HYPERNEX

Shift2Rail

HYPERNEX Final Conference

Observatory
Centre for Research and Technology Hellas (CERTH)

23 February 2022

HYPERNEX: Ignition the European Hyperloop Ecosystem S2R-OC-IPX-01-2020: Innovation in guided transport Ref: 101015145

The hyperloop system

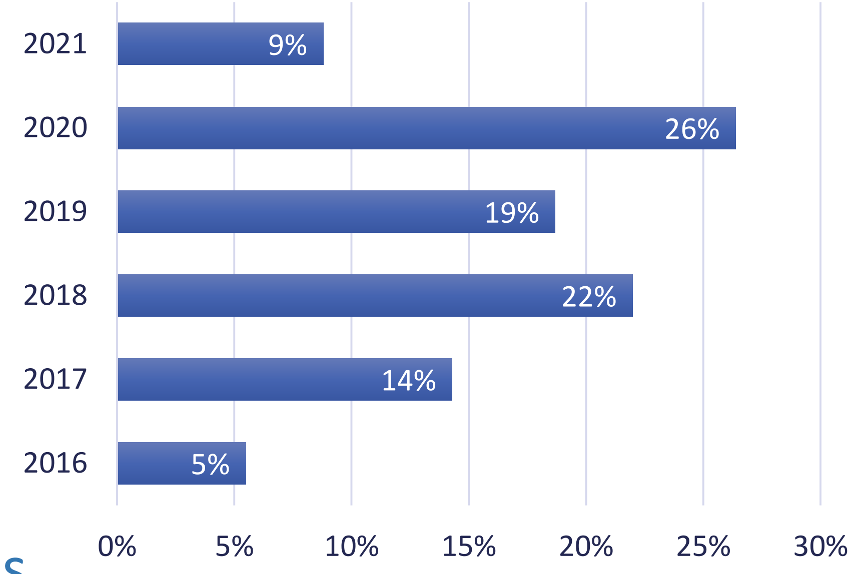
The hyperloop is a new mode of ground transport, in which a vehicle (pod) is capable to transfer passengers or cargo autonomously, reaching ultra-high speeds in a low-pressure environment.

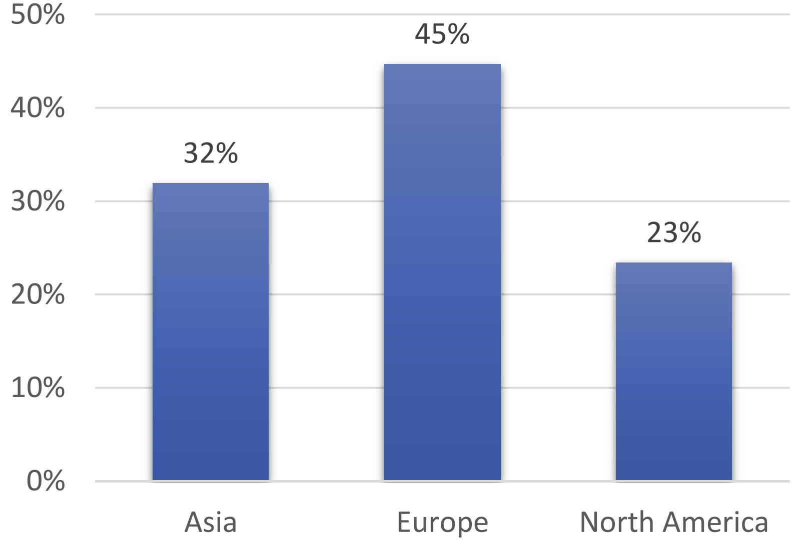
It integrates technologies
High-Speed Railway (HSR) & Aviation, and consists of:

- Pod: structure, interior, electrical system
- Interfaces: levitation & propulsion
- Infrastructure: tube, pylons, pressure maintenance systems, stations, airlocks, high-speed switches & power delivery
- Communications - ensuring safety, comfort & an autonomous system

