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HyperRapid

The ultimate high speed tube transportation system

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Objectives

- Provide the ultimate solution for the high speed tube transportation system in terms of near zero pressure level
- Reach very high speeds up to the permissible comfort limit
- Reduce the complexity
- Increase the reliability
- Use only electromagnetic forces for guidance / levitation (no wheels – ESM / no air cushion)
- Use proven technology where possible (TransRapid, MagLev)
- Develop new technologies where needed: tube, vacuum, stations, emergency procedure, safe egress, re-pressurization
- Overcome thinking barriers: near 0 Pa is possible, choking (the Kantrowitz limit) does not constitute a speed limit
- Making use of the choking effect to create almost vacuum

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Target Group

- The HyperRapid saves time and provides a convenient way to travel long distances
- It competes directly with the Hyperloop concepts and provides an alternative system with special advantages
- It targets in particular those who profit from a reduced duration of travel, i.e. business people, travelers who prefer to spend more time at their destination, time critical traffic between airports
- In order to increase profitability, freight transport may be used during off times

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Conventional High Speed Trains

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Magnetic Levitation (MagLev)

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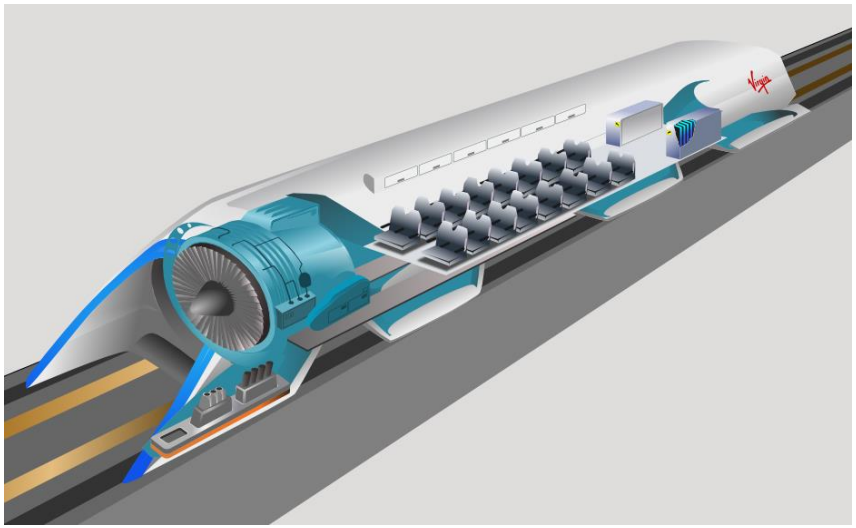
Tube Transportation Systems

oto courtesy of SpaceX Hyperloop



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Comparison of different tube transportation systems

	Swissmetro	Hyperloop	HyperRapid
Pressure	7000 … 10000 Pa	10 … 100 Pa	near 0 Pa
Time	1989 … 1998	2012 …	2019 …
Max. speed	100 m/s	340 … 1000 m/s	1000 … 2000 m/s
Tube diameter	5 m	3.5 … 4 m	2.8 m
Vehicle diameter	3.2 m	2.6 m	2.6 m
Vehicle length	80…100 m	20…30 m	20…30 m
Passengers	200	26 … 40	50 … 60
Levitation	EDS	Air cushion	ESM
Propulsion	LIM	LIM	LIM
Acceleration	0.1 G	1 G	1 G
Lateral acc. / curvature	0.1 G 10 km	0.1G 115 km	0.5 G 50 km

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Main Features

- Elimination of the aerodynamic problems of driving by reducing the pressure to almost 0
- Due to elimination of drag, a very high speed is possible
- Two step approach to reach such low pressures, using vacuum pumps and deliberately the vehicles as sweeping pistons
- 2 layer tube with 2 pressure levels to reduce leakages and enhance stiffness
- Magnetic Levitation by ESM and propulsion by LIM (Proven TransRapid technology)
- Use of non-metal tube material to avoid eddy currents
- Can be built anywhere, on land, across mountains (tunnels) and in sea (suspended tunnels)
- Weather independent
- Connects city centers directly

