KOVRA
2018.11.9

HyperTube (HTX)

- 1,200Km/h Future Innovative High Speed Transportation

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Korea Railroad Research Institute

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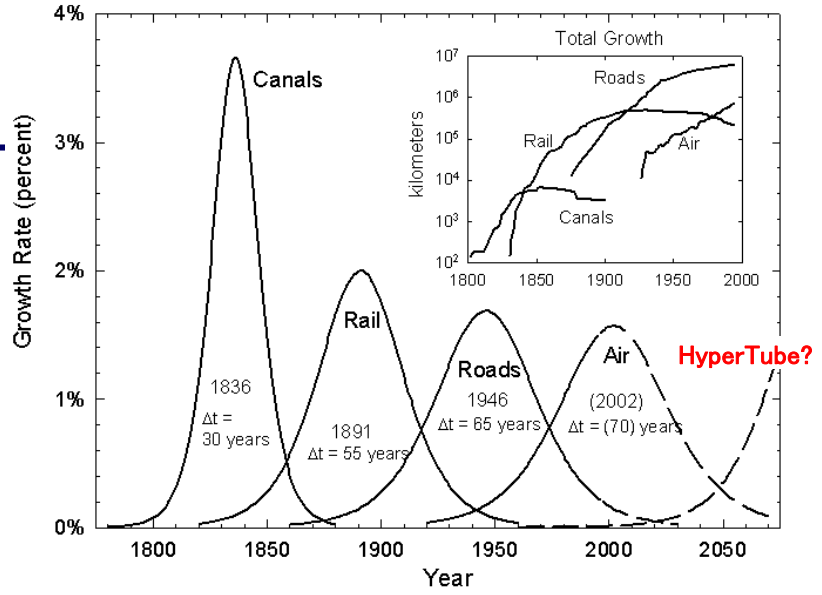
Next Generation New Transportation ?

Requirements

- **Safer**
- **Faster**
- **Lower cost**
- **More convenient**
- **Immune to weather**
- **Sustainably self-powering**
- **Resistant to disaster**
- **Not disruptive to those along the route**
- **On Demand Point-to-Point Transportation**



[J. H. Ausubel, C. Marchetti, P. Meyer, ''Toward green mobility: the evolution of transport,'' *European Review*, Vol. 6, No. 2, 137-156 .]

Hyperloop Development In the world

(USA) Virgin Hyperloop One

- Fund raising more than 300 Mil. US$
- Staff : more than 300
- Pod running at 384km/h (500m test track in Nevada)

(USA) HTT(Hyperloop Transportation Technology)

- Fund raising more than 100 Mil. US$
- Engineering design for test line by partnership business model

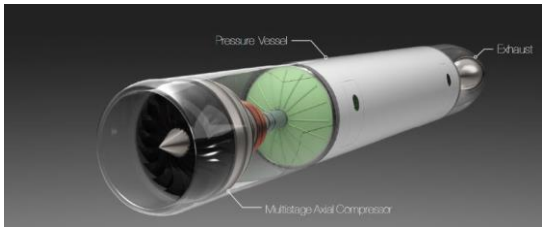
Virgin Hyperloop One

(Canada) TransPod

- Staff : more than 30
- Under developing Hyperloop Pod

(France) SNCF, Saint-Etienne uni., Toulous city

- Feasibility Study on Lyon-AaintEtienne line (With TransPod, HTT)
- Fund Investment to Virgin Hyperloop One



TransPod

(China) Seonam Transportation Uni.

- 30Km/h low-vacuum small scale test track

What is HyperTube HTX (Hyper Tube eXpress)?

- Advanced concept transportation which flights inside sub-vacuum tube with above 1000km/h, and has function of on-demand & core point-to-point connection (Blend new to be developed in Korea)

- Cover between Seoul and Busan in 20 minute
- Cheaper construction and operating cost(LCC) than existing high speed railway

  * LCC : Life Cycle Cost

Advanced Concept Transportation Network

Necessity of HyperTube HTX

- As First Mover rather than Follower, lead new transportation and differentiate with other country

- Improve symbolic representation of national science & technology superiority
- Establish foundation for creative economic growth engines
- Lead new business by technology preemption for 5G MachTrans commercialization

- Need of new line due to rapid increase of high speed railway passengers and anticipatory action for undersea line(Mokpo-Jeju, Korea-Japan/China)

- KTX passenger utilization rate is already saturated by 103%(2014)
- Latent demand of undersea line due to increase of tourism and national exchange

- Lead nation-wide speed up & informationization by innovative 5G future transportation system

- Sub sonic(over 1000km/h) speed
- On-demand → rapid and comfortable transport to desired place at desired time
- Seamless transport between core points

1G : Ship	2G : Train	3G : Car	4G : Airplane
- Low speed - Environmental problem due to accident	- Difficult to flexible operation due to heavy system	- Congestion due to road capability saturation - Environmental problem	- Low accessibility - Large take-off & landing time - Large dependency of weather

Characteristics of HyperTube HTX

Main Features of HyperTube HTX

- Sub-vacuum tube guideway : Minimization of air resistance
- Levitation : superconductor EDS
- Propulsion : Linear Synchronous Motor (LSM)
- Tube guideway : lightweight & high strength material
- Capsule train : lightweight & high strength airplane material and active suspension

Comparison

HyperTube HTX Vs. Hyperloop

	HyperTube HTX	Hyperloop
Pod Size (width x height x length)	1.7×1.5×41m	1.35×1.1×26m
Pod Weight (full)	31 ton	15 ton
Max. number of passengers	40	28
Tube diameter / pressure	2~3m / 0.001 atm	2.23m / 0.001 atm
Levitation method	Superconductor EDS	Air bearing (or EDS)
Levitation gap	Over100mm	0.5~1.3mm
Propulsion method	LSM	LIM
Max Speed	1220 Km/h	1220 Km/h

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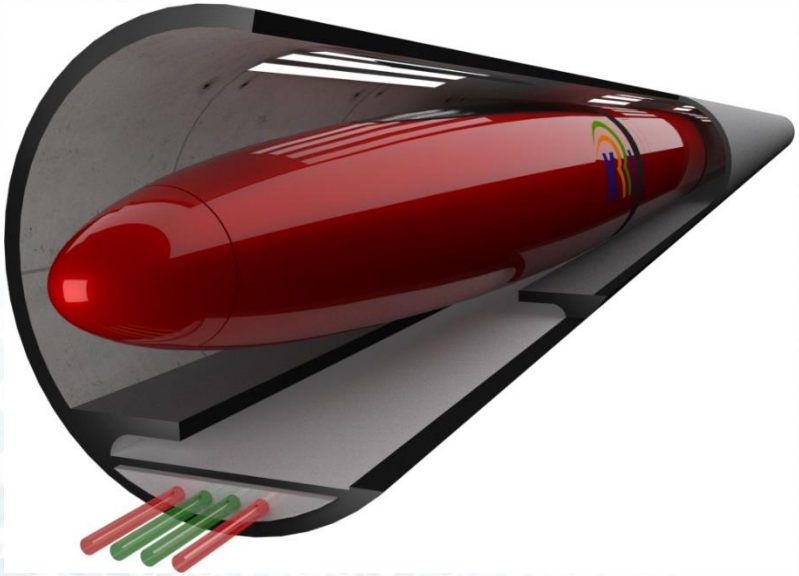
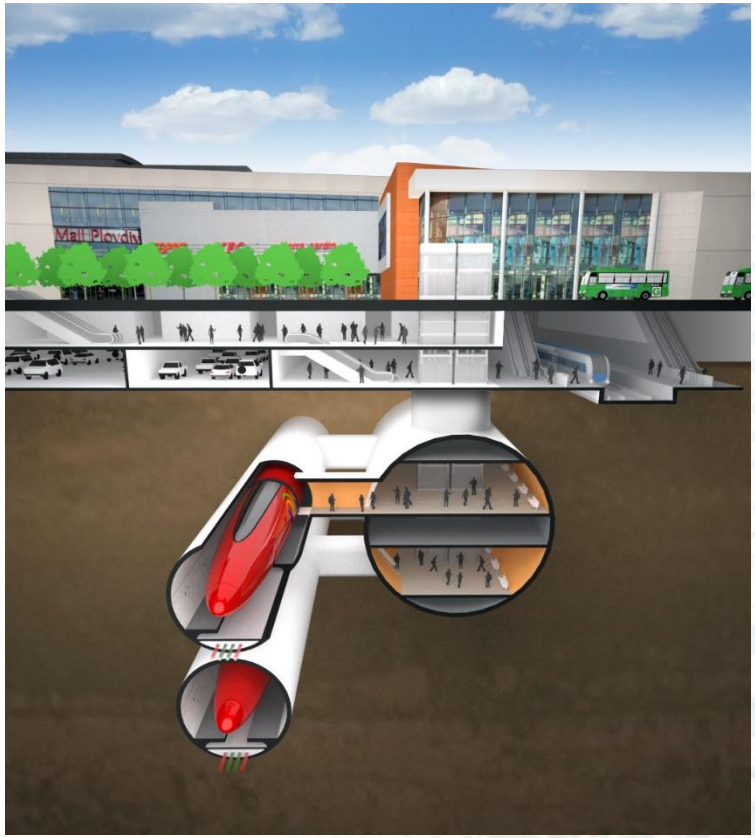
R&D for Tube Train('09~'11)