Stakeholders

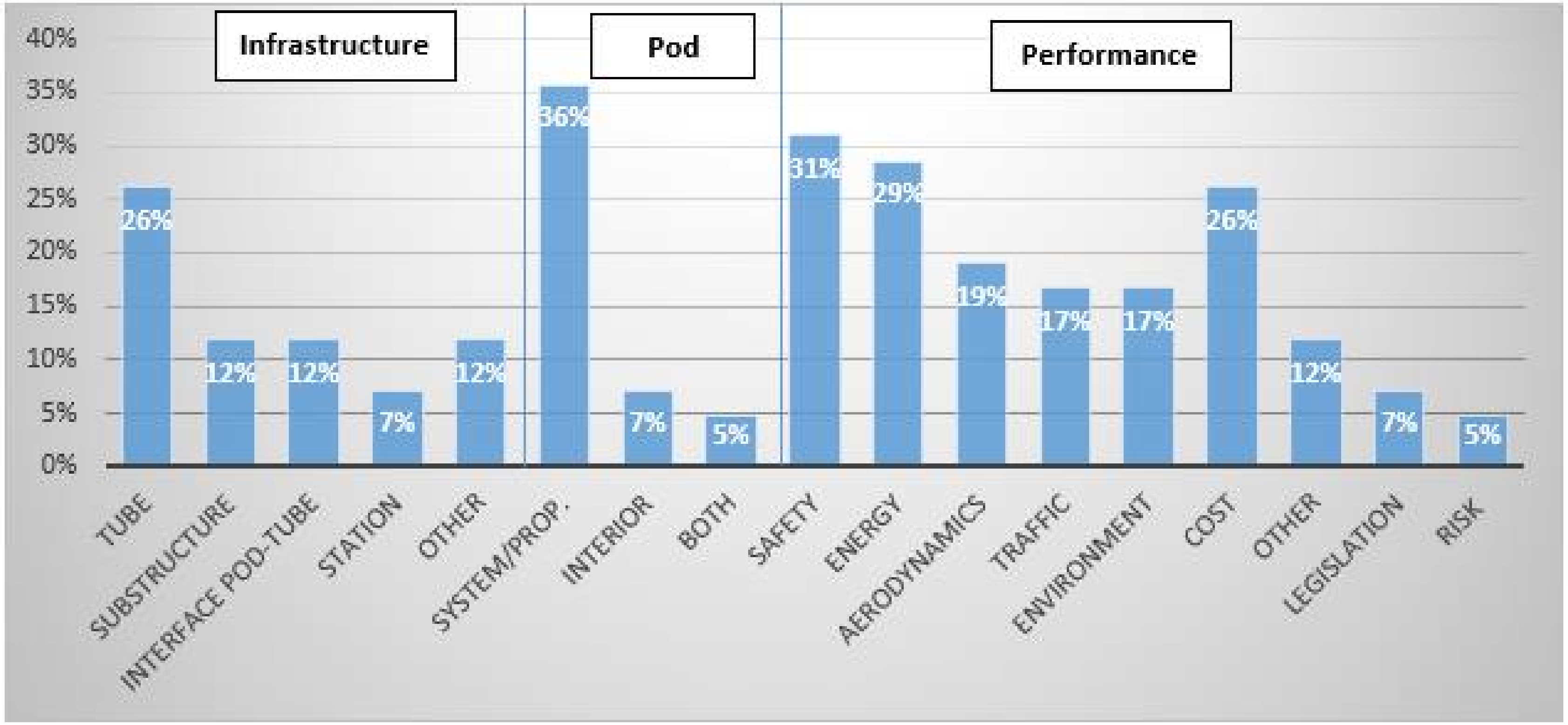
- Research and public organizations
- Private companies
- Public and private initiatives





