MAGLEV TRAINS

For
THE HUMANITIES SECTION

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LETTER OF TRANSMITTAL

October 15, 2009

Ms Anwesha Das
The Humanities Section
Thadomal Shahani Engineering College
Bandra
Mumbai-400050

Dear Madam

We feel pleased to present our formal report on “Maglev Trains”. The report focuses on the technology empowering the highly successful transportation method of Maglev Trains, and their advantages. Giving, them an edge over the conventional trains thus, proving a better choice in the long run.

The main objective of this report was to bring to light, the revolution that has to be brought in the field of transportation, considering the exclusive and unbeatable benefits of the Maglev Train, and its undisputed performance, making it the future of transportation.

We would like to thank you for motivating us to work on this report. This report would not have been possible without your continual guidance and persistence.

Yours Sincerely

Bhavana Vishnani
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INTRODUCTION

Origin of the Report

This report has been prepared by the second year EXTC students as a part of the curriculum ‘Presentation and Communication Techniques’ for the year 2009-2010. The report is titled ‘MAGLEV TRAINS’ and deals with the evolution and development of Maglev technology and its execution in transportation via trains.

Purpose

Our report titled ‘MAGLEV TRAINS’ is an informative report which explains about Magnetic levitation or Maglev, as a form of transportation that suspends, guides and propels vehicles via electromagnetic force. This method can be faster than wheeled mass transit systems potentially reaching velocities comparable to an aircraft or a turboprop. Our report aims at providing knowledge about the various aspects of this new emerging automotive technology called maglev trains.

Scope

This report specifically looks into the origin, techniques, implementation, features, updates and accidents involved in maglev trains. However, the report has not dealt with the expenses, recommendation and alternative technologies of maglev trains.

Limitations

This report uses the internet as its primary source of information. Due to the constraint of time, this report could not extract information from other sources.
SUMMARY

The report titled ‘MAGLEV TRAINS’ accomplishes a research on the developing discipline of magnetic levitation and its application to transportation through trains. It provides detailed information about the evolution of maglev science, its progression and improvisation till date. High-speed magnetically levitated ground transportation (maglev) is a new surface mode of transportation, in which vehicles glide above their guideways, suspended, guided, and propelled by magnetic forces. This report tries to explain the complexities involved in this technology in a simple but precise manner, so that all the methods implemented in it are understood by the reader at prima facie. This report, tries to compare the conventional modes of transport with maglev trains in various aspects such as safety, durability, speed, comfort and so on. Thus, providing the advantages and disadvantages of the trains. Further, this report helps us to learn about the various cities around the world, where maglev trains currently run and also provides an overview of the proposals for such trains, which are being considered as a promising investment globally. Consecutively, it deals with the accidents that have occurred at places where maglev trains have been implemented and the reasons that triggered them. This data has been included so that such incidents may be avoided in the future and in order that certain necessary modifications are made to improve the safety measures of these trains. Capable of travelling at speeds of 250 to 300 miles-per-hour or higher, maglev would offer an attractive and convenient alternative for travellers between large urban areas for trips of up to 600 miles. It would also help relieve current and projected air and highway congestion by substituting for short-haul air trips, thus releasing capacity for more efficient long-haul service at crowded airports, and by diverting a portion of highway trips. Finally, our report gives a peek into the future expansions of maglev trains and thus undoubtedly assures its readers that maglev trains are no longer a science fiction, and are in fact the future of world transportation.
1. BACKGROUND

Transportation is the direct product of the social link and social relationship of the people. Revolutionary changes have taken place in the life of the mankind since human beings acquired the capability of walking upright as a result of evolution from the ape. Human being’s vision was widened to enable itself to better observe the surroundings and to be watchful against any possible crises. But due to the low productive forces and constraints on people by the conditions of the nature in the primitive times, usually they could not but live by hunting animals or gathering plants within a certain region to maintain the lease of life by making use of a few elements of the nature, let alone any act of transport for the commercial intercourse among the peasants, workers and merchants.

Nevertheless, with the development of human society, people gradually widened their vision in the geographic space through several forms of lateral social contact in their production activities and injected active seeking factor into the passive man, environment relationship. Gradually, human being mastered the use of tools and other special at his service. Among others, the horse, an animal which changed the speed of human transportation, enabled a cart to run at some 10km/h, thus the region scoped varied and the link between city and city became closer, enhancing the progress of culture and civilization in various places.