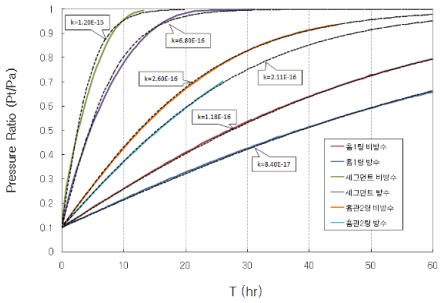
- **To develop core technologies for super speed tube train**
  - **LSM propulsion & EMS Levitation**
  - **Air resistance analysis inside tube**
  - **Preliminary test for low pressure tube**



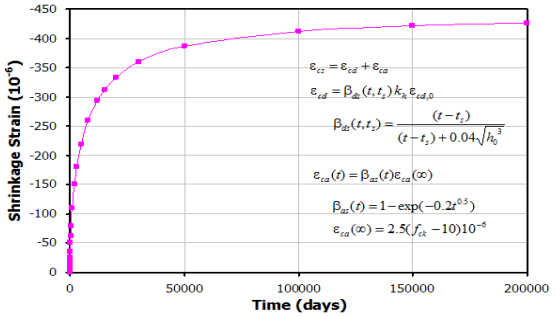


Outcomes

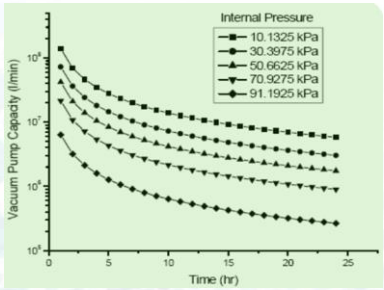
- **Tube performance investigation**
  - **Airtightness**

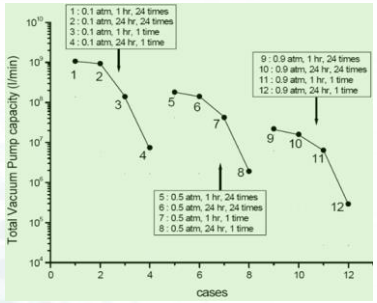


  - **Strength change with conditions**

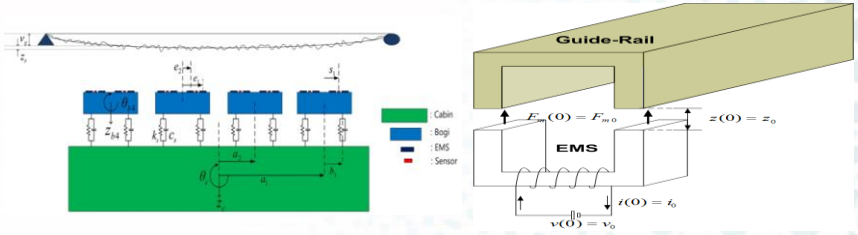


- **Pump capacity estimation**
  - **Parametric analysis**



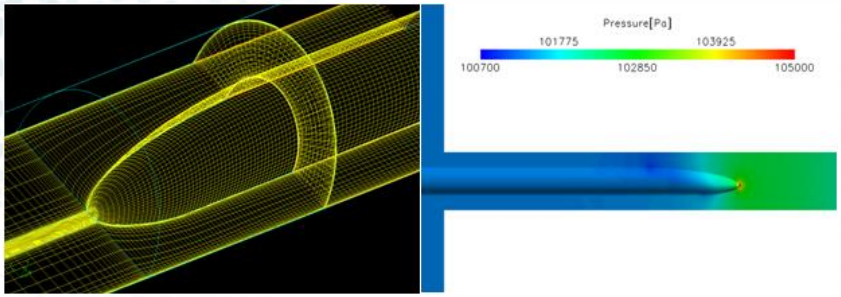


- **Guideway-vehicle interaction anaysis**



High speed Experiment in Sub-vacuum tube

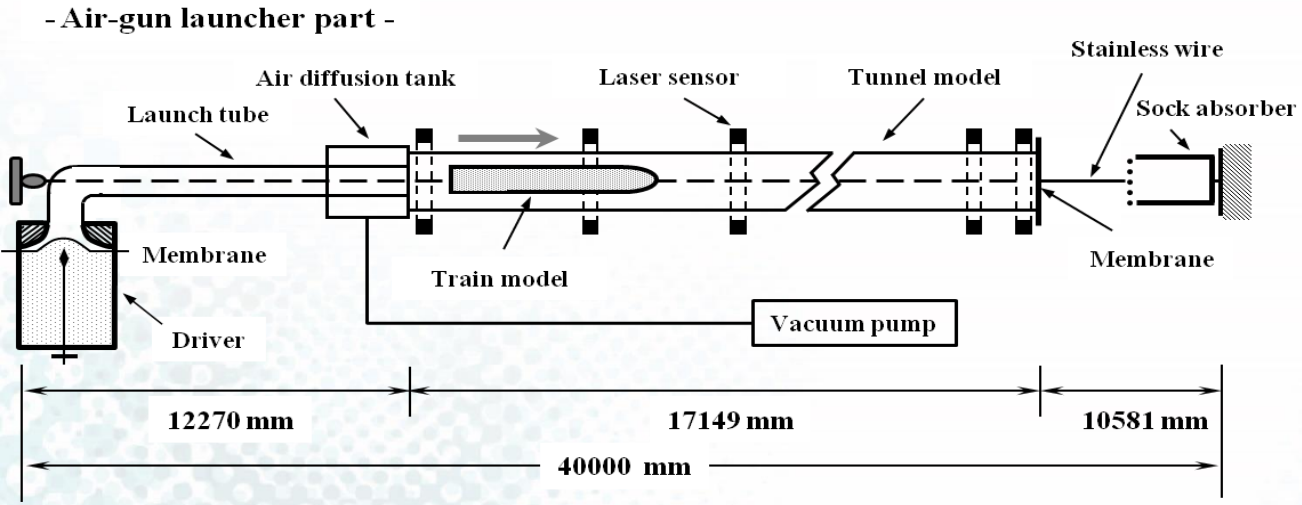
- **Aero dynamic analysis**
  - **Numerical simulation**



