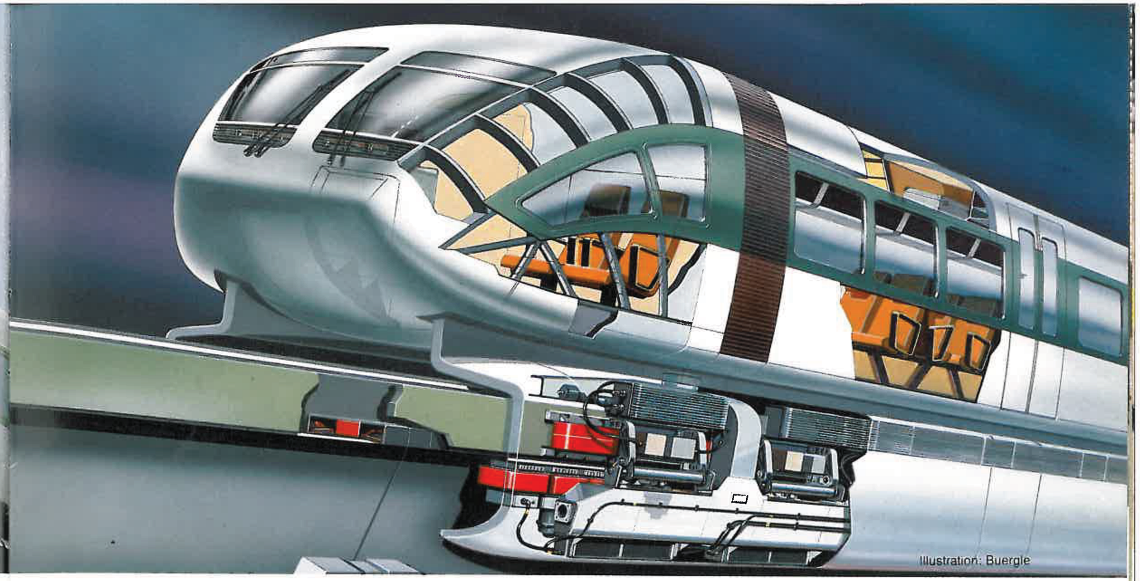
On 17 August 1984, TRANSRAPID 06 achieved its first world record, 302 k.p.h.



A new means of transport cannot be realised with old technology.

TRANSRAPID 06, the TVE vehicle.

In size, equipment and specifications, there is hardly any difference between TRANSRAPID 06 and future operational vehicles. The vehicle consists of two identical sections, between which additional sections can be inserted later for public transport service. It reaches 400 k.p.h. and is 54 m long; it weighs 120 t and has 196 seats.

Vehicle construction.
The conception and aerodynamic design of the vehicle draw heavily on the experiences gained in aircraft construction. This is the first time, for example, that such a vehicle has been produced with an aluminium sandwich construction. And drag at 400 k.p.h. is only some 37 kN.

The coach body of each vehicle section is mounted on four levitation frames having pneumatic springs fitted with automatic level control. As with vehicle frames in railway trains, the magnetic railway's levitation frames contain the support and guidance system, and the vehicle's part of the propulsion and braking system (the other part of which in the case of the linear motor is in the guideway). These contact-free electromagnetic systems are what is so new about TRANSRAPID

Support and guidance.
The support and guidance system works on the principle of electromagnetic levitation.

This technology works with electromagnets in the vehicle and metal rails in the track. 32 load-bearing magnets per section lift the vehicle up to the track, while a control system ensures an invariable air gap of about 1 cm. 28 guiding magnets per section control the tracking.

Each magnet is 1.5 m long, independently suspended and decentrally controlled. This permits adjustment of

each magnet to the course of the track ("electromagnetic wheel"). When the magnets are switched off, the vehicle rests on a system of sprung skids, on which it also comes to a safe halt in the event of a malfunction.

Propulsion and braking.
The propulsion and braking system works on the principle of the synchronous long-stator linear motor.

With this technology, an electromagnetic travelling wave is produced in the windings in the track over the whole line (hence "long stator") which pulls the vehicle along by its load-bearing magnets. A static frequency changer adjusts the thrust by varying the voltage and frequency to achieve the desired speeds, while braking works by simply reversing the thrust. Independently of this, there is a stand-by mechanical braking system.

The on-board energy supply.
The TRANSRAPID 06 is the first vehicle approaching the stage of implementation in which contact-free energy transfer has been realised. The transfer system is based on linear generators in the load-bearing magnets, which when in motion induce the power for the supporting/guiding system and for the on-board energy supply.

The linear generators are so designed that the power needed for the supporting/guiding system becomes available at about 85 k.p.h. At lower speeds, the power transferred is inadequate. At this stage, the vehicle is powered by buffer batteries, which can be recharged when speeds of more than 125 k.p.h. are achieved.