- In total 91 documents were identified
- 61 unique organizations have been identified in 13 EU countries.
- The majority of EU based organizations that are related to hyperloop → academic or research institutes, whereas, only 13% and 7% of them are industry and non-profit organizations

Research and development



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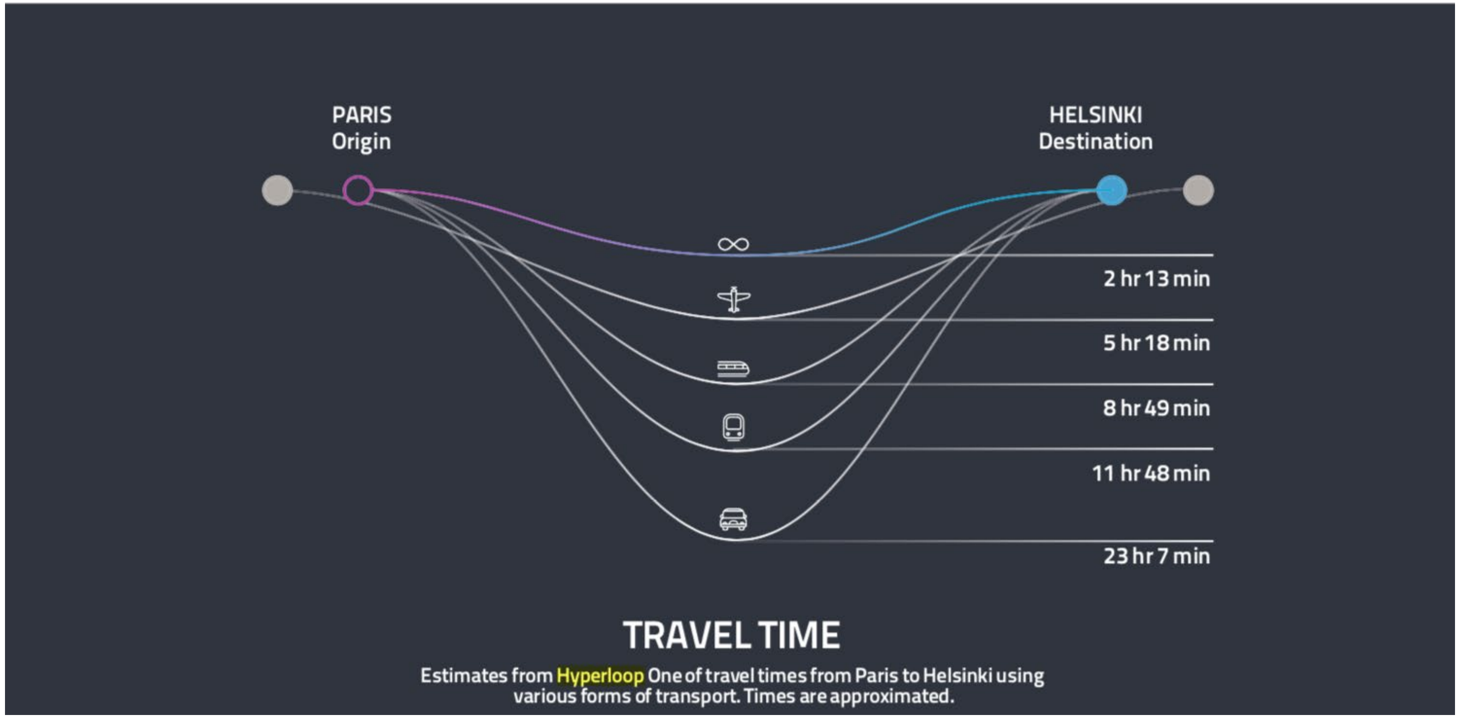
Testing Track Facilities