- 1/52 Scale Train Model

- 700Km/h test in 0.2 atm tube

- **Diagram of Test Bed**



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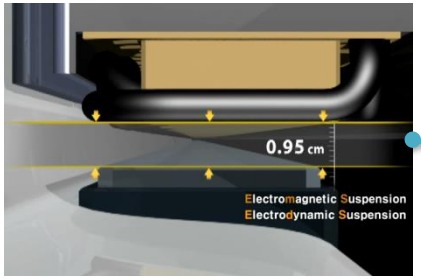
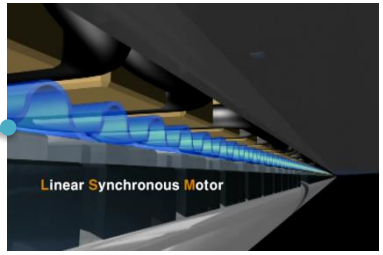
R&D for High Speed Maglev (‘12~’15)

- **To develop the core technologies such as propulsion and levitation for 550km/h level high speed maglev**
- **To construct the real scale maglev vehicle and short length test track to apply developed technologies and verify the performance**



Levitation



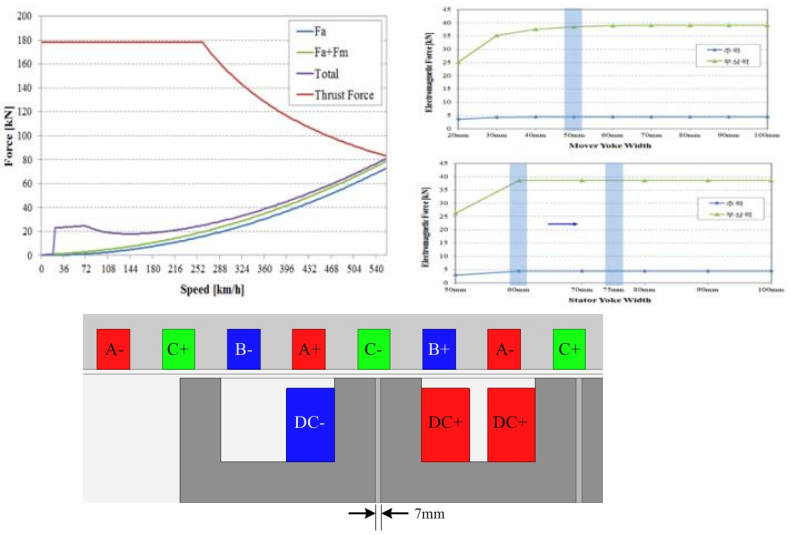
Propulsion

Overview

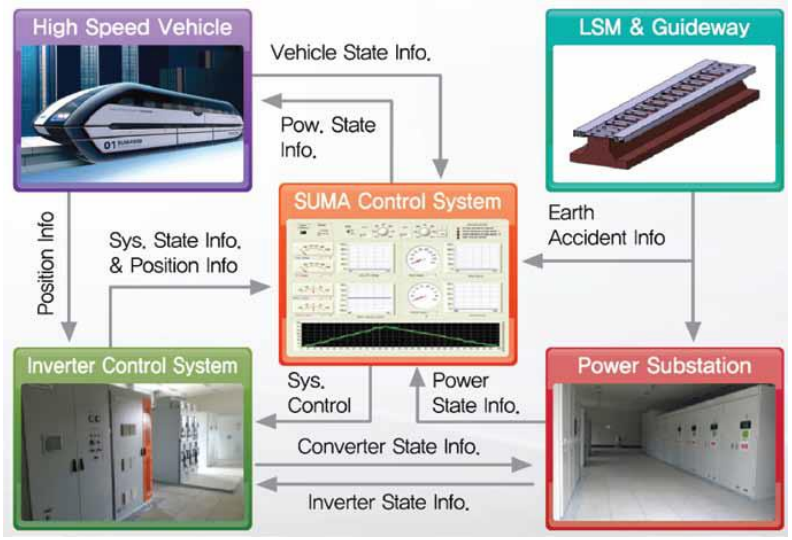
Title	**Development of Propulsion and System Engineering Technology for Super Speed Maglev Railway**
Period	**2011.12~2015.3**
Budget	**$ 21 million (funded from Ministry of Land, Infrastructure and Transport)**
Main fulfillment institute	**KRRI (Korea Railroad Research Institute)**
Sub fulfillment institute	**KRRI (Korea Railroad Research Institute) KIMM (Korea Institute of Machinery & Materials)**
Joint fulfillment institute	**KOREA RAIL NETWORK AUTHORITY Woojin Industrial Systems**
Joint university	**Seoul National University Hanyang University**

Outcomes

- **LSM propulsion system**
  - **LSM design**
  - **LSM control system**
  - **LSM power system**



LSM design



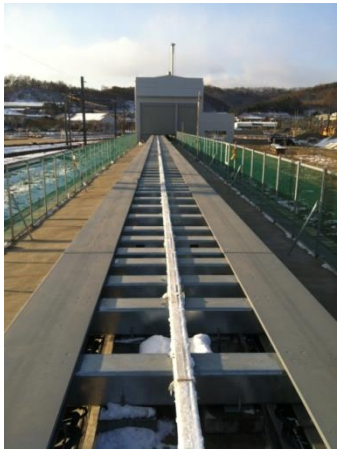
LSM control with power system

Outcomes

Maglev vehicle (SUMA550)

Size (m)	13(length) x 3.5(width)
Full weight	28 ton
Speed	550km/h(design) 30km/h(in test track)
Acceleration	1.1m/s^2
Levitation/Guidance Gap	10mm

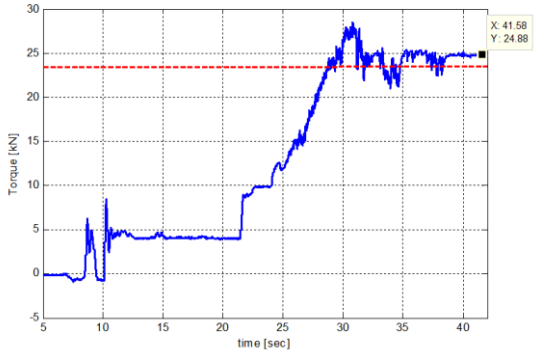
Guideway



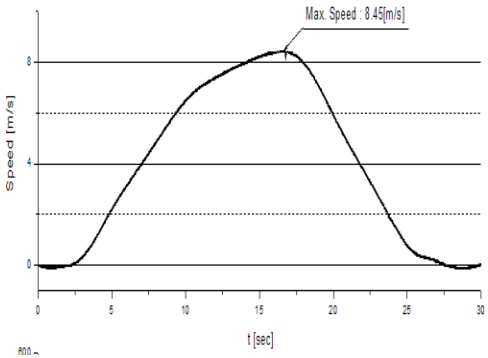
Name		Value	Unit
Guideway Beam Lengths	Guideway type I	13.44	m
	Guideway type II	4.1	m
Guideway geometry	Gauge (distance between lateral guide planes)	2.6	m
	Guideway hover clearance slide plane	516	mm
Tolerance guideway hover clearance	Guideway hover clearance in beam bay	+3/-5	mm
	Relative difference hover clearances at beam joint	±1	mm
Gauge width tolerance	Gauge width in beam bay	±3	mm
	Relative gauge difference at beam joint	±1	mm

Performance - propulsion

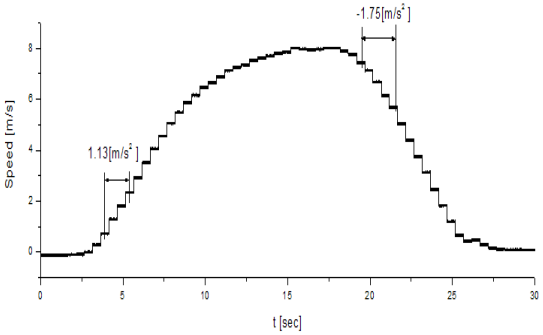
- **Thrust force : 25kN**
  (6 magnets)