1.1 Maglev: The Principle

A method of supporting and transporting objects or vehicles which is based on the physical property that the force between two magnetized bodies is inversely proportional to their distance. By using this magnetic force to counterbalance the gravitational pull, a stable and contactless suspension between a magnet (magnetic body) and a fixed guideway (magnetized body) may be obtained. In magnetic levitation (Maglev), also known as magnetic suspension, this basic principle is used to suspend (or levitate) vehicles weighing 40 tons or more by generating a controlled magnetic force. By removing friction, these vehicles can travel at speeds higher than wheeled trains, with considerably improved propulsion efficiency (thrust energy/input
energy) and reduced noise. In Maglev vehicles, chassis-mounted magnets are either suspended underneath a ferromagnetic guideway (track) or levitated above an aluminum track.

Figure 1.1 depicts the three primary functions basic to Maglev technology:

(1) levitation or suspension;
(2) propulsion; and
(3) guidance.

In most current designs, magnetic forces are used to perform all three functions, although a nonmagnetic source of propulsion could be used. No consensus exists on an optimum design to perform each of the primary functions.

In the attraction-type system, a magnet-guideway geometry is used to attract a direct-current electromagnet toward the track. This system, also known as the electromagnetic suspension (EMS) system, is suitable for low- and high-speed passenger-carrying vehicles and a wide range of magnetic bearings. The electromagnetic suspension system is inherently nonlinear and unstable, requiring an active feedback to maintain an upward lift force equal to the weight of the suspended magnet and its payload (vehicle).

In the repulsion-type system, also known as the electrodynamic levitation system (EDS or EDL), a superconducting coil operating in persistent-current mode is moved longitudinally along a conducting surface (an aluminum plate fixed on the ground and acting as the guideway) to induce circulating eddy currents in the aluminum plate. These eddy currents create a magnetic field which, by Lenz’s law, opposes the magnetic field generated by the travelling coil. This interaction produces a repulsion force on the moving coil. At lower speeds, this vertical force is not sufficient to lift the coil (and its payload), so supporting auxiliary wheels are needed until the net repulsion force is positive. The speed at which the net upward lift force is positive (critical speed) is dependent on the magnetic field in the airgap and payload, and is typically around 80 km/h (50 mi/h). To produce high flux from the traveling coils, hard superconductors (type II) with relatively high values of the critical field (the magnetic field strength of the coil at 0 K) are used to yield airgap flux densities of over 4 tesla. With this choice, the strong eddy-current induced magnetic field is rejected by the superconducting field, giving a self-stabilizing levitation
force at high speeds (though additional control circuitry is required for adequate damping and ride quality.

The Types of Maglev Methods

- Repulsion between like poles of permanent magnets or electromagnets.
- Repulsion between a magnet and a metallic conductor induced by relative motion.
- Repulsion between a metallic conductor and an AC electromagnet.
- Repulsion between a magnetic field and a diamagnetic substance.
- Repulsion between a magnet and a superconductor.
- Attraction between unlike poles of permanent magnets or electromagnets.
- Attraction between the open core of an electromagnetic solenoid and a piece of iron or a magnet.
- Attraction between a permanent magnet or electromagnet and a piece of iron.
- Attraction between an electromagnet and a piece of iron or a magnet, with sensors and active control of the current to the electromagnet used to maintain some distance between them.
- Repulsion between an electromagnet and a magnet, with sensors and active control of the current to the electromagnet used to maintain some distance between them.
Pros and cons of different technologies

Each implementation of the magnetic levitation principle for train-type travel involves advantages and disadvantages. Time will tell us which principle, and whose implementation, wins out commercially.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMS (Electromagnetic suspension)</td>
<td>Magnetic fields inside and outside the vehicle are less than EDS; proven, commercially available technology that can attain very high speeds (500 km/h); no wheels or secondary propulsion system needed.</td>
<td>The separation between the vehicle and the guideway must be constantly monitored and corrected by computer systems to avoid collision due to the unstable nature of electromagnetic attraction; due to the system's inherent instability and the required constant corrections by outside systems, vibration issues may occur.</td>
</tr>
<tr>
<td>EDS (Electrodynanmic)</td>
<td>Onboard magnets and large margin between rail and train enable highest recorded train speeds (581 km/h) and heavy load capacity; has recently demonstrated (December 2005) successful operations using high temperature superconductors in its onboard magnets, cooled with inexpensive</td>
<td></td>
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<td></td>
<td>Strong magnetic fields onboard the train would make the train inaccessible to passengers with pacemakers or magnetic data storage media such as hard drives and credit cards, necessitating the use of magnetic shielding; limitations on guideway inductivity limit the maximum speed of</td>
<td></td>
</tr>
<tr>
<td>Inductrack System (Permanent Magnet EDS)</td>
<td>Liquid nitrogen is used as the vehicle; vehicle must be wheeled for travel at low speeds.</td>
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<td>----------------------------------------</td>
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<tr>
<td>Inductrack System (Permanent Magnet EDS)</td>
<td>Failsafe Suspension - no power required to activate magnets; Magnetic field is localized below the car; can generate enough force at low speeds (around 5 km/h) to levitate Maglev train; in case of power failure cars slow down on their own safely; Halbach arrays of permanent magnets may prove more cost-effective than electromagnets</td>
<td></td>
</tr>
<tr>
<td>Requires either wheels or track segments that move for when the vehicle is stopped. New technology that is still under development (as of 2008) and as yet has no commercial version or full scale system prototype.</td>
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</tr>
</tbody>
</table>
Fig 1.2 EMS suspension system
Neither Inductrack nor the Superconducting EDS are able to levitate vehicles at a standstill, although Inductrack provides levitation down to a much lower speed; wheels are required for these systems. EMS systems are wheel-less.