10.1 m and 11.4 m respectively. The track gauge is 2.8 m.

At-grade guideway consists of open style steel plates with integral substructures bolted to a concrete strip foundation. The beam length is 6.2 m and the foundations are laid approx. 300 mm below ground level to allow for planting. There are open passages with a clearance height of at least 850 mm under the guideway to permit the passage of small animals.

Elevated guideway utilizing steel beams with spans of 2 x 12.4 m and 2 x 31 m are available to traverse greater distances and uneven terrain. For double-track guideway, the substructures include a common concrete foundation supporting both tracks by way of reinforced concrete columns. For the elevated guideway for higher gradients (greater than 3.5 m), the substructure also includes two in-situ columns and a cross beam near the top. The foundations are designed as concrete slabs with or without pilings, depending on the local ground conditions (Fig. 6).

To change tracks near stations, two- and three-way, low speed guideway switches are used with a turnout speed of 100 km/h. The switches consist of a continuous steel box beam, 78.4 m long, which is elastically bent by means of electromechanical setting drives with locks for the end positions. The end position is reliably monitored by sensors.

Four crossovers are planned along the route itself. These will normally consist of four three-way, low speed switches without track widening. The crossovers are to be situated at the junctions of propulsion segments so that in the case of a local malfunction on one track, operations can continue on a single track. Should this happen, then trains scheduled at intervals of 35 minutes are still possible.

Changing tracks within the central maintenance facility will be achieved using a transfer table with three connecting tracks in the maintenance hall.

Vehicles

The vehicle fleet comprises four-section vehicles for passengers, containing about 340 seats. The interior can be varied to suit passengers' requirements, within the limits of the vehicle specification. A design competition for the interior is currently in progress.

As passenger volumes increase after about 2010, five-section vehicles containing about 450 seats will be introduced (Fig. 7).

Propulsion system

A total of 12 substations will ensure the supply of propulsion energy for the trains and serve all the electrical equipment along the route. Two substations with an average energy requirement of 2 MW will be located at the ends of the line in order to supply energy to the propulsion segments at the terminals and parking facilities; another is required for the central maintenance facility. The remaining substations, with an average energy requirement of 7-12 MW, will supply energy to the propulsion segments, which range from 10 to 45 km long, via section feeder cable systems and electrical switching stations (Fig. 8).

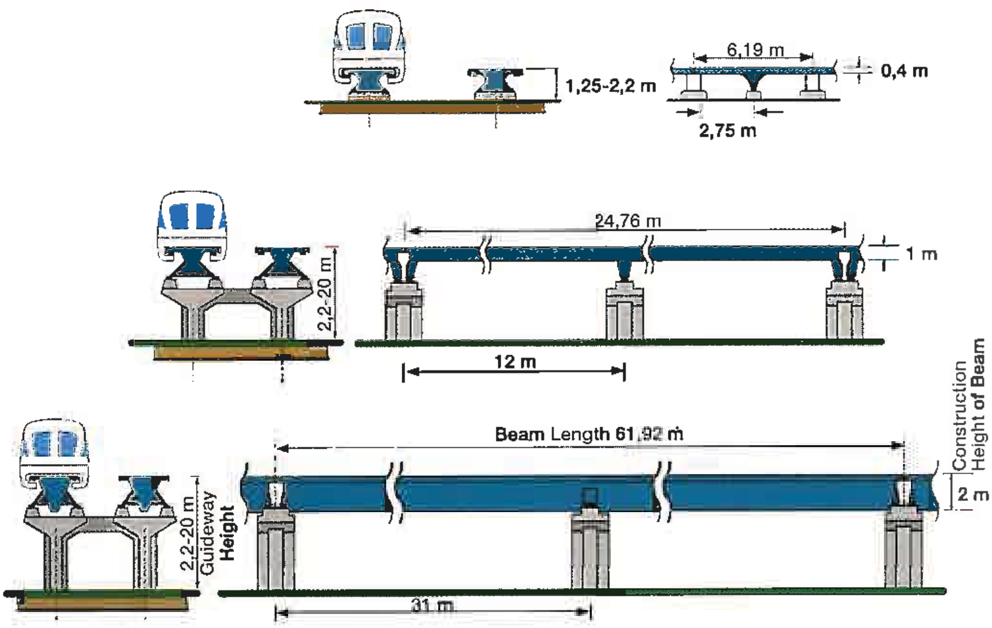
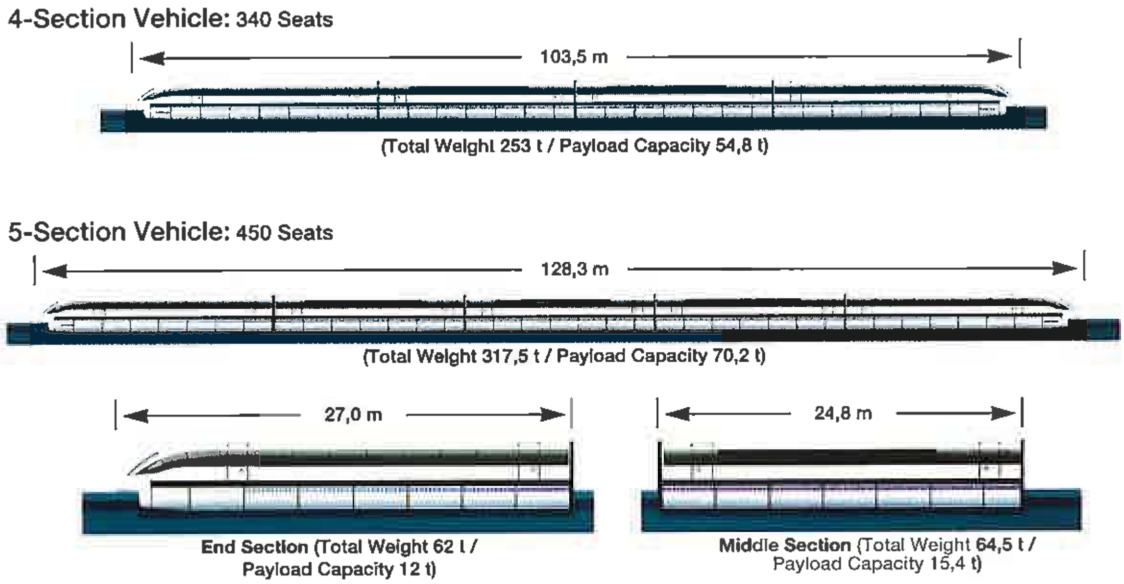