Name	Location	Testing Track Facilities
Hardt	The Netherlands	Completed length 30 m, diameter 3.2 m
HyperloopTT	France, USA, UAE, Germany	Completed in France-length 320 m, diameter 4m Developing in UAE-4.8 km passenger track & test track 1 km, in USA-multiple routes under study, in Germany-100 m cargo route
KRRI	South Korea	60 meter track, 20-30cm vehicles
Nevomo	Poland	Completed- length: 48 m at Developing - length 500 m
SouthWest Jiaotong University	China	Completed: Circular test track in 2014 Developing: 1.5km test track 3m diameter for 1500km/h testing
SwissPod	Switzerland	Developing- 40 m length
Transpod	France, Canada	Completed 3 km length, diameter 2m
Virgin Hyperloop One	USA, Saudi Arabia, India	Completed in USA- length 500 m, diameter 3.3 m, Developing full scale projects in USA, Saudi Arabia and India.
Zeleros	Spain	Completed: 6 key subsystem prototypes. Developing: 3-4 km tube test-track for system integration at high speeds. 20-40km track for commercial certification and manned tests by 2030. Facilities for industrialisation of vehicle manufacturing and testing.

Speed

- **1,200 km per hour (760 miles per hour)**
- Reduce inter-city travel time
- Challenges → Optimal design
  - Reduce the aerodynamic drag
  - Ensure performance, reliability and low cost
  - Maximize passenger safety, travel experience and comfort

in a very challenging environment (sealed low pressure tube environment).



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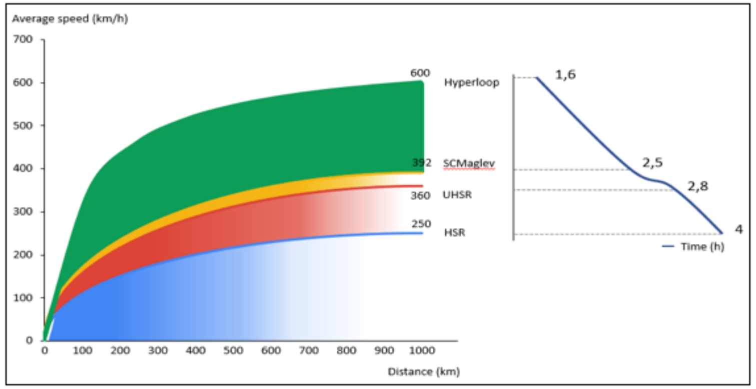
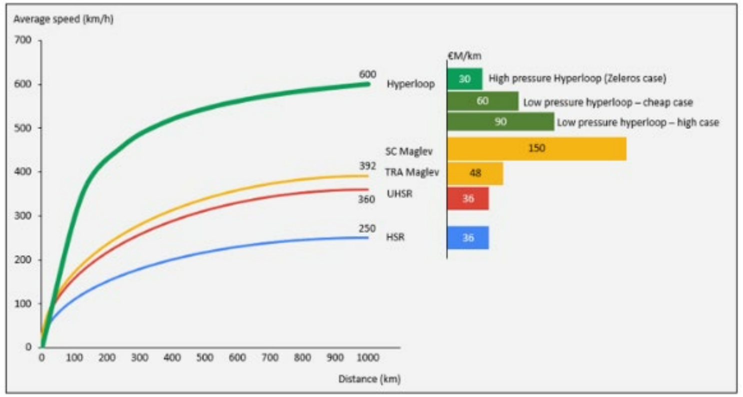
Hyperloop Development and Infrastructure

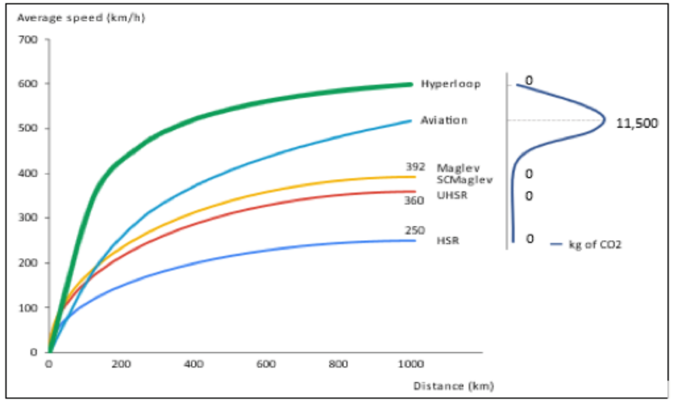
- Stations (city-centre, city periphery, or joint to an existing infrastructural hub, such as an airport)
- Urban development (elevated tubes, good intermodular transport connection → social and environmental concerns)
- Long-distance development



