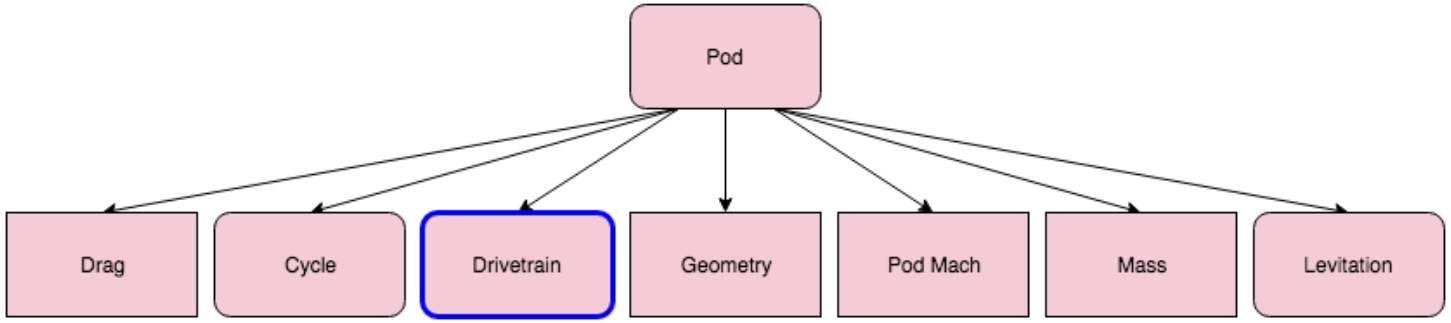
Drag: drag polar generated with RANS CFD simulations

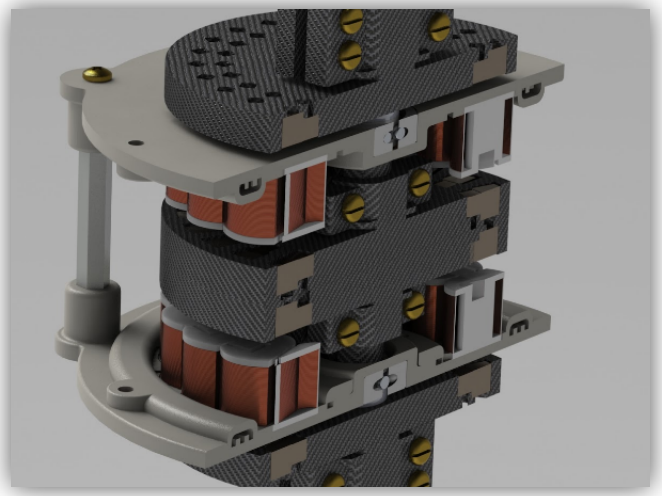


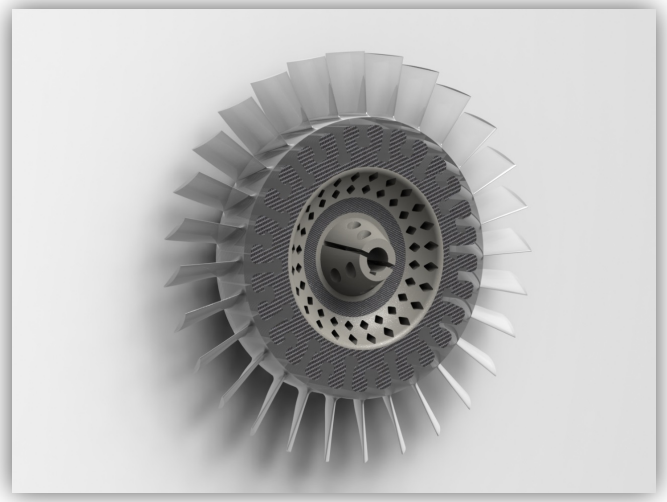


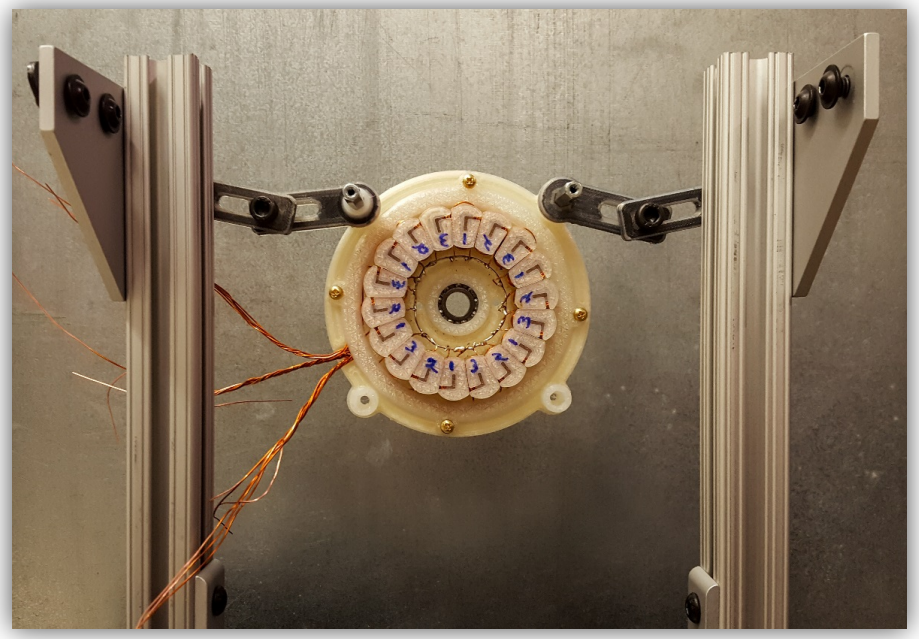


Drivetrain: characterizes the onboard motor, inverter, and battery using first principal electrical relationships and empirical models