Fig. 6: Types of Steel Guideway, Maglev System Berlin–Hamburg

Fig. 7: Vehicle Configuration, Maglev System Berlin–Hamburg



Control system

The operation of the Berlin–Hamburg maglev system is carried out automatically and technically safeguarded. A control center near the Schwerin terminal handles all communications, information, control, and operating tasks for the entire maglev system.

Directional radio data transmission is employed for data transmission and communication between the stationary control equipment along the route and the mobile installations in the vehicles. A pair of neighboring stationary transceiver units mounted on masts ensures a built-in redundancy for the radio contact with every vehicle by covering both tracks. The masts are located alongside the guideway every 1-3 km. Data transmission between the control center, terminals, substations, switches, and radio masts is realized by means of fiber optic cables.

Energy supply

The substations for the maglev system are connected to the public grid via dead-end feeders. The connection will normally be at 110 kV level by means of high-voltage switching systems in the substations. The electrical consumers along the route will be fed from the substations via medium voltage cables and transformer substations (1 kV/20 kV).

Route periphery

The facilities and installations for the maglev system which are situated along the route, e.g. auxiliary stopping areas, transformer substations, electrical switching stations, radio masts, and cables, will be designed and positioned as part of an integrated design process based on the route alignment as well as the position of the track crossovers and substations, taking into account the existing infrastructure and local circumstances. This will ensure that technical systems are optimized along the route periphery with sufficient accuracy for planning permission purposes (Fig. 9).