Faster than any other railway technology (1,000 km)



Low infrastructure cost



Emissions for 1,000km

Systematically, it outperforms aviation on routes of up to 1,200km, and remains competitive beyond 2,000km, the latter representing 90% of all flights in Europe

Credit: Zeleros

Transport Demand and Forecast

→Passenger transport (fares, journey time, frequency, and comfort and reliability)

→Freight transport (demand for different modes of transport, but also to understand the desired characteristics of the shipment)

→Travel distances of less than 300 km would not allow for speed advantages.

→One possible way to reduce the implementation costs is to partially use existing infrastructure, such as airports, train stations, and ports, for example, when incorporating hyperloop into intermodal supply chains.

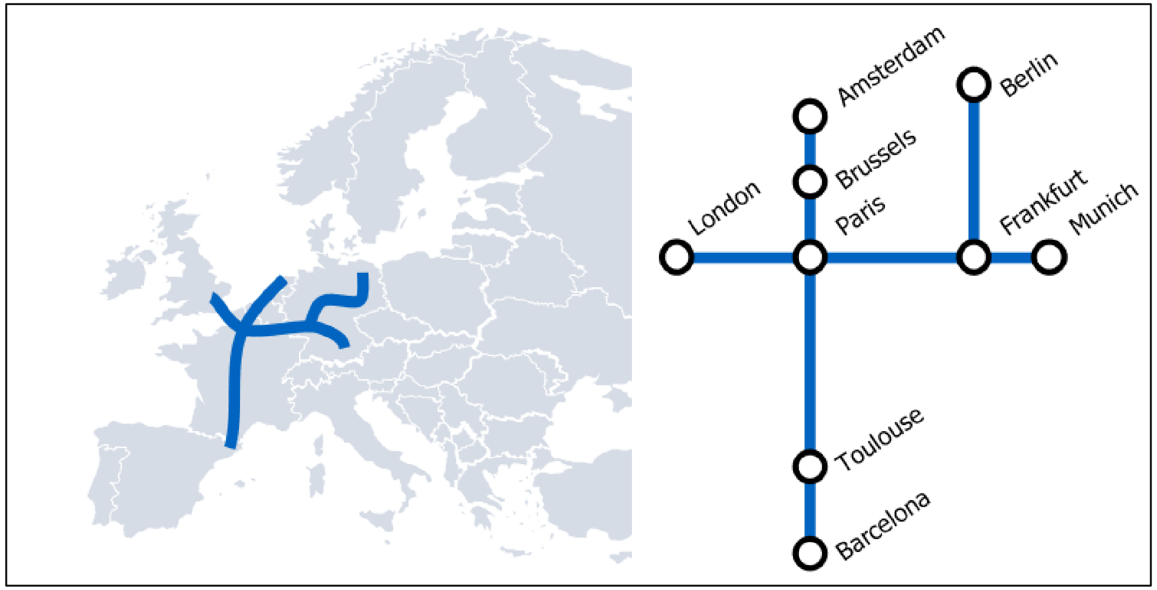
Hyperloop has the potential to become the solution of choice for customers in routes from 500 km onwards, with an optimum between 750 and 1,200 km, and remaining competitive even at 2,000 km.

