International Conference Series on European Hyperloop Technology

Technological Development in Large Scale Research Infrastructures

Dr. Ralf Effenberger, INTIS GmbH, February 23rd 2021

Presentation contents

- About INTIS GmbH
- What does "Large Scale" mean?
- Example for Large Scale (testing) infrastructure – Space Research
- Example for Large Scale (testing) infrastructure – Aerospace Testing
- Example for Large Scale (testing) infrastructure – TVE (maglev)
- Why maglev can help to develop Large Scale Research Infrastructures for Hyperloop
    - Technology
    - Operations & Maintenance
- Large Scale Research Infrastructures – a must for the validation of Hyperloop technology and operational aspects
- TVE being available for the provision of Large Scale Research Infrastructure services
- Questions?

About INTIS GmbH

- Company founded in December 2011 in Hamburg; spin-off of the “Transrapid-Versuchsanlage Emsland (TVE)” maglev test track
- INTIS is 100% owned by IABG mbH, a company based in Ottobrunn near Munich

<u>Our focus (1):</u> **Charging Technology for e-mobility**

- turn key wireless power transfer solutions (“inductive charging”)
- Combined (WPT & DC-conductive)
- for use in public environment (incl. micromobility), industrial & maritime applications

<u>Our focus (2):</u> **finding way’s to re-use the TVE/ testing of future high speed rail guided systems**

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What does “Large Scale” mean?

Large Scale Research Infrastructures

- Large ↳ in terms of it’s size: “big” or “huge”
- Scale ↳ with respect to size of test specimen(s)
- Large Scale ↳ for research, validation- & qualification testing at (up to) system level, usually at scale 1:1

Example for Large Scale (testing) infrastructure – Space Research

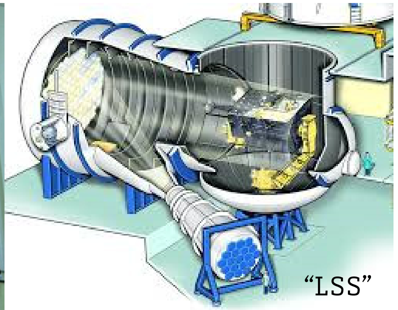
ESA/ESTEC: → European Space Research and Technology Centre (Noordwijk, The Nethelands)

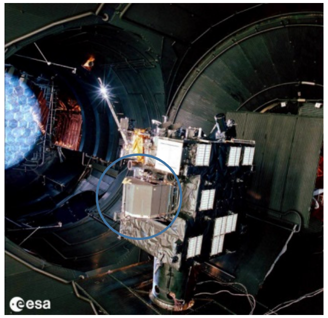
Largest Space Test Center in Europe (about 200m x 200m → not very large in size…)

… operating an environmental test centre for spacecraft, with supporting engineering laboratories specialised in systems engineering, components and materials, and working within a network of other facilities and laboratories.

…but testing of different satellite development stages at scale 1:1 possible (sources: ESA)

ATV-StM in "LEAF"





Rosetta-FM with lander Philae in "LSS"

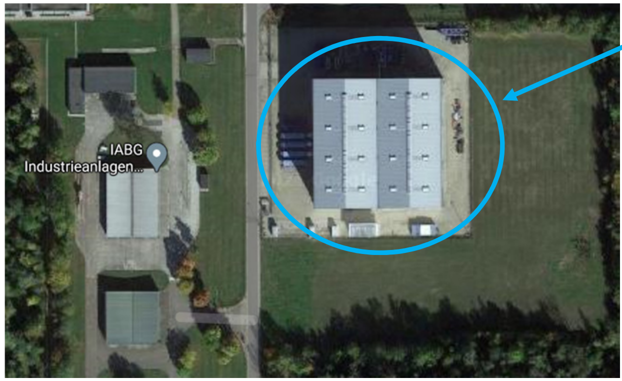
ATV-FM in EMC-chamber

AEOLUS-StM on multi-shaker

LEAF – Large European Acoustic Facility; LSS – Large Space Simulator; StM – Structural model; FM – Flight model; Rosetta and its lander Philae did have a rendezvous with the comet Tschurjumow-Gerassimenko (2014 … 2016, 12.11.2014); Aeolus: ESA satellite for earth observation (in service)