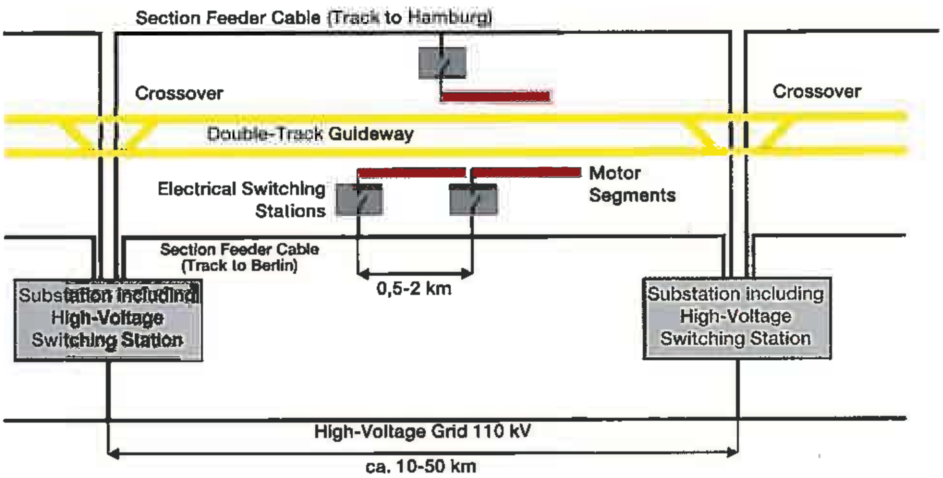


Fig. 8: Propulsion System, Maglev System Berlin–Hamburg

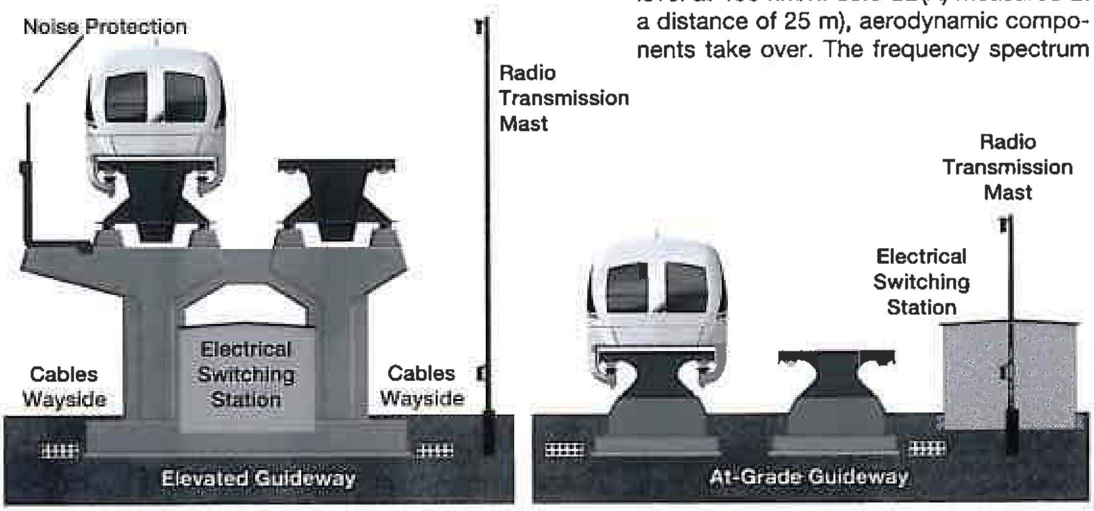


Fig. 9: Route Periphery, Maglev System Berlin–Hamburg

3.2 Operating data

- ▷ Maximum operating speed is 450 km/h.
- ▷ Acceleration up to 1.5 m/s2, e.g. from 0 to 400 km/h in approx. 3 min. over approx. 10 km.
- ▷ Trains at least every 20 min. during peak periods (10 min. by expanding the fleet of vehicles and the propulsion system for an increasing traffic volume).
- ▷ Distinction between lines: no intermediate stops or stopping at every terminal.
- ▷ Carrying capacity of 12-30 million seats p.a. can be flexibly adjusted (by expanding the fleet of vehicles and the propulsion system for an increasing volume of traffic and expansion of the operating program).
- ▷ Average power requirement for operations and power supply of all electrical equipment (including all facilities) is approx. 65 MW.
- ▷ Environmentally friendly operation and high technical availability.
- ▷ Each vehicle travels 2,700 km per day on average.
- ▷ Each vehicle travels 1 million km p.a. on average.

3.3 Environmental data

The non-contact and non-wearing support, guidance, and propulsion functions of the maglev system are the foundation for environmentally compatible operation.

Noise

The noise emission of the maglev trains are distinguished by relatively low levels. At low speeds (peak level at 200 km/h: 75.7 dB(A) measured at a distance of 25 m), mechanical noise components predominate, whereas at higher speeds (peak level at 400 km/h: 88.5 dB(A) measured at a distance of 25 m), aerodynamic components take over. The frequency spectrum