Transport Demand and Forecast

The case of Europe has been selected to explore market opportunities generated by a long-distance hyperloop network

- The infrastructure cost must not surpass the 30 M€/km. Even with 40 M€/km it may financially work, but chances are reduced
- NPV>0 within the first years of operation will be challenging → User acceptance
- The whole network should be fully operational
- By 2050 hyperloop will be preferred for short haul routes

- In terms of cargo, hyperloop would also absorb traditional aviation products, such as:
  - Spare parts for land vehicles
  - Spare parts for the aerospace industry
  - Materials for fairs and events



Future Steps

Establishing initiatives and collaborations, with both the private and public sector → the technology readiness level will be increased.

Certain focal points that can be identified:

- Establishing a common framework for standardization
- Setting up the foundation for implementation
- Continuing R&D
- Knowledge sharing
- Investing in a long test track
- Securing financing
- Transportation planning simulation
- Transport engineering standards and guidance

Table 6. Short-term gap analysis for hyperloop system components

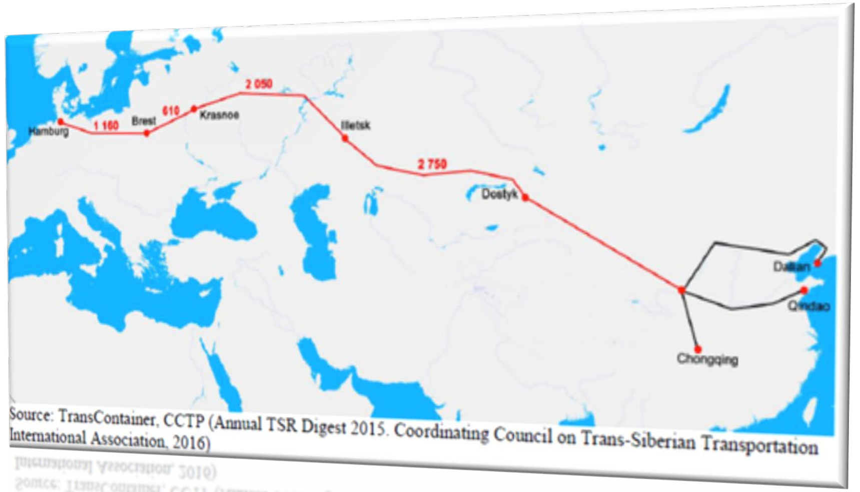
Component	Short-Term Goal	Current State	Identified Gap	Action Plan
Tube	• Tube design: definition tube diameter size, material and proof of concept for dimensional stability of the tube. • Perfect alignment of different tube segments. • Define the strategy for tube installation, transport, thermal joints and connections of different tube segments. • Define the number and characteristics of airlocks (equipped with gate valves) for fast and efficient boarding and disembarking of passengers.	• Various companies created smaller scale testing infrastructures. • Most companies have identified the technical requirements. • Maximum existing length for full-scale test track is: 500 m with 3.3 m diameter. • Tube design under study. Multiple sub-components have not yet been defined (i.e., materials, thermal joints, diameter size are still in design and test phase).	• Lack of testing facilities in real scale and bigger lengths. • The choice of the tube diameter is a trade-off solution between pod size, speed, power consumption and not yet defined. • Few initial studies available on the prediction of the infrastructure cost. • The choice of the tube material is a trade-off solution between stiffness, leakage, environmental impact and cost. Steel and/or reinforced concrete are certain predominant options, however limited design concepts are available.	• Simulations are required to optimize tube pressure and passenger-carrying capacity. • Tube prototypes to be tested for structural integrity, leakage rates and vehicle operations at low speeds and various scales, investigating new findings at a lower cost. • Longer full-scale test facilities should be created. • R&D studies to define the structural integrity using steel, reinforced concrete and/or composites. • Exact diameter and dimensional stability shall be verified by documentation and testing.