Example for Large Scale (testing) infrastructure – Aerospace Testing

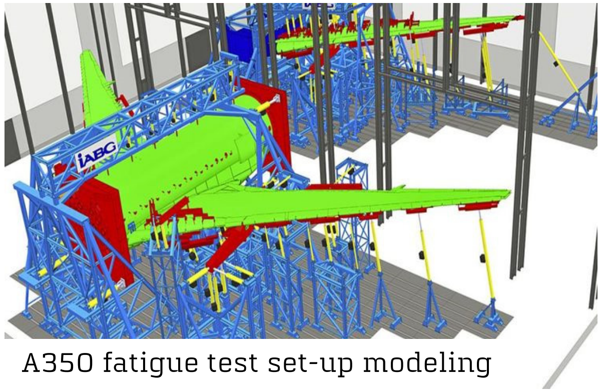
IABG's aircraft full-scale testing facility at the airfield near Erdingen



<u>Test Hall Size</u> (about 5000m2 → not very large in size…)

…but full-scale (1 : 1) testing of relevant aircraft structures possible (sources: IABG)

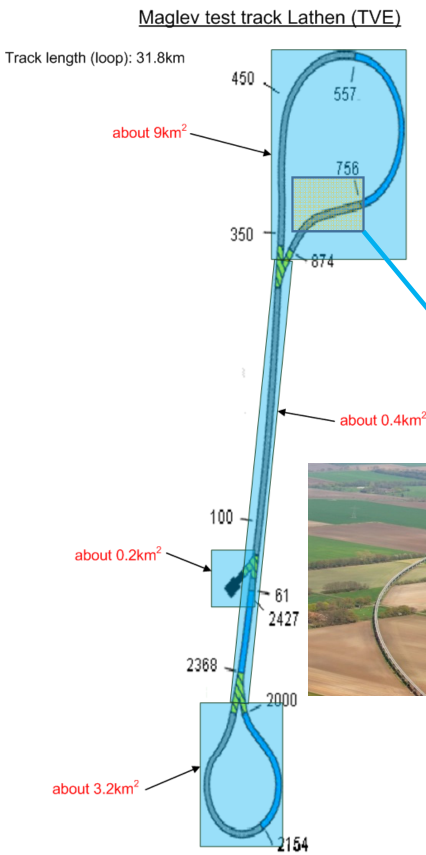

A350 test building


A350 fatigue test set-up modeling


A350 fatigue testing

Example for Large Scale (testing) infrastructure – TVE (maglev)

IABG's high speed rail (maglev) full-scale testing facility (Lathen, Emsland)



<u>Test site "land occupation"</u> (about 12.8 km2 → large size, for full scale testing of all subsystems & at system level)

- erected on private land (rented from several different land owners)
- operated between 1983 and 2011
- not surrounded/ secured by e.g. fences

→ <u>operated in public environment</u>

- operations & maintenance ruled by law: „Gesetz über den Bau und den Betrieb von Versuchsanlagen zur Erprobung von Techniken für den spurgeführten Verkehr"
  - approving authorities to be appointed
  - any kind of activities to be validated/ approved by independent expert witness (assessors)
  - operations and maintenance to be done on the basis of approved procedures
- show video "November 2011 - TR09 last ride on TVE"

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Example for Large Scale (testing) infrastructure – TVE (maglev)

Transrapid (maglev) Testing Facility Emsland (TVE)

The TR09 at the German Transrapid Testing Facility (TVE)

copyright: IABG mbH, September 2010

Example for Large Scale (testing) infrastructure – TVE (maglev)