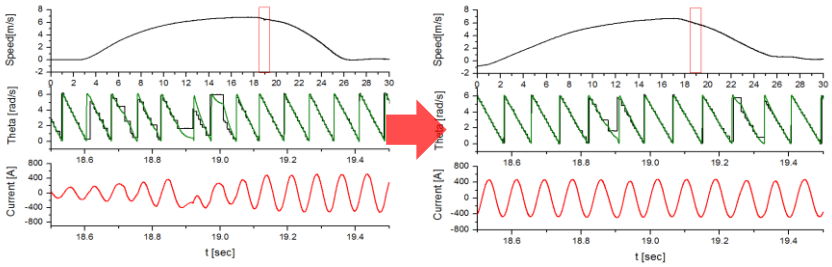
- **Speed : 30km/h**



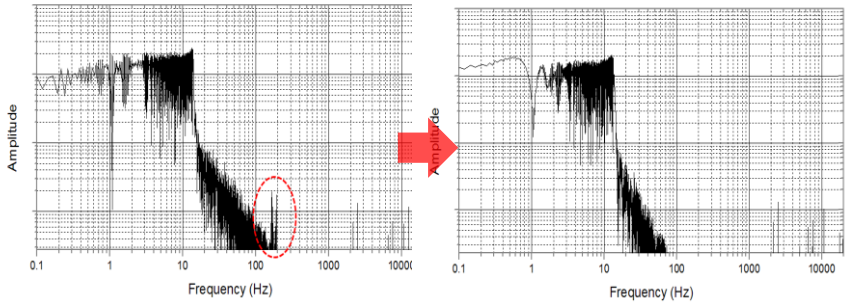
- **Acce. : 1.1m/s²**



- **Position estimator for performance improvement**



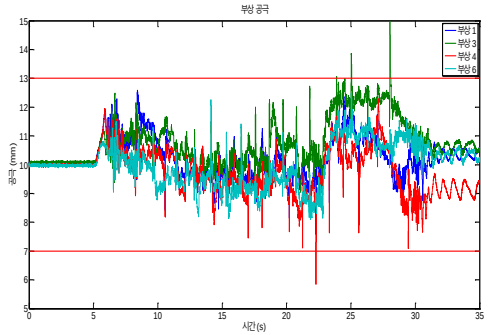
Position and current profile improvement

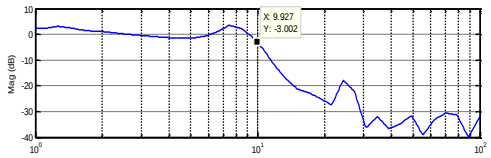


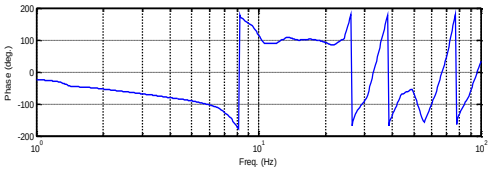
Current profile(FFT) improvement

Performance – Levitation & Guidance

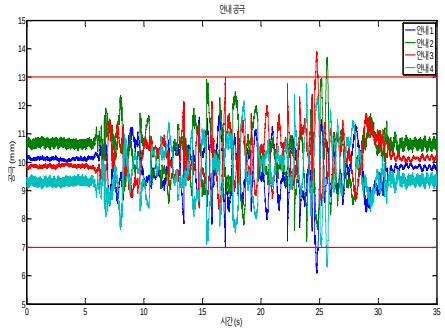
- **Levitation**
  - **Gap variation : ±3mm**
  - **Bandwidth : >8Hz**

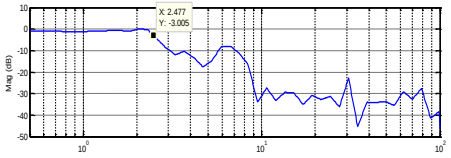


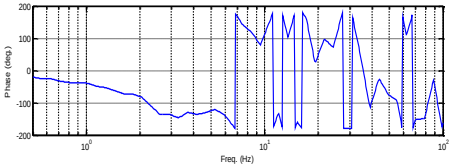




- **Guidance**
  - **Gap variation : ±3mm**
  - **Bandwidth : >2.5Hz**







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R&D for HyperTube HTX ('16~'30)

▪ Object : Development for HyperTube Technology

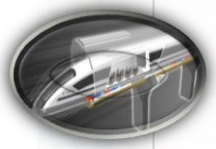
- Over 1000km/h level levitation/propulsion system development
- Capsule pod development
- Sub-vacuum tube infra development

※ The Project is supported by Korea Ministry of Science, ICT and Future Planning

▪ Development Plan

- Stage 1 : Core technology development
- Stage 2 : Prototype test track development
- Stage 3 : Construction of Trial Commissioning Line

Development Roadmap of HyperTube HTX

year	'16	'17	'18	'19	'20	'21	'22	'23	'24	After '25
Milestone	Core technology development					Prototype test track development				Commercialization
Main contents	- Core technologies • EDS levitation • LSM Propulsion • Flight stabilization • Sub-vacuum tube					- Small scale test track • **capsule** : dummy passengers • **speed** : over 1000km/h • **length** : 2km				- Trial commissioning line • **capsule** : full passengers • **speed** : over 1000km/h • **length** : 24km

Core technologies for HyperTube HTX

Category	Core technologies	비고
Systems Engineering	Higher efficiency for land and transport	
	Economic and operative analysis for new transport	
	Aerodynamics	✓
	Safety, real time hazard detection, and autonomous maintenance	
	RAM, Test & Evaluation	
Propulsion & Levitation	Electromagnetic – air hybrid EDS levitation	✓
	High power converter	
	Module based subsonic speed LSM	✓
Capsule Pod	Capsule pod stabilization in Tube	✓
	Air compression for pod	
	Subsonic speed flight body	
Tube Ingra	Sub-vacuum tube and airtightness	✓
	Low weight high strength material	
	High capacity vacuum pump system	
	Pedestal & bridge	
	Tunnel structure	
	Tube turnout	
	Station & maintenance depot	
Electric Power Supply	High power smart power supply and energy storage	
	Wireless electric power supply	
Operation control/ Communication	High speed data communication	
	Intelligent IoT & Autonomous	
	Subsonic capsule pod operation control	✓

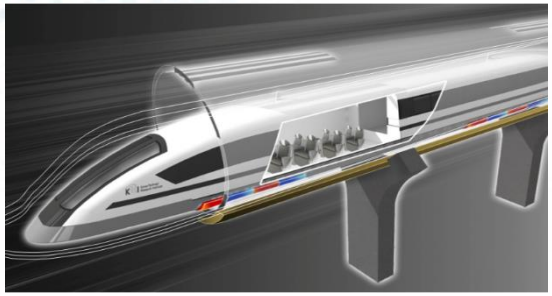
√ : 1st Stage Development

Objective (1st Stage)