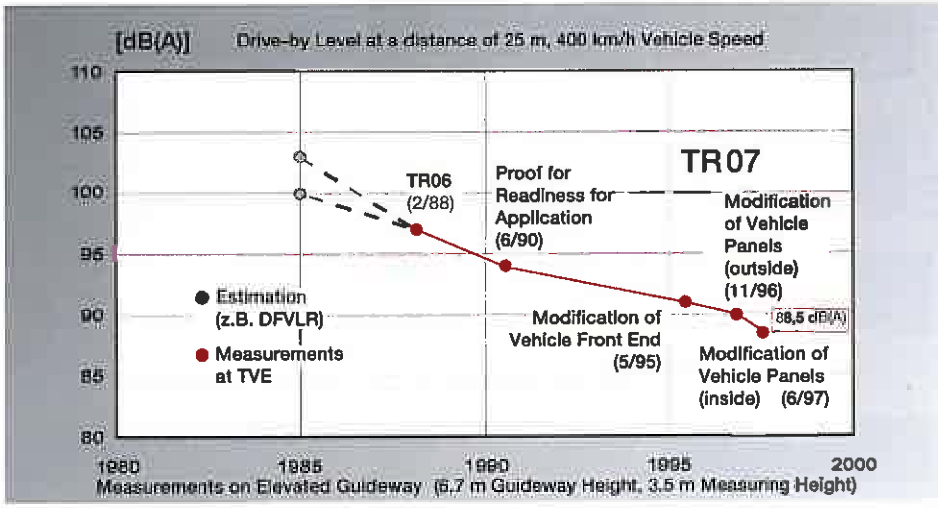


Fig. 10: Reduction of Noise Emission (Drive-by Level)

exhibits a uniform level over the range from 200 Hz to 4 kHz without conspicuous peaks.

The noise emission has been reduced through aeroacoustic optimization of the front end of the vehicle and by modifying the body work panels at the front and underneath (Fig. 10).

The noise level calculations were carried out in accordance with the Maglev Train Noise Abatement Act. Taking the proposed operational program as a starting point, assessment levels can be determined, which in most cases lie below the statutory limits, e.g. 49 dB(A) in residential districts at night time. However, if a further reduction in noise emissions is required, then this can be accomplished by way of conventional noise protection measures.

Energy consumption

The specific secondary energy requirement of the Berlin–Hamburg maglev system is approx. 66 Wh per seat kilometer. This favorable figure is the outcome of the virtually non-contact operation, the high degree of efficiency of the synchronous long-stator motor as well as the low vehicle weight and low aerodynamic resistance. The carbon dioxide emissions are also correspondingly low at approx. 2.5 kg per 100 seat kilometers.

3.4 Project timetable

The end of the regional planning harmonization is indicated by comments given by the five federal states affected. The planning permission procedures which now have to be started will mean that the project will be checked once again by the Eisenbahn-Bundesamt (Federal Railway Authority) in its capacity as planning authority. After accomplishing the public hearings and after gathering and weighing-up all arguments and issues, each section of the line will be approved in turn. At the same time, the program for obtaining type certification for vehicles, propulsion system, control system and guideway including switches will be brought to a conclusion.