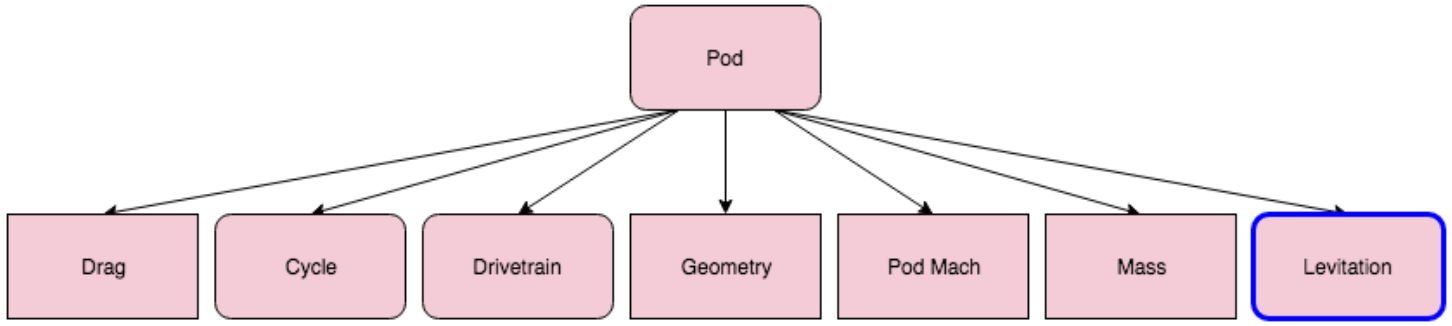


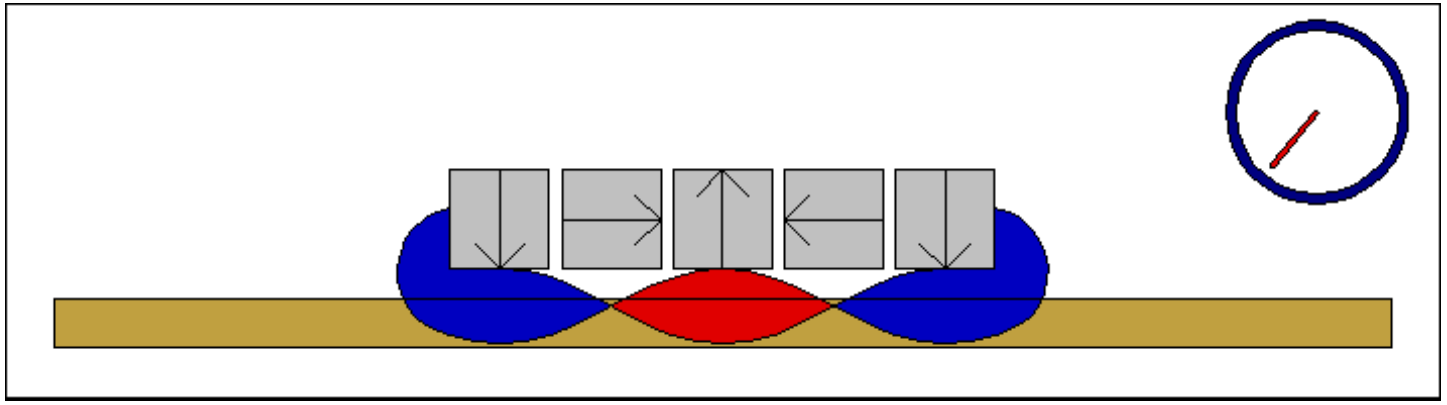






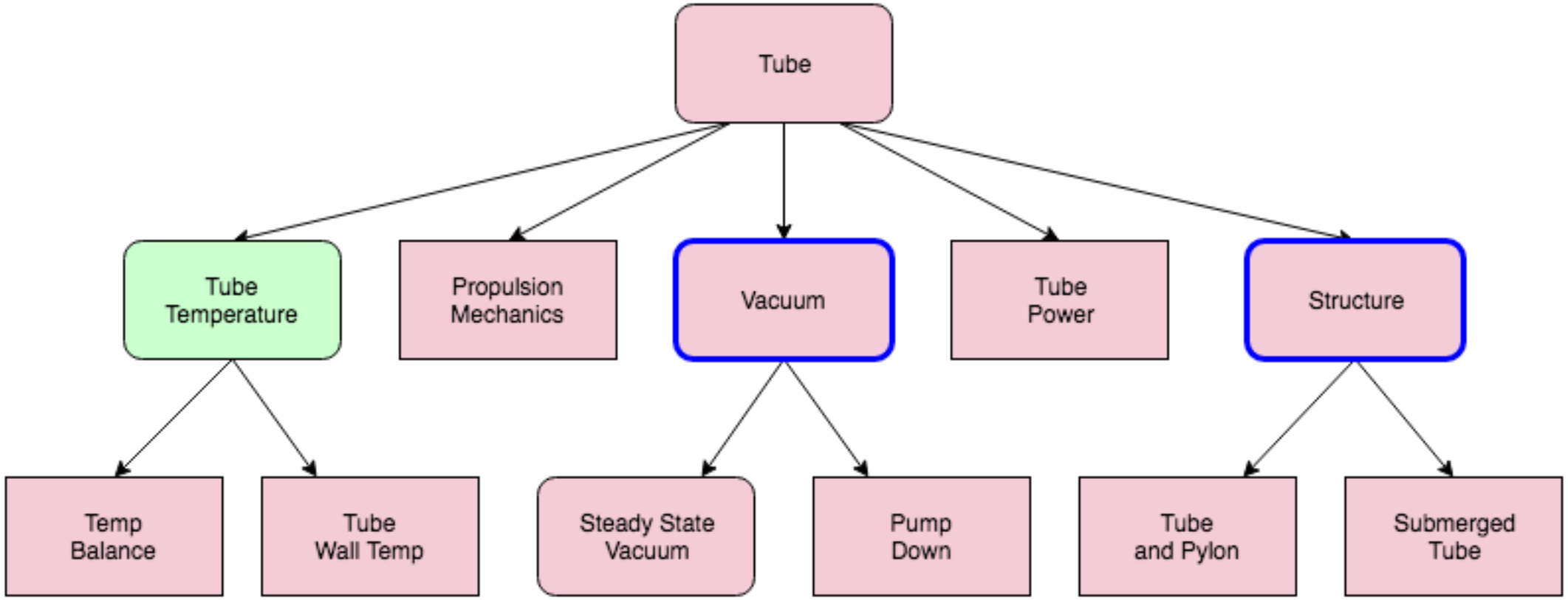
Levitation: computes the magnet mass and drag from the passive MagLev subsystem using 1st principal physics models