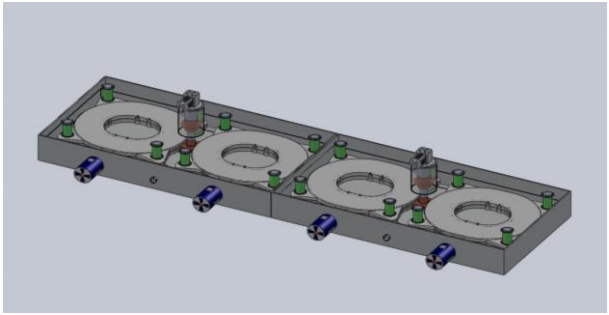
1st Stage : Core technology development

- Core technologies by detail parts

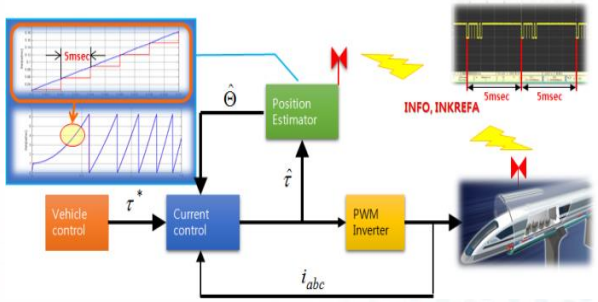
Aerodynamic & Safety



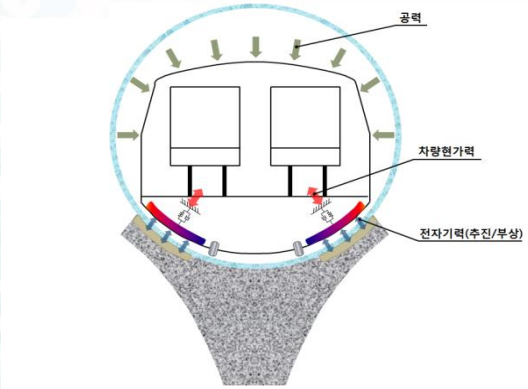
Superconductor EDS Levitation



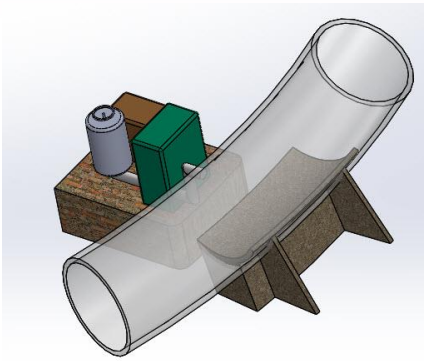
Module based LSM Propulsion



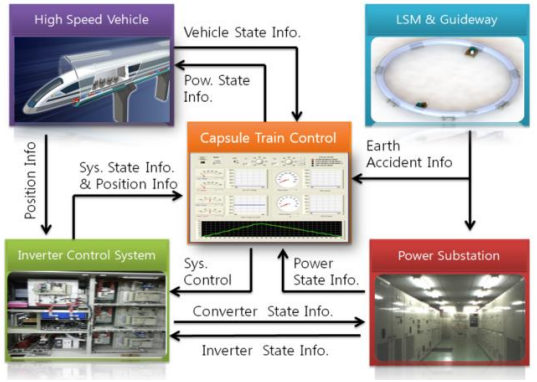
Capsule pod flight stabilization



High strength & light weight sub-vacuum tube



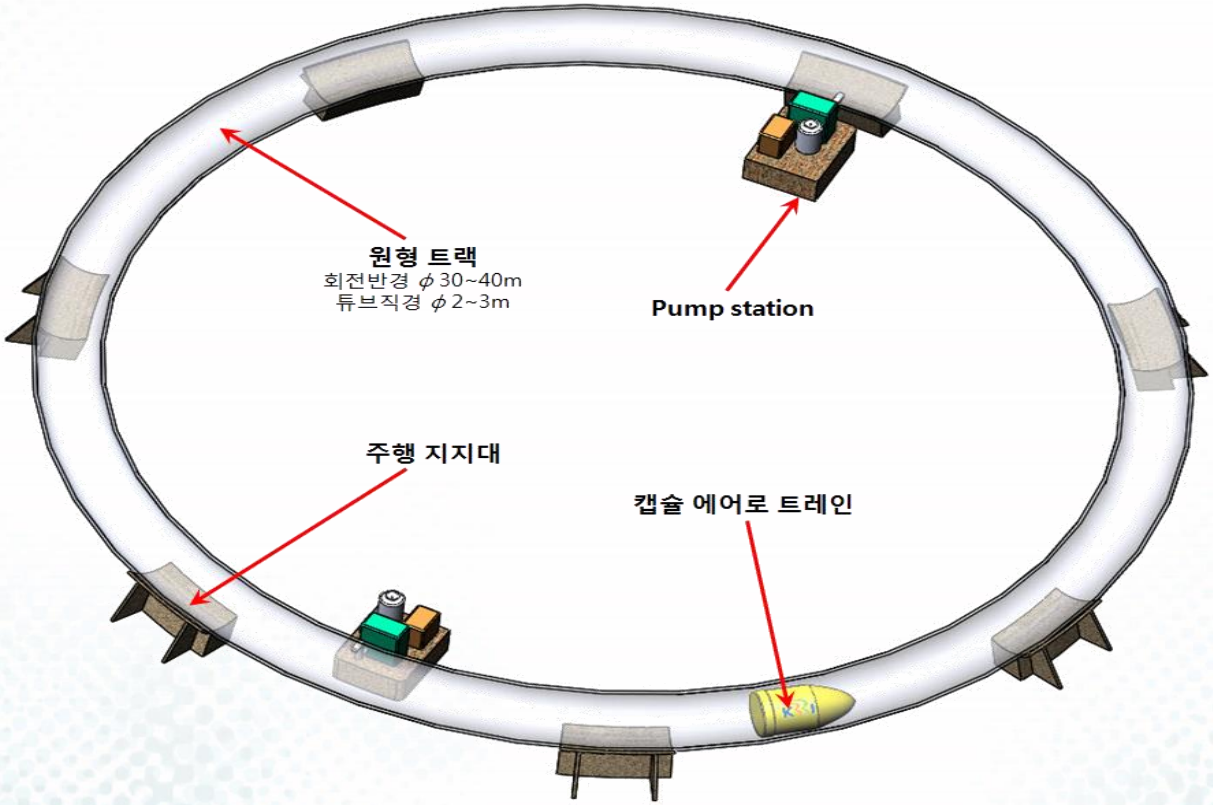
Capsule pod control system



Objective (2nd Stage)

2nd stage : Small scale test track development

- Small scale test track (an example)



Objective (3rd Stage)

Future Transportation Leading the 4th Industrial Revolution

1,200km/h HyperTube Commercialization

HyperTube for Feight

3Km TEST LINE

- Components for Freight Transportation
- Test Line for Freight
- Test & Standardization

HyperTube for Passenger

24km Commissioning Line

- Components for Passenger Transportation
- Trial Commissioning Line for Passenger
- Test & Standardization

Development System

Role allocation & cooperation system

Ministry of Sci, ICT future planning
- IoT tech. support
- Future original tech. support

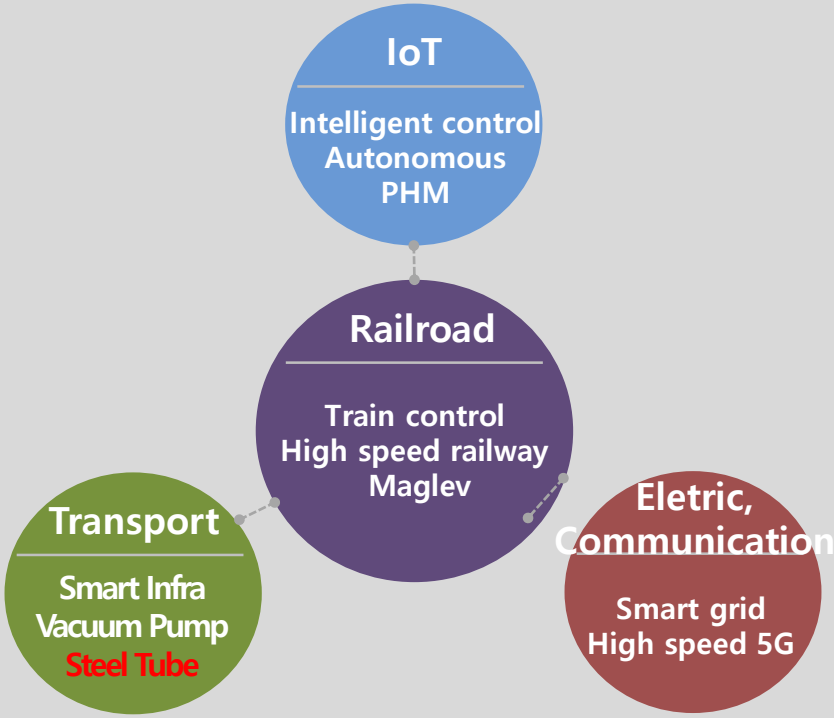
Ministry of land, infra. and transport
- Relevant regulation establishment
- Commercialization