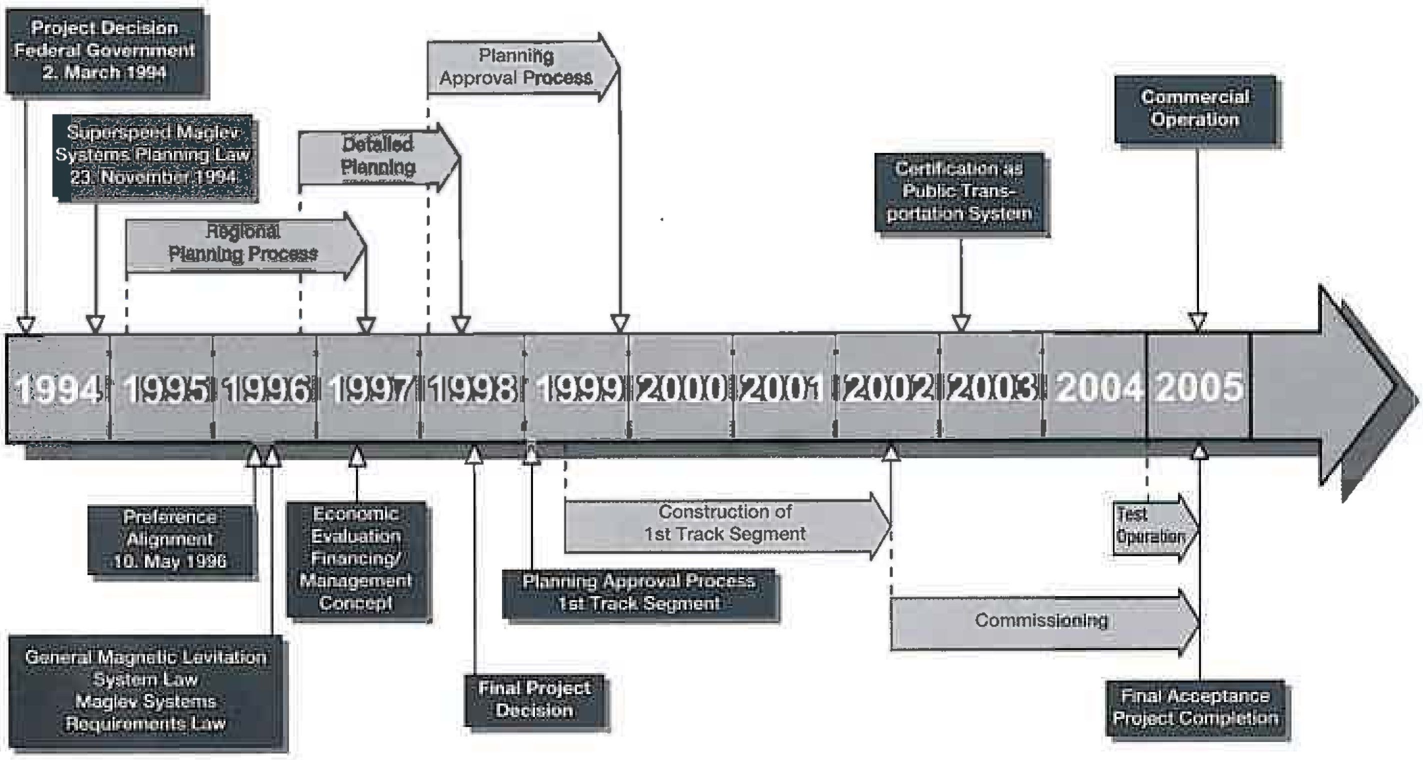


Fig. 11: Project timetable, Maglev System Berlin–Hamburg

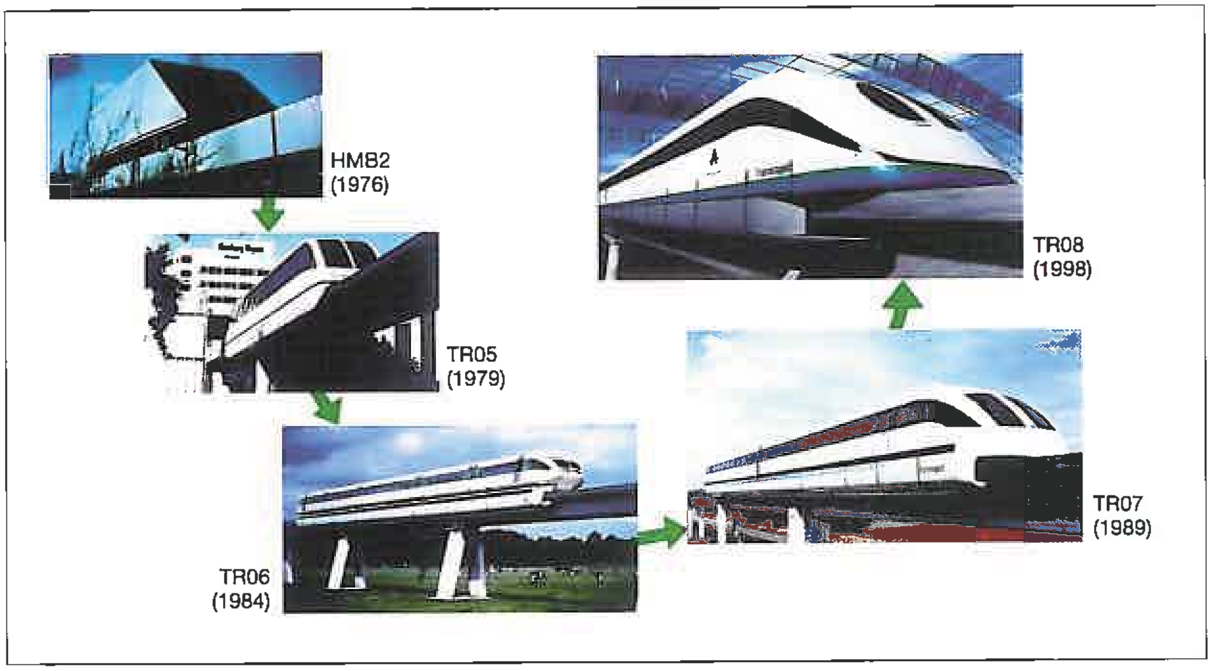


Fig. 2: Development of Transrapid Vehicles

land, TVE), the only facility of its kind in the world.

The passing of the Maglev Systems Planning Act by both houses of the German Parliament and the formation of Magnetschnellbahn-Planungsgesellschaft mbH (Maglev Planning Company) in October 1994 to coordinate the planning were further important milestones on the way to realizing the Berlin–Hamburg Project.

ARGE Systemauslegung Transrapid has been established by the system companies in order to handle the systems design for this pioneering transportation project. As a subcontractor to the Magnetschnellbahn-Planungsgesellschaft and working closely together with Deutsche Bahn AG and the various consultants involved with the project, ARGE will carry out the technical work on systems for the public legal planning process (Fig. 3).