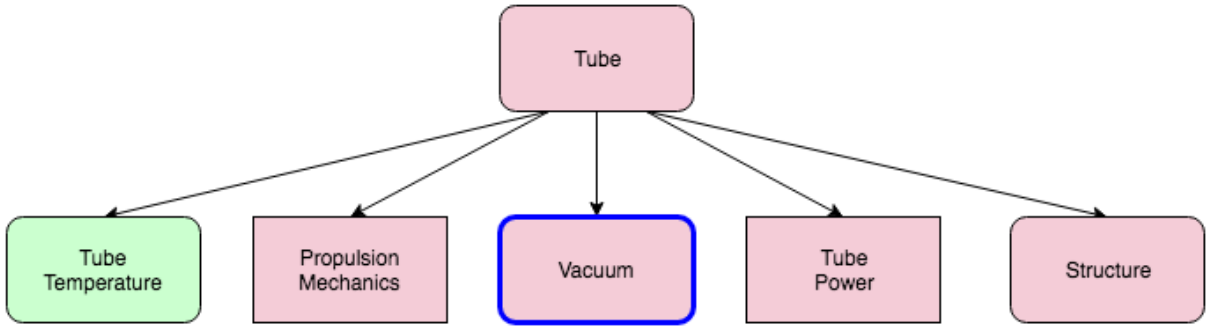


[Bradley University 2016]

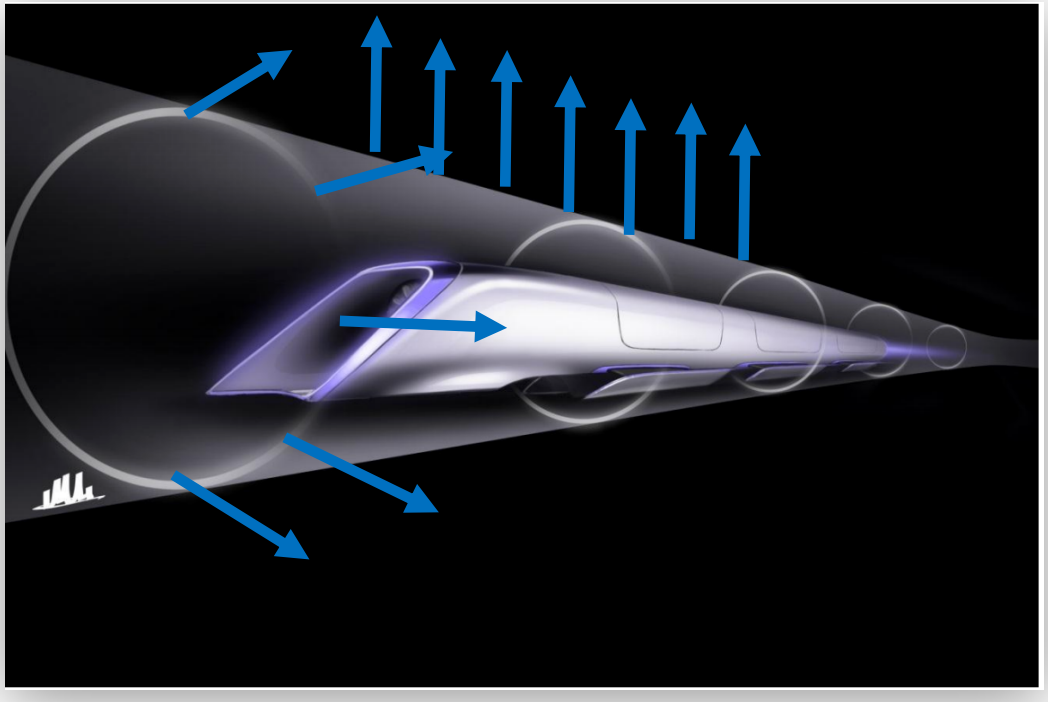
Tube: models subsystems associated with the travel tube



Vacuum: computes the energy usage for the pump-down and steady-state vacuum pump systems using 1D thermodynamics models