KRRI
- General management
- Core tech. development
- KIET, ETRI, KICT, KIMM, KOTI, KRIHS

Company
- Manufacture capsule pod & infra

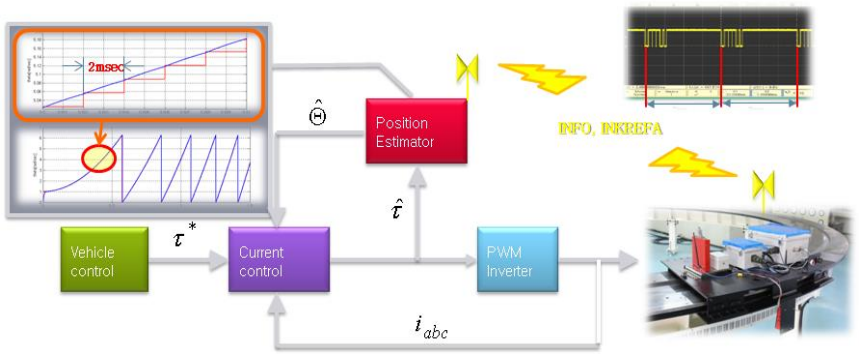
Academic
- Foundation tech. research
- UNIST, Hanyang U.

Similar business combination & connection

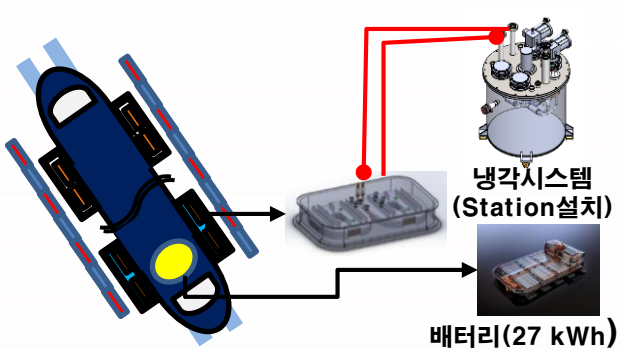


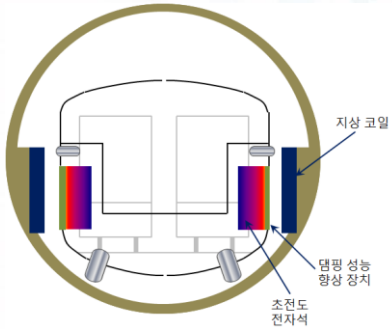
Outcomes so far

- **LSM propulsion design for HTX**

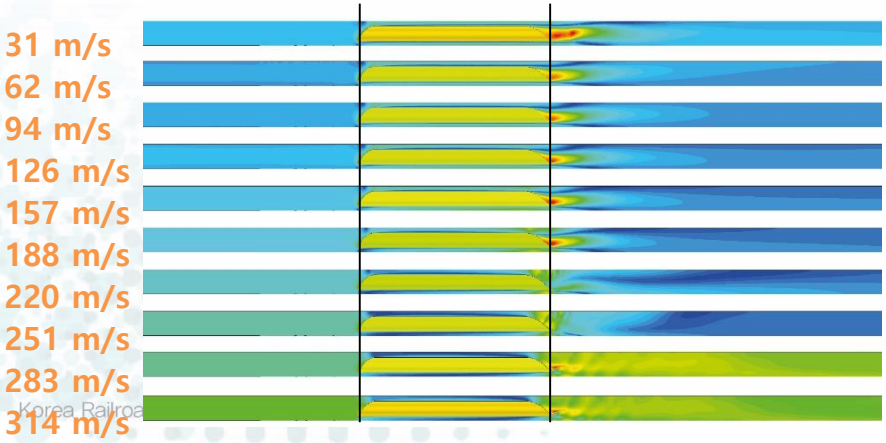


- **Superconducting EDS levitation**
  - **Capsule dynamic analysis**





- **Aero dynamic analysis**
  - **Numerical simulation**



- **Basic Design for HyperTube System**

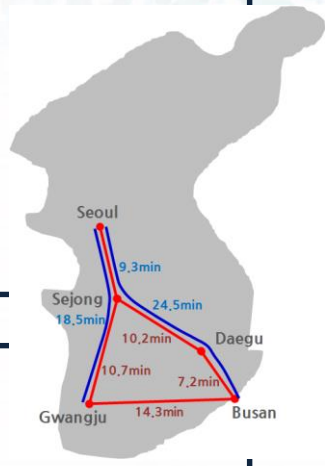
Effects

01 Social effect

- Seoul•Busn in 20 min. → 30 min. life zone within whole country

- Improvement of people life and lead speed up/informatization era
- Decrease intraregional disparity

30 min. life zone Within whole country



02 Industrial effect

- Development of relevant industry development & new business

- Railway market size : 223 trillion won(2014)→ 610 trillion won(2025)
- By assuming of 30% occupation of capsule train,
  creation of new business with 183 trillion won is expected(2025)

03 Technological effect

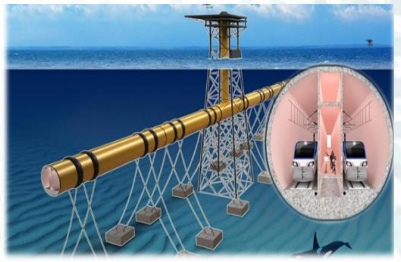
- Lead sci. & tech. by obtaining world first sub-sonic capsule train

- Lead the commercialization technology of new concept transportation
- Obtain standard and technology leadership

Application Plan

- Application to Transportation
  - New line network between main cities
  - 1 hour transportation line after Korea unification
  - Undersea line to Jeju, Japan, and China
  - Intercity lines around 1000Km (over 100conturies, 2600 lines)
  - Intercontinental connection to US, India, Europe

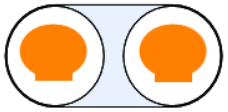
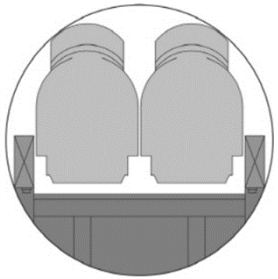
- Application to Industry
  - Automatic transportation in port & logistics depot
    (ex : Busan port, Incheon logistics depot etc.)
  - Transportation of small parcel service in underground or guideway
    (ex : main parcel service site (Seoul stn.- Yeogdeungpo stn. etc.)
  - Precision transfer system
    (ex : TFT LCD glass & panel transfer system etc.)



Requirement of Commercialization

Lower construction & operation cost than existing high speed railroad

▪ Construction limit : KTX vs HTX

HTX	KTX
	
30 ㎡	110㎡

- In case of Hyperloop of America (LA to SF, 670Km)
  - Construction cost : one tenth of existing high speed railroad (US$ 6.5 billion)
  - One way ticket : $20

▪ Reduction factors of construction and operation cost

	HTX	KTX
Construction limit	3m (small capsule, No cartenary)	6m
Weight	30 ton	40 ton
Distance Between lines	3m	Over 7m
Train organization	1	Ave. 15
Power system	1/2~1/4	1
Energy consumption	1/2~1/4	1
Operating engineers	1/2~1/4	1
Wear/ replacement	1/2~1/4	1