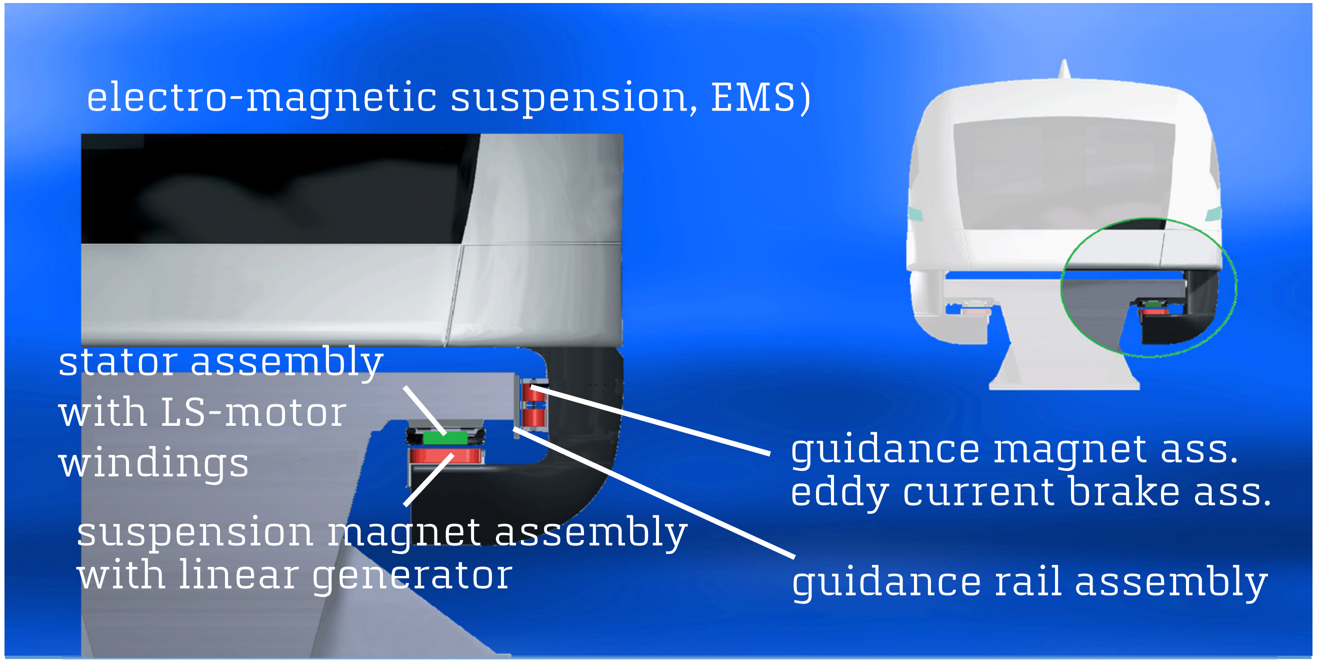
Transrapid (maglev) Testing Facility Emsland (TVE)

The TR09 at the German Transrapid Testing Facility (TVE)

Why maglev can help to develop Large Scale Research Infrastructures for Hyperloop → Technology

- Maglev (here Transrapid) already provides proven technical means for high speed rail guided (contactless) applications up to 500km/h but without tube & vacuum

→ Experience from maglev system level testing can help to define technical requirements for Hyperloop Large Scale Research- & Testing Infrastructure



Why maglev can help to develop Large Scale Research Infrastructures for Hyperloop → Operations & Maintenance

- Maglev (here Transrapid) already provides operational procedures for high speed rail guided (contactless) applications up to 500km/h but without tube & vacuum

→ Experience from maglev system operations and maintenance can help to define operational requirements for Hyperloop Large Scale Research- & Testing Infrastructure

Example: passenger evacuation:

Large Scale Research Infrastructures – a must for the validation of Hyperloop technology and operational aspects

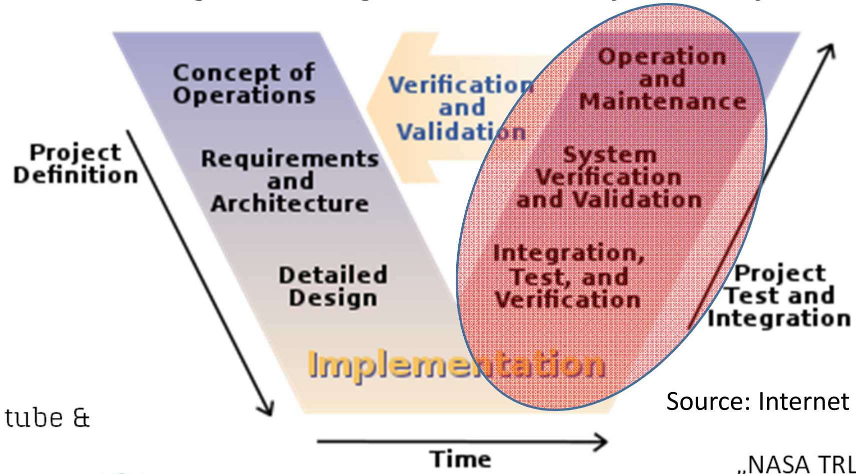
SDLC - systems development life cycle

„V-Model“ : a SDLC* -presentation, applicable for the different hard- and software configuration stages, (at unit-, subsystem- & system level)