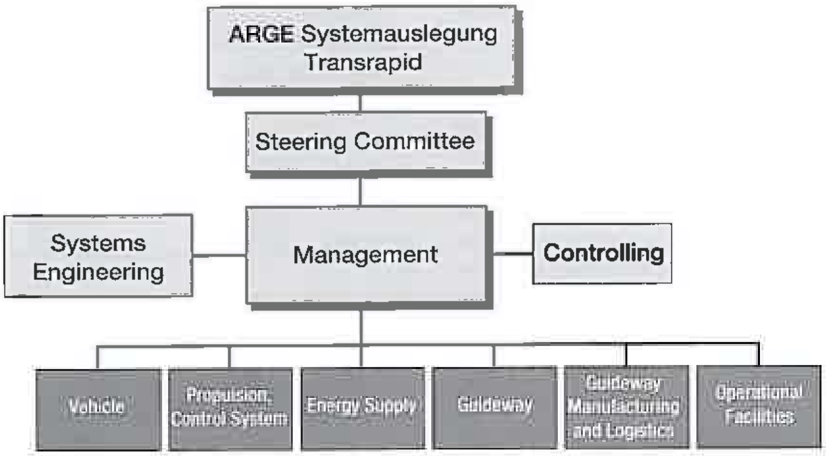


Fig. 3: Organization of ARGE Systemauslegung Transrapid

2 The Superspeed Maglev System

2.1 Maglev system technology

The essential system characteristics of maglev system technology are outlined below:

- ▷ The electromagnetic levitation and guidance systems for the non-contact levitation function.
- ▷ The synchronous, ferromagnetic longstator motor for the non-contact propulsion and braking functions.
- ▷ The non-contact transfer of energy into the vehicles via linear generators integrated into the levitation magnets for the safe-life, on-board power supply.
- ▷ The additional, non weather-dependent eddy current brakes in the vehicles for the safe-life braking function.
- ▷ The steel or concrete guideway, at-grade or elevated, with various spans to enable a flexible route alignment suited to the local conditions.
- ▷ Two- and three-way guideway switches for low or high speed track changes and track crossovers with or without an increase of the distance between tracks as well as transfer tables for changing tracks in depot areas are available to suit operational needs.
- ▷ Automatic and technically safeguarded operation.

The modular concept of the vehicle and propulsion functions, with built-in redundancies as well as failure-tolerant and self-diagnosing electrical and electronic subassemblies, forms the basis for high technical availability and maintenance mainly restricted to rectifying faults and results in low maintenance costs [3] (Fig. 4).

2.2 Status of development and certification

A comprehensive program started in 1991 with assistance from the Federal Ministry of Education, Science, Research and Technology, had the following objectives:

- ▷ To optimize subassemblies and subsystems for mass production manufacturing.
- ▷ To complete the operational concepts with proof of the economic and environmentally compatible operation.
- ▷ To obtain type certification for subsystems and components from the Eisenbahn-Bundesamt (Federal Railway Authority).

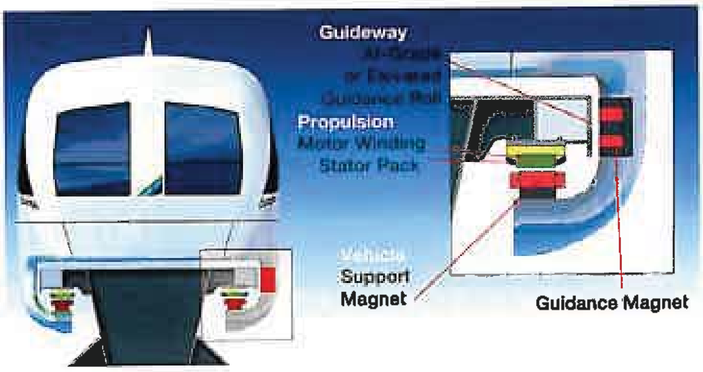


Fig. 4: Superspeed Maglev Technology

Work on these aspects is primarily backed up by data and experience gained from extensive operations at the Test Facility, which itself is undergoing modernization. The interim results, particularly those concerning availability, safety, and environmental compatibility, already confirm the basis for reliable, safe, and economic operation [3].

3 The Berlin–Hamburg Project

The guidelines for the Berlin–Hamburg Project were as follows:

Implementation of a superspeed maglev system link, integrated into the existing transport infrastructure, to carry approx. 12- 15 million passengers annually (traffic volume in 2010) between Hamburg Central Station and Berlin Lehrter Station, with a journey time of less than 60 minutes; construction is dated to commence in 1999 and commercial operation in 2005.

This led to the following detailed project requirements and targets based on the system data and functions specified:

1. Elevated and at-grade, double-track guideway for a maximum route speed of 450 km/h (normal operating speed 430 km/h).
2. Construction of the maglev terminals Hamburg Central Station, Moorfleet, Schwerin, Spandau, and Berlin Lehrter Station.
3. Manufacture and commissioning of a fleet of four- and five-section maglev trains.
4. Construction of maintenance and parking facilities as well as for operation control and administration.
5. Manufacture and installation of propulsion, operation control, and energy supply systems.