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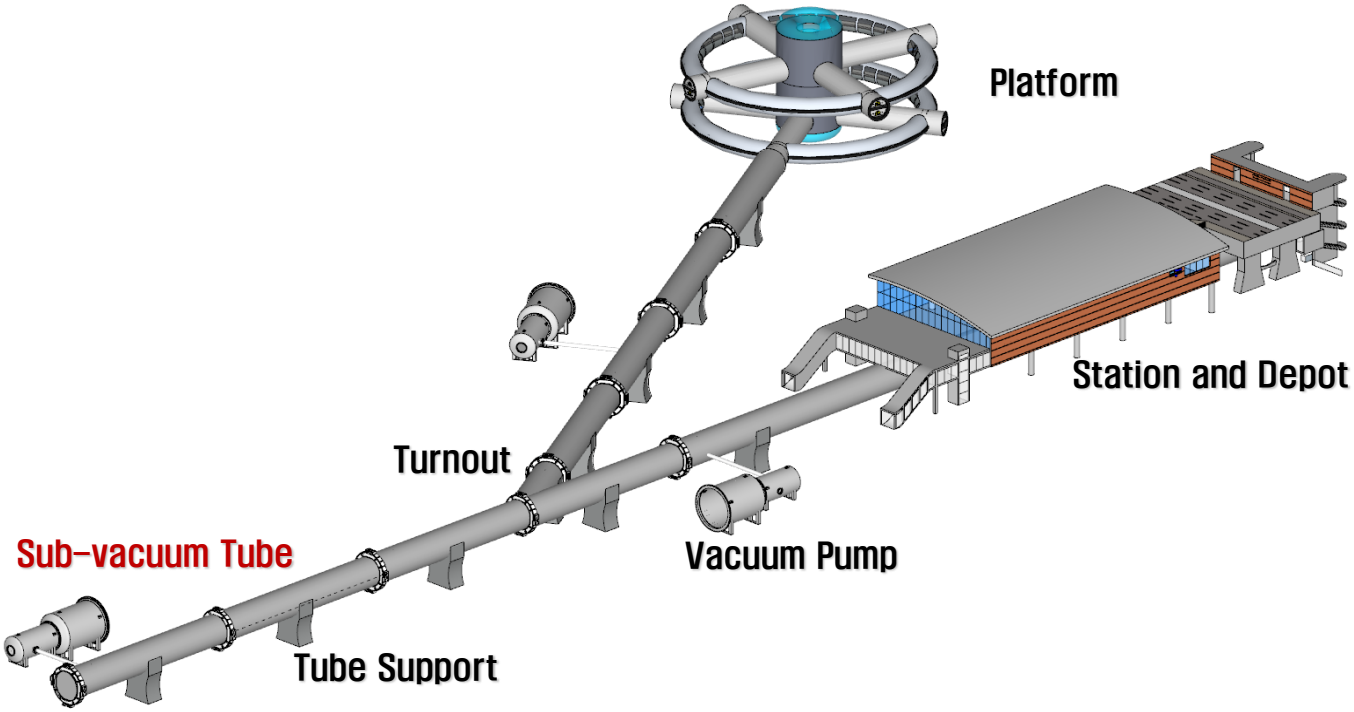
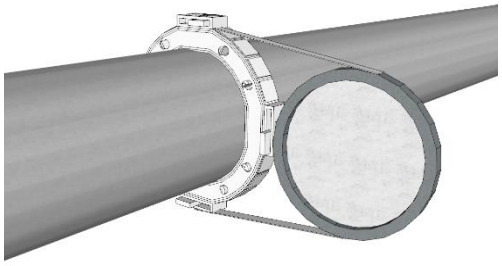
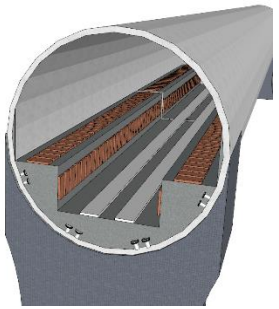
Infra for HyperTube





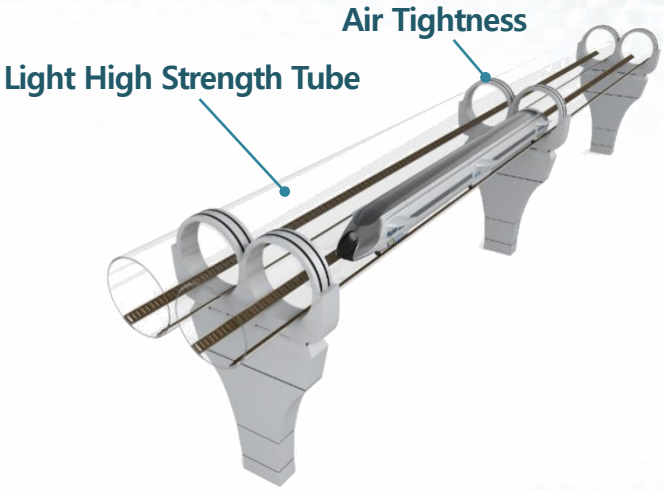
Space Separator

기밀 유지 및 신축 이음장치



Guideway

Sub-vacuum Tube



- Material Requirements for Sub-Vacuum Tube
  - Structural Strength
  - Gas Tightness
  - Manufacturing and Connection with other materials
  - Lower Weight
  - Economics
  - Minimum eletro-magnetic drag force

Steel is optimal so far

Merits	▪ High strength and durability ▪ High resistance for inner/outer shock ▪ High tensile stress and flexibility ▪ Easy welding ▪ Easy connection with faciilities
Demerits	▪ Weak for corrosion and electric corrosion ▪ Difficult for partial maintenance ▪ Magnetizing and Electric conduction ▪ Heavy weight

Steel Tube

(Virgin Hyperloop One)

Steel Tube

(Virgin Hyperloop One)

Steel Tube

(Virgin Hyperloop One)

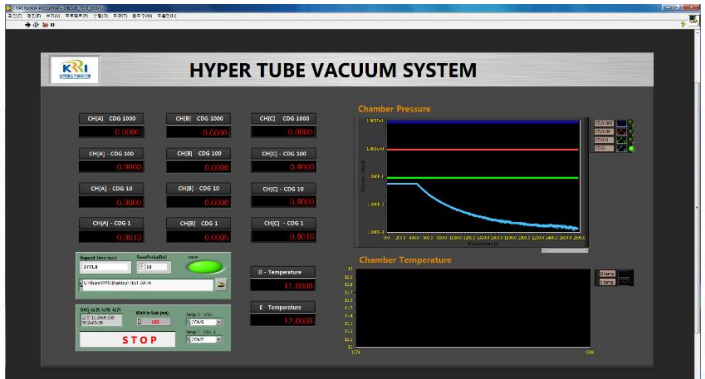
Steel Tube

(Virgin Hyperloop One)

Steel Tube for HyperTube

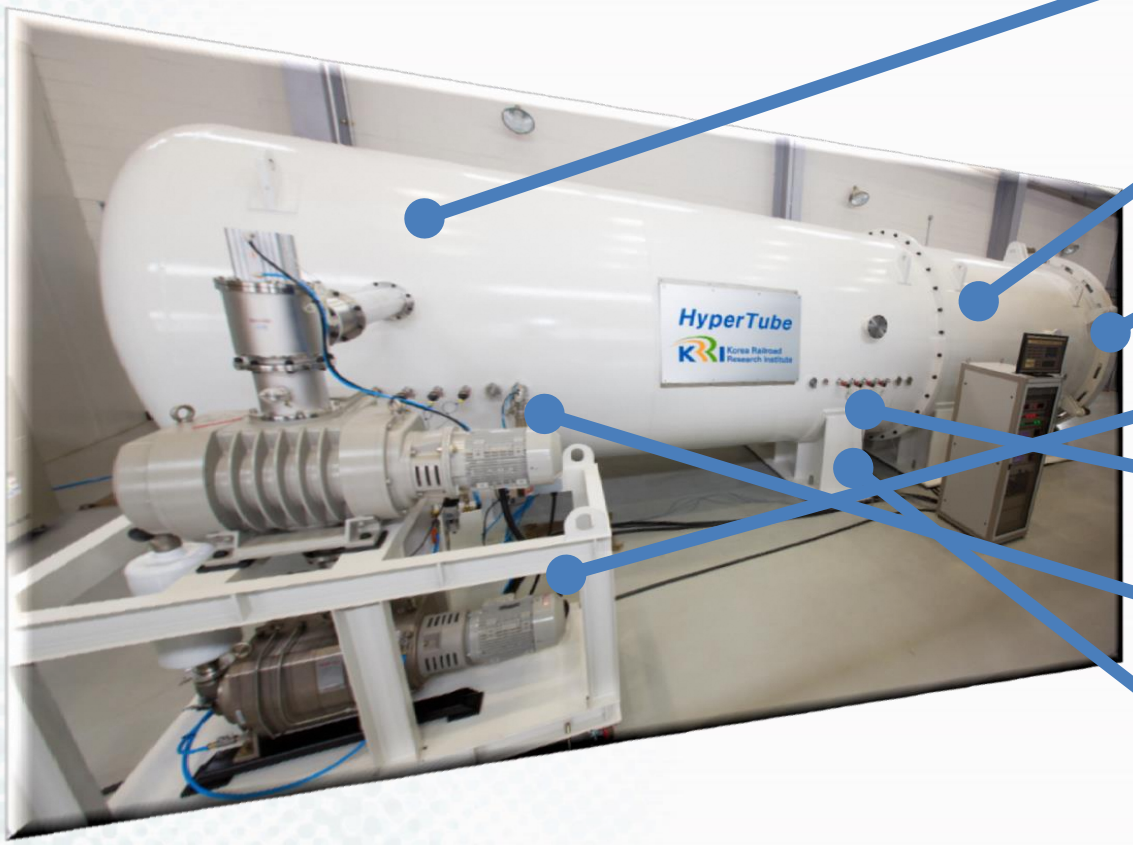
(Korea Railroad Research Institute)