Large Scale Research Infrastructures for:

- functional validation of subsystems, e.g.:
  - guideway with tubes and vacuum system
  - propulsion-, levitation-, guidance
- functional validation at system level, e.g.:
  - interactions (propulsion, levitation, guidance, vehicle, tube & vacuum system)
- supporting the process for gathering approvals/ permissions, e.g.:
  - HARA- generation & validation (operations, maintenance, safety matters, emergency procedures, etc…)

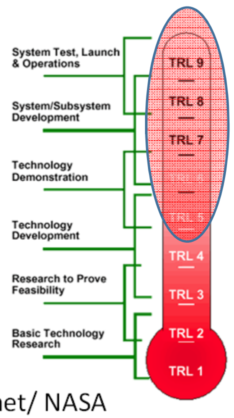
Σ → supporting TRL-phases 5 to 9+



Source: Internet

- Large Scale Testing Facilities involvement required

„NASA TRL- Meter“:



Source: Internet/ NASA

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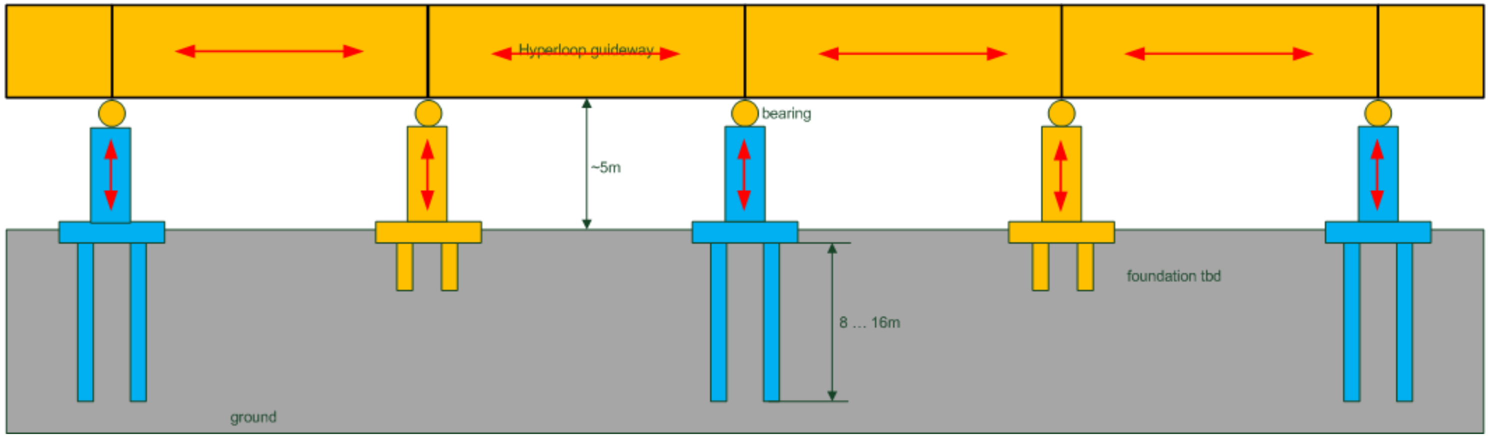
TVE being available for the provision of Large Scale Research Infra-structure services (1)

… e.g. for design & functional validation of guideway/ tube construction:

- How to design guideway/ tubes & bearings at supporting pillars in order to handle lateral expansion, due to temperature changes - and how to maintain air tightness at tube section interface/ cross-over?

lateral mechanical expansion, caused by temperature changes:



TVE being available for the provision of Large Scale Research Infra-structure services (2)

… e.g. for design & functional validation of guideway/ tube construction:

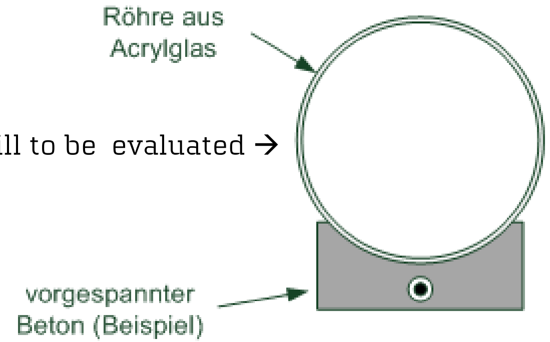
- How to design guideway/ tubes in order to cope with static loads & loads induced by rolling stock, wind, etc.?