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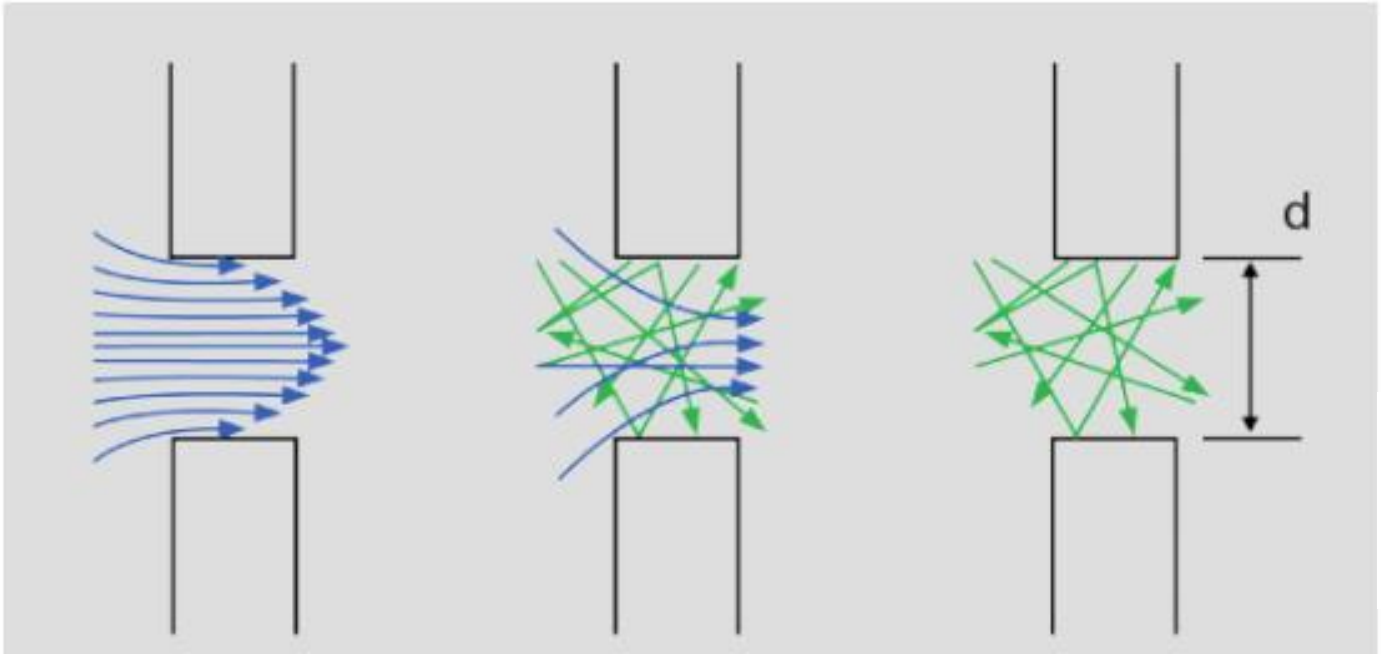
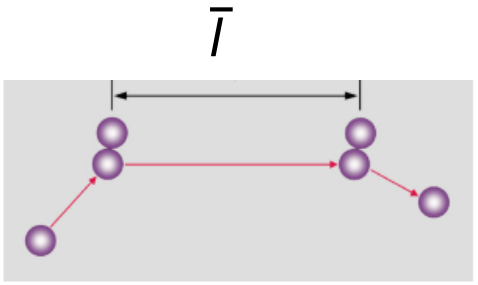
Knudsen Number / Flow topology



$$Kn = \frac{\bar{l}}{d}$$



Kn < 0.01
viscous flow
coarse vacuum

0.01 < Kn > 0.5
Knudsen flow
fine vacuum

Kn > 0.5
Molecular flow
ultra fine vacuum

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Vacuum Pressure Ranges

	Pressure [Pa]	Particles [1/cm3]	Average free path [m]
atmosphere	101‘325	2.7 E19	6.8 E-08
Rough vacuum	30‘000 100	E19 E16	E-08 0.0001
Fine vacuum	100 0.001	E16 E13	0.0001 0.1
High vacuum	0.001 E-07	E13 E09	0.1 1000
Ultra high vacuum	E-07 E-12	E09 10‘000	1 km 100‘000 km
Extremely high vacuum	< E-12	< 10‘000	> 100‘000 km

Swissmetro Hyperloop N_A=6 E23 HyperRapid

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Main Technologies

- How to reduce the pressure to almost 0 Pa
- How to maintain the pressure at almost 0 Pa
- How to keep leakages at a minimum
- Multi Layer Tubes
- Tube Material (stiff, air tight, versatile, non inductive)
- High precision manufacturing of tubes
- Suspension / Levitation of Vehicle, Damping
- Stations (allowing fast exchange)
- Emergency exit (no additional leakages)
- Re-pressurization
- Maintenance

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Challenges – research requirement

- Tube material, must be airtight and inexpensive
- Vehicle material – must be extremely light weight, composite
- Vehicle length, operational concept – power for acceleration limits the vehicle mass, vehicle length and number of passengers
- Propulsion, levitation and guidance – based on Transrapid, probably innovative solutions required for large accelerations
- Braking – eddy currents, regenerative
- Vacuum technology – combination of pumps and vehicle itself
- Passenger comfort – peak accelerations acceptable for humans
- Safety concept – exit hatches, tube alignment, sabotage, repressurization

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Thank you!