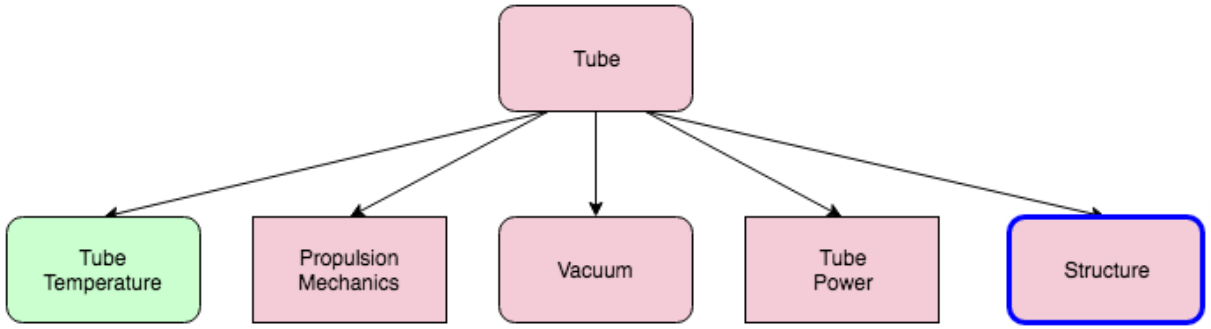


- Pump-down evaluates the energy required to drop pressure from ambient to operating condition
- Steady-state evaluates the energy required to maintain the operating condition



[SpaceX 2011]

Structure: computes the required tube wall thickness using beam and thin-walled cylinder analytic structural solutions



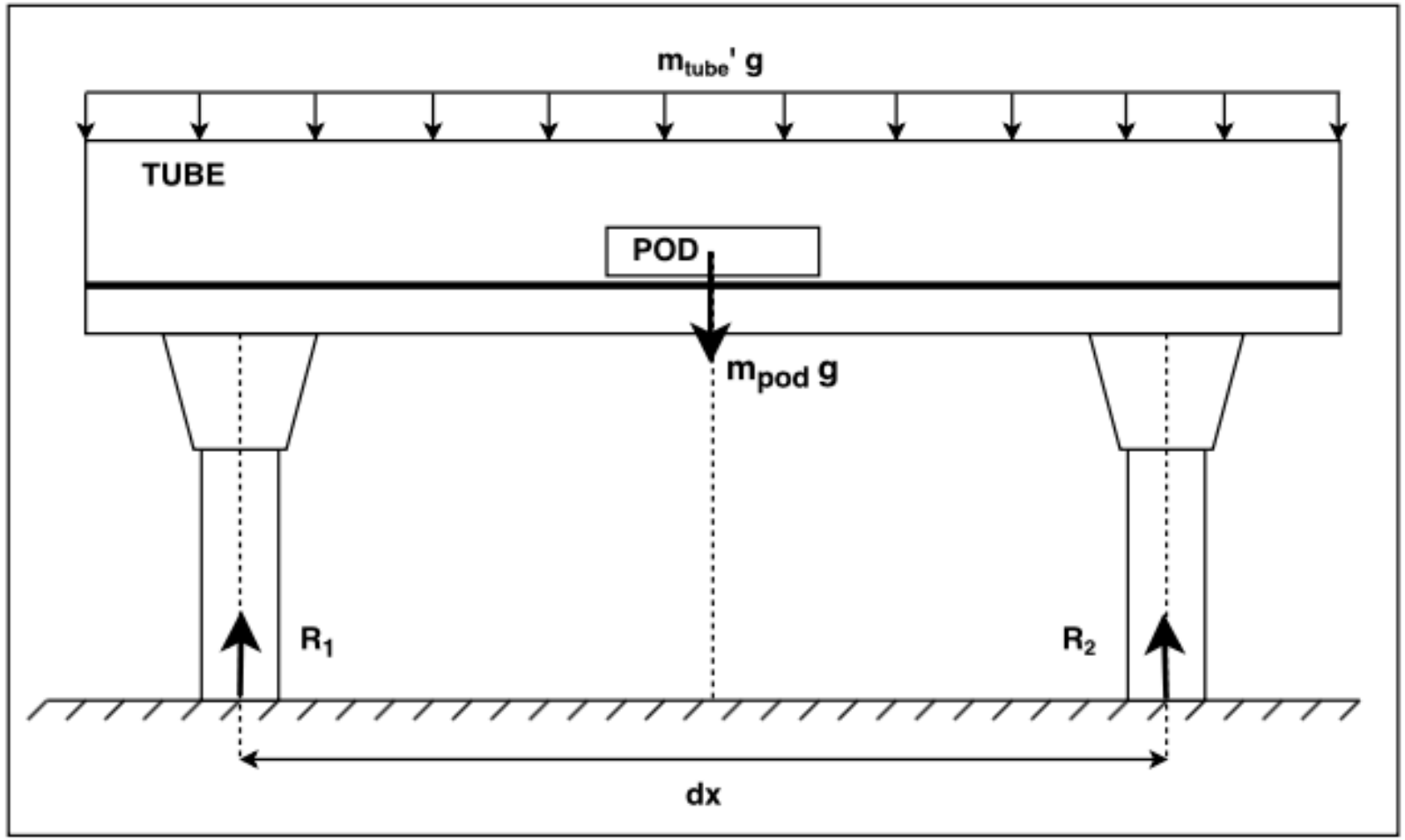
- When traveling over-land, the tube is supported by pylons of a given height above the ground
- When traveling underwater, the tube is supported at a certain depth below sea level

[Tesla 2013]