<u>… e.g. acrylic glass without concrete support (examples):</u>

Bestimmung des max. Biegemoments Acrylglas		
Eingaben:		
Durchmesser außen:	4	m
Durchmesser innen:	3,9	m
Wandstärke=	0,05	m
Länge Röhre:	25	m
Dichte Acryl:	1,185	g/cm^3
E-Modul:	3000	N/mm^2
Zugfestigkeit:	40	N/mm^2
Zugfestigkeit für Berechnungen:	25%	
Bauteildaten:		
Q-Fläche außen=	1,26E+01	m^2
Q-Fläche innen(Öffnung)=	1,19E+01	m^2
Q-Fläche=	6,20E-01	m^2
Volumen=	1,55E+01	m^3
Eigengewicht=	183.812,62	N
mechanische Eigenschaften:		
IY,IZ:	1,21E+00	m^4
amax:	2	m
Wax:	6,05E-01	m^3
Mb=	6,05E+06	Nm
max. Biegemoment durch Eigengewicht=	5,74E+05	Nm
max. Durchbegung durch Eigengewicht (Trägerhälfte)=	**10,30**	**mm**
verbleibendes Biegemoment für Verkehrslast=	5,48E+06	Nm
Fahrzeuglinienlast (Beispiel)=	1,00E+04	N/m
Fahrzeuglänge=	12,5	m
Fahrzeuggesamtgewicht=	1,25E+05	N
max. Biegemoment durchVerkehrslast=	5,86E+05	Nm
verbleibendes max. Biegemoment (Reserve)=	4,89E+06	Nm
Sicherheitsfaktor Durchbiegung:	834,75	%
max. Durchbegung durch Verkehrslast (Trägerhälfte)=	4,03	mm
max. Durchbegung gesamt (Trägerhälfte)=	**14,33**	**mm**

Bestimmung des max. Biegemoments Acrylglas		
Eingaben:		
Durchmesser außen:	4	m
Durchmesser innen:	3,9	m
Wandstärke=	0,05	m
Länge Röhre:	12,5	m
Dichte Acryl:	1,185	g/cm^3
E-Modul:	3000	N/mm^2
Zugfestigkeit:	40	N/mm^2
Zugfestigkeit für Berechnungen:	25%	
Bauteildaten:		
Q-Fläche außen=	1,26E+01	m^2
Q-Fläche innen(Öffnung)=	1,19E+01	m^2
Q-Fläche=	6,20E-01	m^2
Volumen=	7,76E+00	m^3
Eigengewicht=	91.906,31	N
mechanische Eigenschaften:		
IY,IZ:	1,21E+00	m^4
amax:	2	m
Wax:	6,05E-01	m^3
Mb=	6,05E+06	Nm
max. Biegemoment durch Eigengewicht=	1,44E+05	Nm
max. Durchbegung durch Eigengewicht (Trägerhälfte)=	**0,64**	**mm**
verbleibendes Biegemoment für Verkehrslast=	5,91E+06	Nm
Fahrzeuglinienlast (Beispiel)=	1,00E+04	N/m
Fahrzeuglänge=	12,5	m
Fahrzeuggesamtgewicht=	1,25E+05	N
max. Biegemoment durchVerkehrslast=	1,95E+05	Nm
verbleibendes max. Biegemoment (Reserve)=	5,71E+06	Nm
Sicherheitsfaktor Durchbiegung:	2924,83	%
max. Durchbegung durch Verkehrslast (Trägerhälfte)=	0,88	mm
max. Durchbegung gesamt (Trägerhälfte)=	**1,52**	**mm**

→ proposed solution, still to be evaluated →



- in both cases still unacceptably high tube deflection / bending!