Table 6. Long-term gap analysis for hyperloop system components

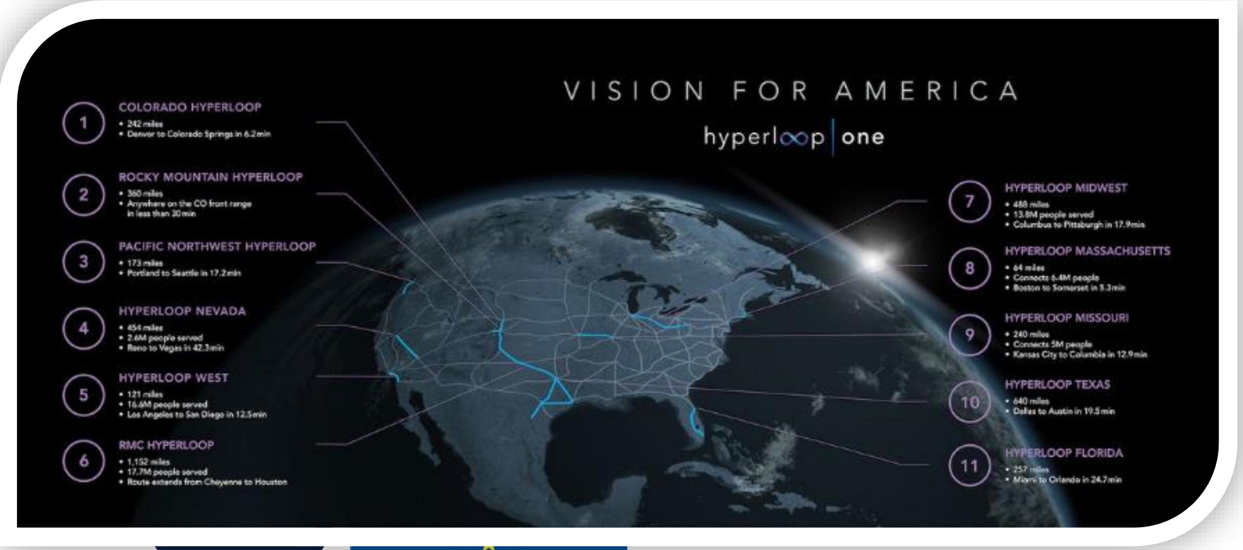
Component	Long-Term Goal	Current State	Identified Gap	Action Plan
Tube	• Construction of a reliable and low-cost tube and its supporting structures. • Commercial operations to be planned when TRL 9 is achieved. • Minimize cost of tube construction and tunnelling. • Development of high-speed switches to realize point-to-point connections. • Develop maintenance and monitoring systems for the high-speed switches to ensure lateral guidance and safety on switching. • High-speed track-switching technology combined with	• Structural integrity, vacuum leakage rates and vehicle operations have been tested at very low speeds. Only one company (Virgin Hyperloop One) has shown proof of concept at real scale on just 500 m of track. • Current developments on high-speed switches are in the early stages and the technological feasibility is yet to be proven. Existing switching systems are functional at very low speeds. The only hyperloop switching technology demonstrated publicly is the one developed	• Increase of speed and testing facility size is required. • More than 40 km test tracks are required to get to the final TRL 9 for the full system[25], however currently only 500 m testing track is operational. • No known scaled version of a high-speed switch exists. • Implementation of high-speed switching with only electromagnetic components has not been proven at scale.	Longer full-scale testing facilities to be created and several aspects to be tested at scale: • Tube junctions with high-speed track switching. • Passenger-friendly airlock systems. • Emergency exits. • Noise impacts on neighbouring land use. • Thermal expansion over a long distance. • Station/portal systems. • System performance under high-speed operation. • Dimensional stability.

GLOBAL VISIONS

Potential to foster business between Europe & Asia, if the combination of speed and cost is optimized



Alignments proposed for a Europe-China connection



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Thank you for your attention!

Centre for Research and Technology Hellas

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Credit: 1. Zeleros, 2. Hardt Hyperloop

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