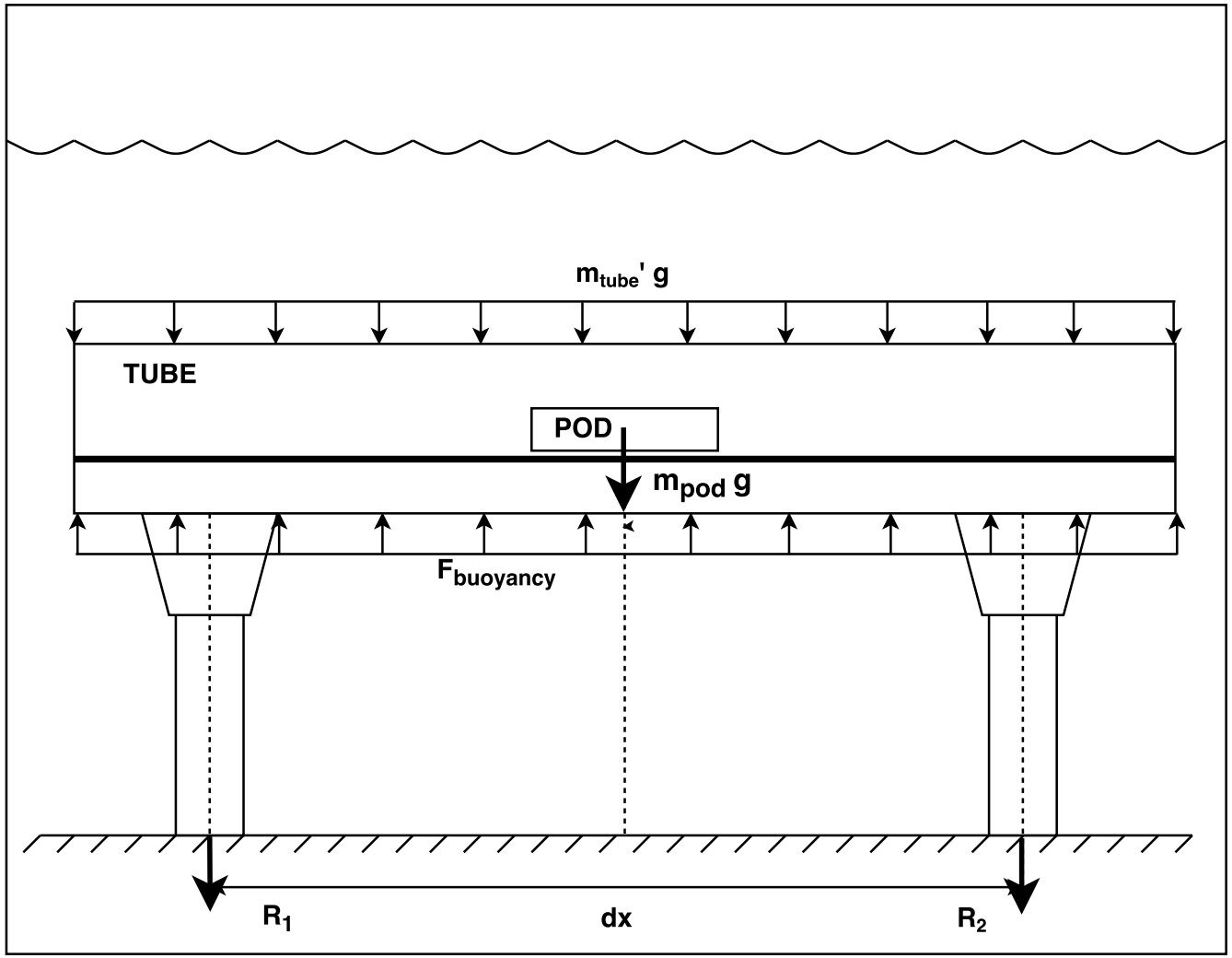
Overview

- System Model
- **Trade Studies**
  - **Underwater vs. over-land**
  - Optimal tube pressure
- Looking Forward

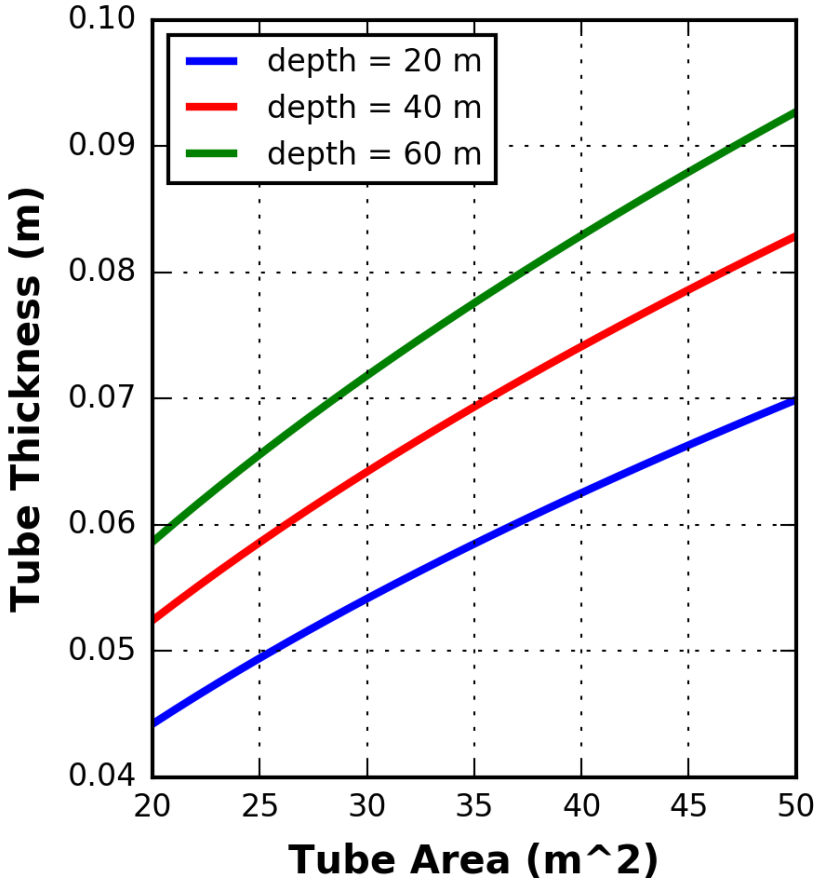
Over-land analysis is a tube, suspended by evenly spaced pylons