3.1 Systems design

Terminals

The maglev terminals will be integrated into the existing railway stations in such a way that transfer between conventional and maglev trains will take 10 minutes at most, where possible without even having to change platforms. The maglev platforms will include platform gates to ensure the safety of passengers when boarding or leaving the maglev trains as well as during the arrival, departure, or passage of a maglev train.

In the event of a non-scheduled stop, e.g. as the result of a malfunction, the maglev train automatically continues to one of the auxiliary stopping areas located along the route. In such locations, the on-board power supply, e.g. for lighting and air-conditioning, is guaranteed. In an emergency, passengers can also be evacuated safely using equipment carried on board.

Maintenance and parking facilities

Parking facilities will be built near the Hamburg Central and Berlin Lehrter Stations; together they will accommodate the fleet of trains. In addition, the facilities in Hamburg will include a plant for exterior washing of the trains. A maintenance facility sized to hold one train will be incorporated into each area. The modular electronic components can be exchanged here - like a "pit stop". These facilities, together with the central maintenance facility in Perleberg, will form the basis for servicing and repairing all the subsystems of the maglev system.

Guideway, Switches

The guideway for the maglev train will be designed as double-track throughout with track center-to-center distances of 4.4 m for up to 300 km/h and 5.1 m for up to 450 km/h; the clearance envelopes are

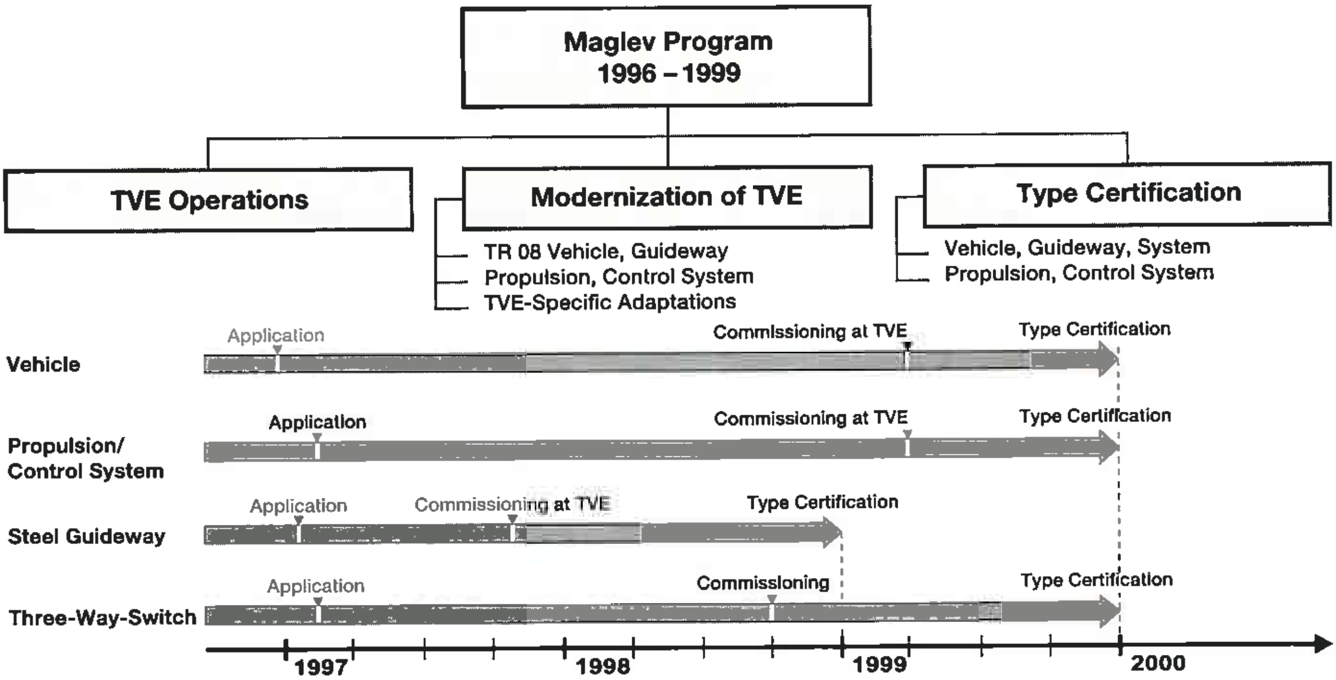


Fig. 5: Maglev System Programm 1996 - 1999 (sponsored by Federal Ministry of Education, Science, Research and Technology)