- Prototype of KRRI Vacuum Chamber (Length 10m, Diameter 2.5m)



Steel Tube for HyperTube

(Korea Railroad Research Institute)



Steel Tube #1

Steel Tube #2

Hydraulic door

Vacuum Pump

Exhaust Line and Sensor Port

Vent V/V

Tube Support

Steel Tube for HyperTube

(Korea Railroad Research Institute)

- Technical Characteristics of KRRI Steel Tube Chamber

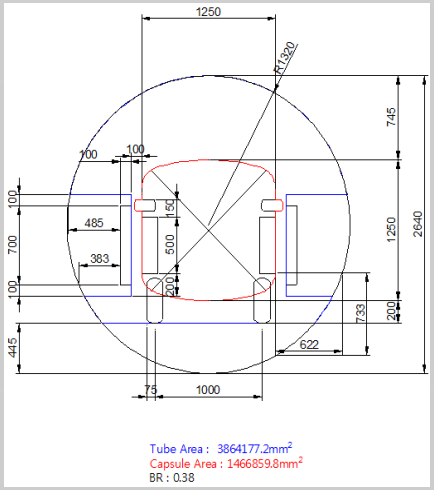
  - Vacuum Pressure : less than 0.75 torr (1 mbar)
  - Chamber Material : ASTM A516 Grade 70(Pressure Vessel Steel)
  - Steel Tube #1 : Dia 2640mm, Length 6000mm, Thickness 23mm
  - Steel Tube #2 : Dia 2640mm, Length 4000mm, Thickness 23mm
  - Gas Exhaust Capacity : 40 min(at 0.75 torr)
  - Weight : 27 ton

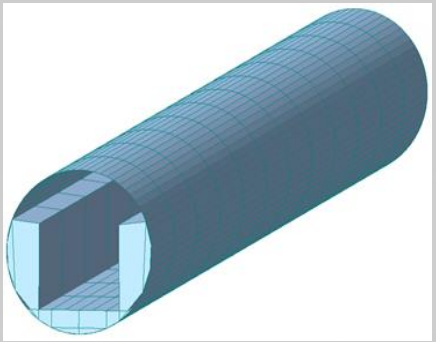
Steel Tube for HyperTube

(Korea Railroad Research Institute)

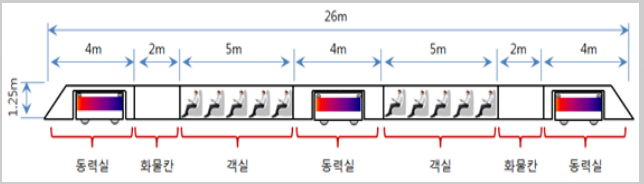
Structural Health Analysis for Sub-vacuum Steel Tube

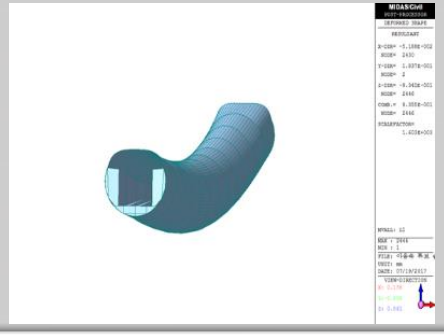
- Properties
  - Inner Dia : 2.64 m, Thickness : 23 mm, Length : 30 m
  - Distance between Tube and Capsule Magnet : 600 mm
  - Unit Weight of Steel Tube : 76.98 kN/m^3
  - Elastic Coefficient of Steel : 205 GPa
  - Unit Weight of concrete Guideway : 24.52 kN/m^3
  - Elastic Coefficient of Concrete : 29.9 MPa

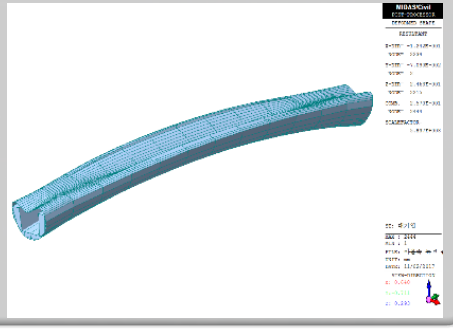




- Structural Health Analysis
  - Self Weight of Tube and Concrete Guideway
  - Capsule Pod Load : 200kN, Axial Load : 33.3kN
  - Environment : Air Pressure 1 atm, Temperature ± 30°
  - Deflection due to Dynamic Load : 0.93 mm
  - Deflection due to Pressure : 0.25 mm
  - Stress : 40.2Mpa (Guideway Ppoit)

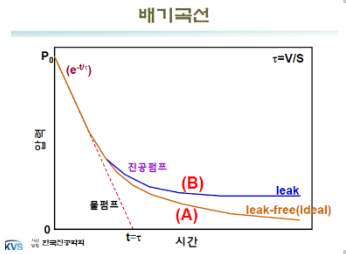






Sub-Vacuum Sysem for HyperTube

(Korea Railroad Research Institute)

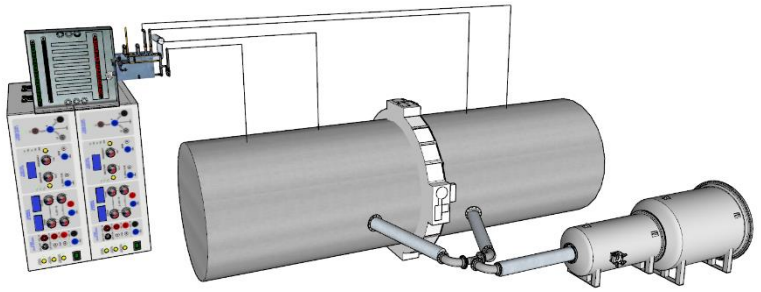


◈ Capacity Calculation of Vacuum Pump

$$S(L/\min) = 2.303 \times k(V/T) \times Log(P_1/P_2)$$

V : Volume of Chamber
T : Time to Targeted Vacuum
P1 : Initial Air Pressure of Chamber
P2 : Targeted Vacuum
k : Safety Factor

- Low Vacuum Pump : over Exhaust Speed 2000L/min
- Needed Pumps : 103EA/km (including Outgassing)



◈ Gas Tightness Test

- Chamber (Inner Dia : 2.64m, Length : 2@5m)
- Gas kit, Flexible Joint(bellows) leakage

◈ Flexible Joint

- Unit Tube Length 30m
- Resist to pressure difference
- Expansion and Contraction due to Temperature Variation

Thank you for your attention.