Underwater analysis is a tube, under a distributed buoyant load with point loads holding it down



Underwater routes offer potential advantages for both practical and technical aspects of travel

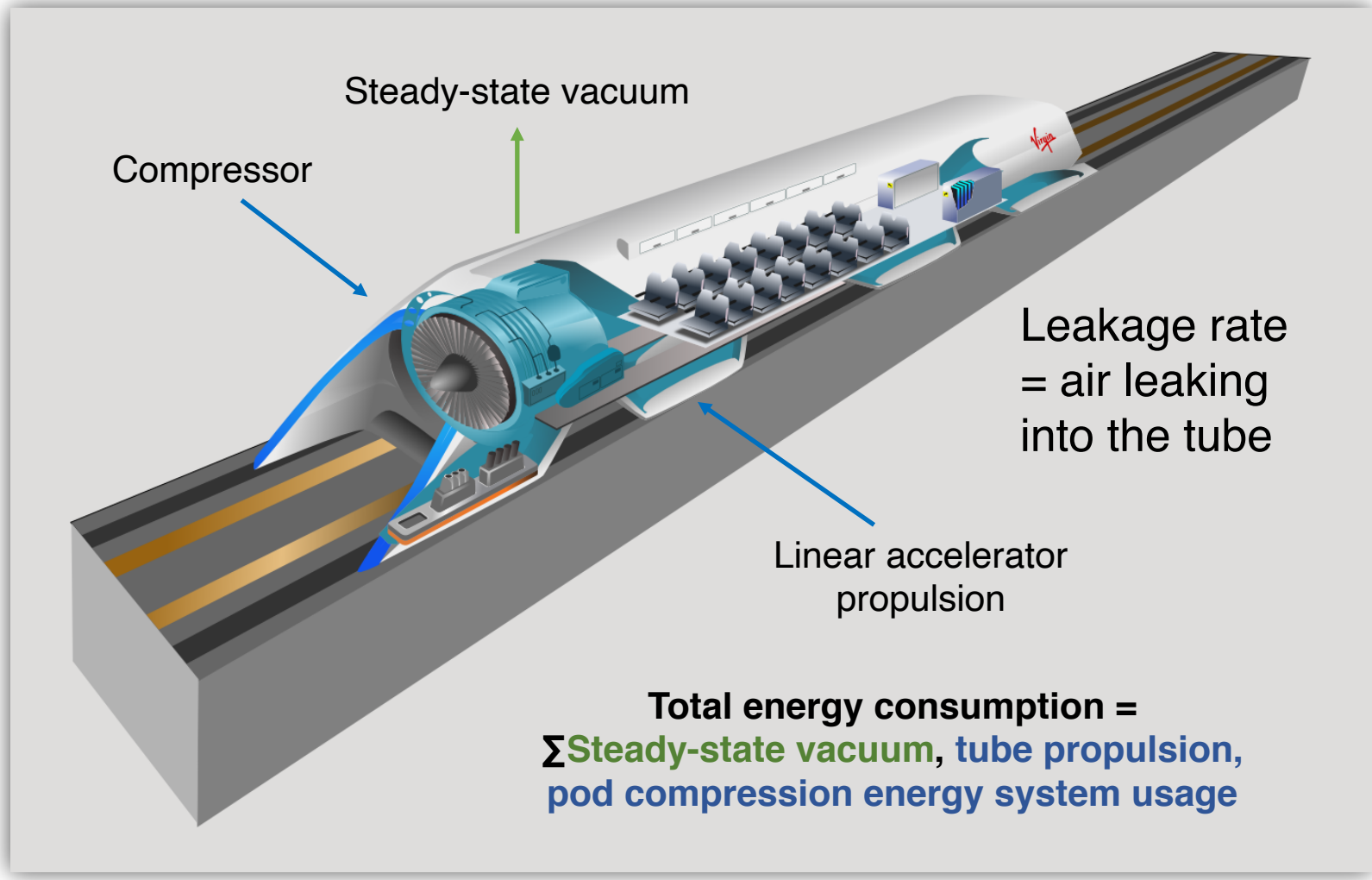


- Underwater, the buoyancy of the tube helps to significantly reduce the required tube wall thickness
- Underwater routes don't suffer the same right-of-way challenges that over-land ones do