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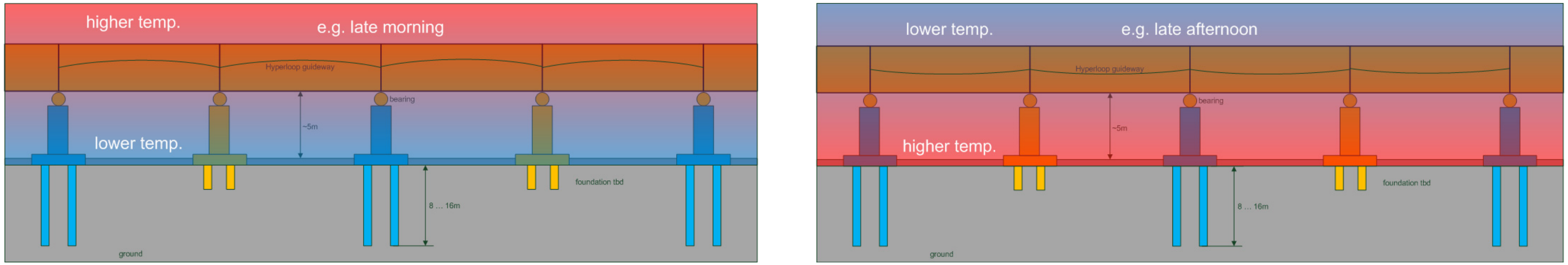
TVE being available for the provision of Large Scale Research Infra-structure services (3)

… e.g. for design & functional validation of guideway/ tube construction:

- How to design guideway/ tubes in order to keep deformation by thermal gradients (day-night temperature changes) as low as necessary?

mechanical bending, caused by guideway temperature gradients:



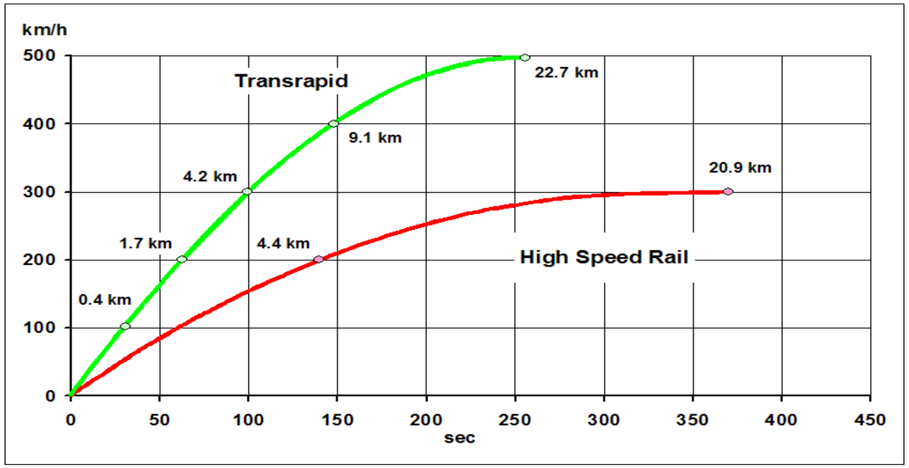
TVE being available for the provision of Large Scale Research Infra-structure services (4)

… e.g. for design & functional validation of Hyperloop propulsion system:

- in order to ensure, that the propulsion & braking system provides the required acceleration & deceleration forces?

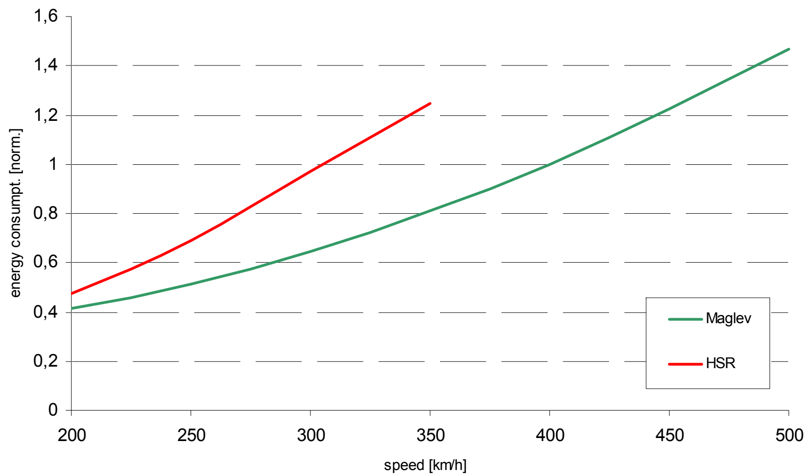
example: maglev acceleration ability:

- comparably high acceleration at all speed levels and during braking phase
- independent of the weather conditions, no friction forces required (rail-wheel)



example: maglev energy consumption (secondary):

- 200 km/h: 22 watt hours per seat and km vs. 29 (CRS)
- 300 km/h: 34 watt hours per seat and km vs. 51 (CRS)
- 400 km/h: 52 watt hours per seat and km vs. ?? (CRS)



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Questions ??

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