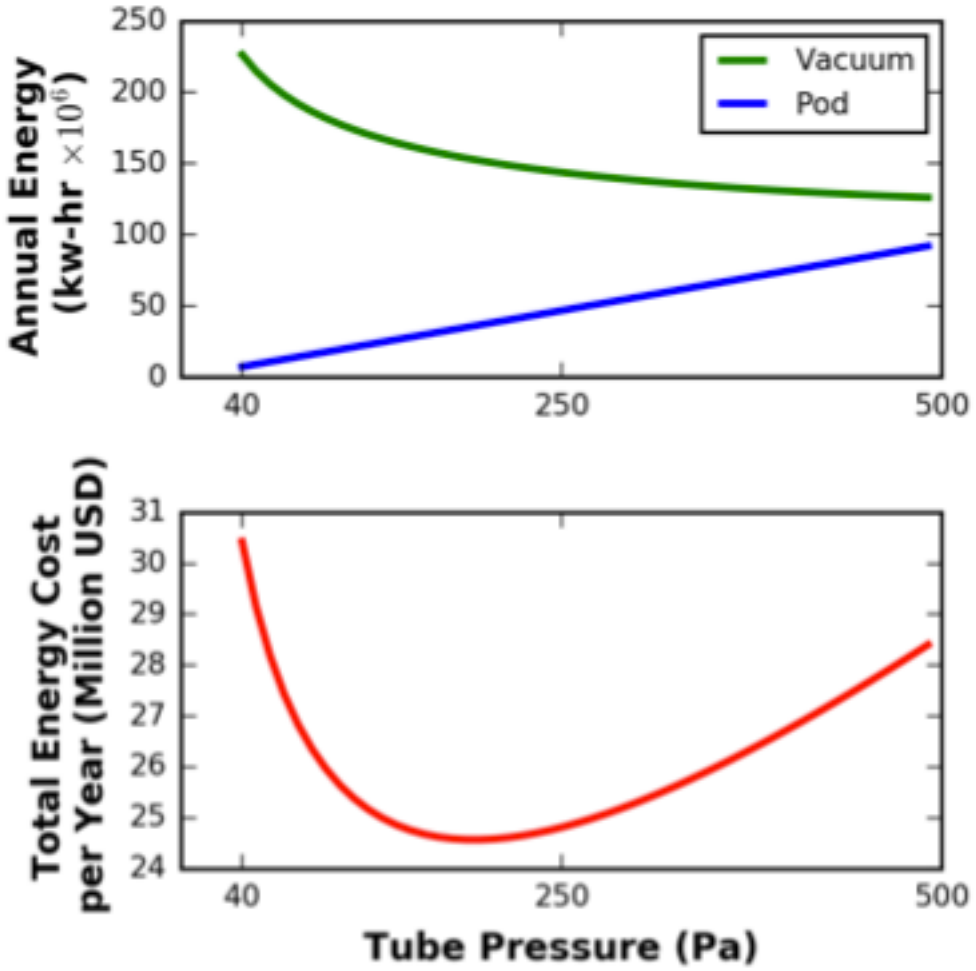
Overview

- System Model
- **Trade Studies**
  - Underwater vs. over-land
  - **Optimal tube pressure**
- Looking Forward

There exists a tube pressure that minimizes overall energy usage

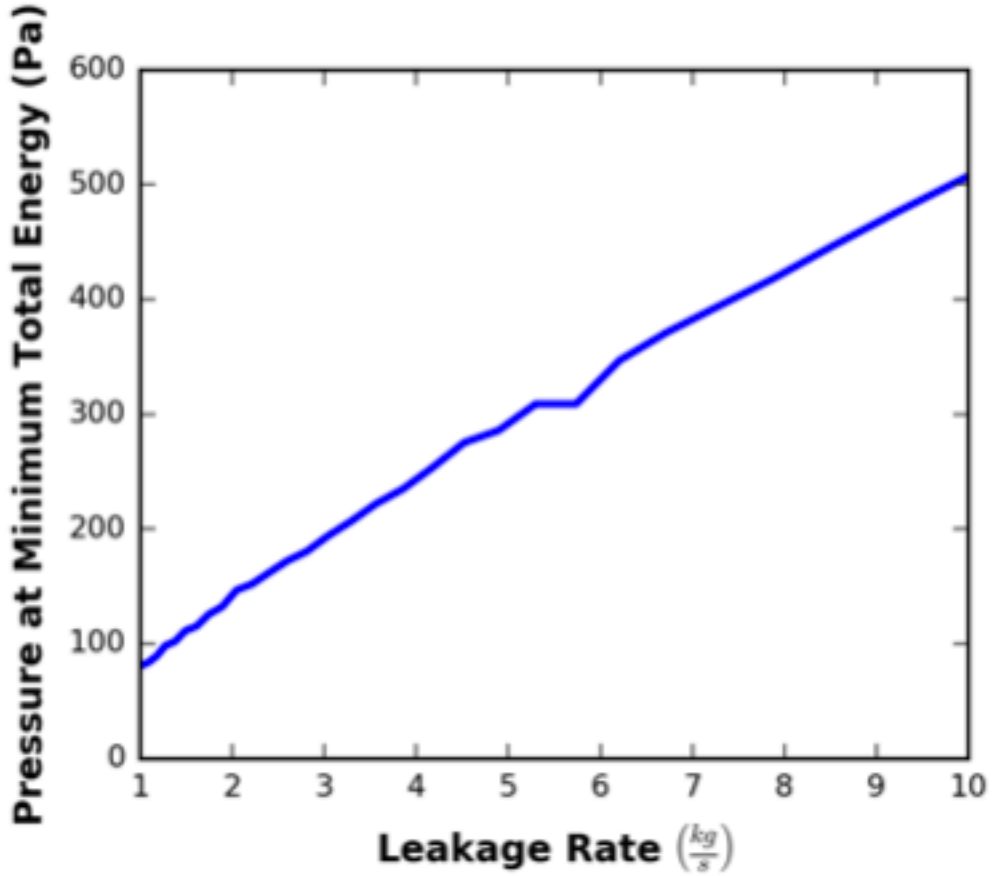


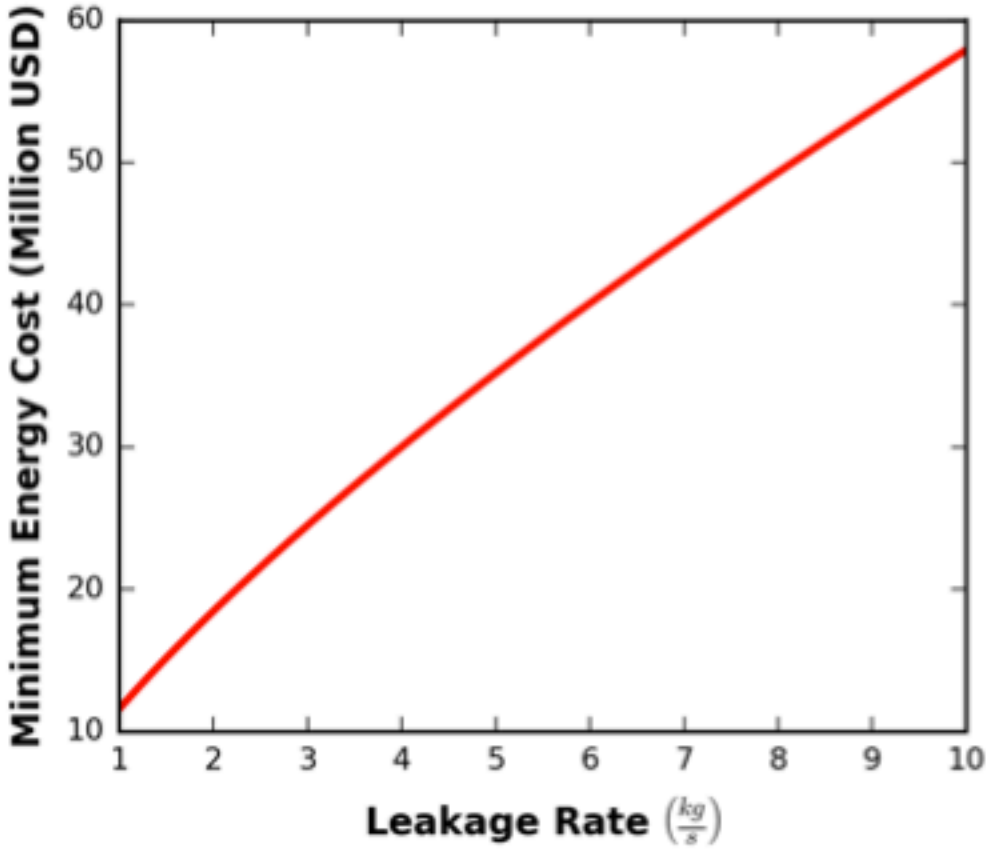
For a fixed leakage rate, there is an optimal operating pressure for the tube



Leakage rate = 3 kg/s
Optimal tube pressure = 190 Pa

Leakage rate is the dominant factor accounting for total energy usage of the whole system



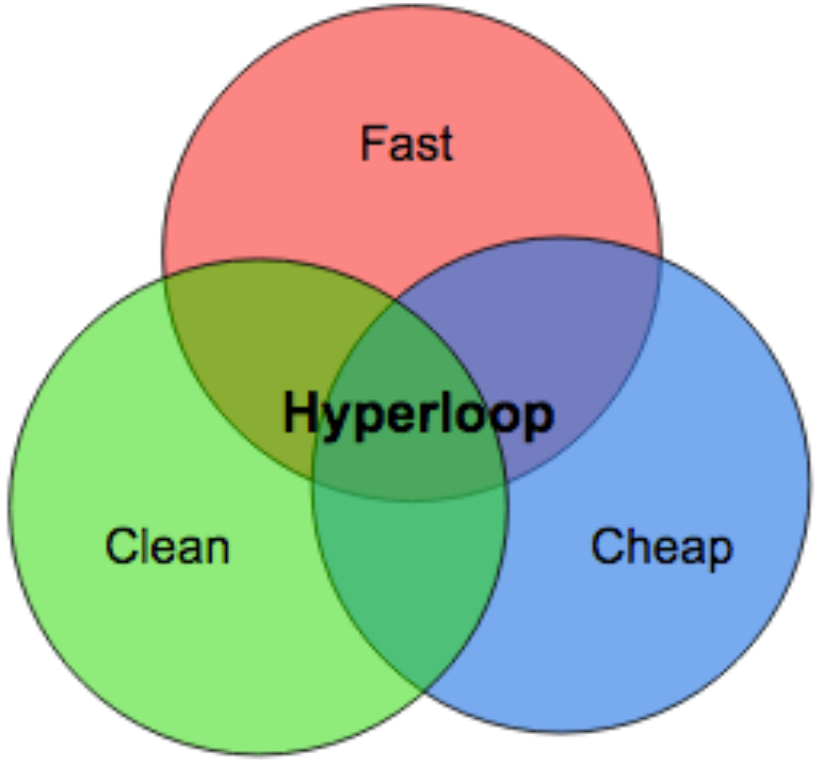


Overview

- System Model
- Trade Studies
- **Looking Forward**

Hyperloop is a faster, cheaper, and cleaner alternative to existing modes of transportation

- This concept can move people between cities faster than existing modes of transportation
- Underwater routes offer potential advantages vs. over-land routes and should be strongly considered.
- By utilizing wind and solar power, the Hyperloop could be a true zero-carbon, all-electric transportation system



Acknowledgments

- NASA Multidisciplinary Aeronautics Research Team Initiative

- Convergent Aeronautical Sciences Project for the Innovation Lab

Thank you! Questions?

System Model:

https://github.com/NASA-MARTI/MagnePlane