The German Transrapid, Japanese HSST (Linimo), and Korean Rotem EMS Maglevs levitate at a standstill, with electricity extracted from guideway using power rails for the latter two, and wirelessly for Transrapid. If guideway power is lost on the move, the Transrapid is still able to generate levitation down to 10 km/h (6.2 mph) speed, using the power from onboard batteries. This is not the case with the HSST and Rotem systems.
1.2 Evolution of Maglev

The goal of using magnets to achieve high speed travel with non-contact magnetically levitated vehicles is almost a century old. In the early 1900's, Bachelet in France and Goddard in the United States discuss the possibility of using magnetically levitated vehicles for high speed transport. However, they do not propose a practical way to achieve this goal.

On August 14, 1934, Hermann Kemper of Germany receives a patent for the magnetic levitation of trains. Research continues after World War II. In the 1970s and 1980s, development, commissioning, testing and implementation of various Maglev Train systems continues in Germany by Thyssen Henschel. The Germans name their Maglev system "Transrapid".

In 1966, in the USA, James Powell and Gordon Danby propose the first practical system for magnetically levitated transport, using superconducting magnets located on moving vehicles to induce currents in normal aluminum loops on a guideway. The moving vehicles are automatically levitated and stabilized, both vertically and laterally, as they move along the guideway. The vehicles are magnetically propelled along the guideway by a small AC current in the guideway.

In 1992, the Federal Government in Germany decides to include the 300 km long superspeed Maglev system route Berlin-Hamburg in the 1992 Federal Transportation Master Plan.

In June of 1998, the US congress passes the Transportation Equity Act for the 21st Century (TEA 21). The law includes a Maglev deployment program allocating public funds for preliminary activities with regard to several projects and, later on, further funds for the design, engineering and construction of a selected project. For the fiscal years 1999 - 2001, $55 million are provided for the Maglev deployment program. An additional $950 million are budgeted for the actual construction of the first project. In November of 1999, the Chinese Ministry of Science and Technology and Transrapid International sign a letter of intent to select a suitable Transrapid route in the People's Republic of China and evaluate its technical and economic feasibility.

In January of 2001, in the US, Transportation Secretary Rodney Slater selects the Pittsburgh and the Washington - Baltimore routes for detailed environmental and project planning. Later that month in China, a contract is concluded between the city of Shanghai and the industrial consortium consisting of Siemens, ThyssenKrupp, and Transrapid International to realize
the Shanghai airport link. In March, the construction of the Shanghai project begins.

Currently, the original Powell-Danby Maglev inventions form the basis for the Maglev system in Japan, which is being demonstrated in Yamanashi Prefecture, Japan. Powell and Danby have subsequently developed new Maglev inventions that form the basis for their second generation M-2000 System. Other Maglev Train systems are in the planning and development stages in various cities in the US, including projects in Georgia, California and Pennsylvania.

In the future, Maglev promises to be the major new mode of transport for the 21st Century and beyond because of its energy efficiency, environmental benefits and time-saving high velocity transport. Because there is no mechanical contact between the vehicles and the guideway, speeds can be extremely high. Traveling in the atmosphere, air drag limits vehicles to speeds of about 300 - 350 mph. Traveling in low pressure tunnels, Maglev vehicles can operate at speeds of thousands of miles per hour.

The energy efficiency of Maglev transport, either in kilowatt-hours per passenger mile for personal transport, or kilowatt hours per ton-mile for freight, is much lower for Maglev than for autos, trucks, and airplanes. It is pollution free, can use renewable energy sources such as solar and wind power, and in contrast to oil and gas fueled transport, does not contribute to global warming. It is weather independent, and can carry enormous traffic loads - both people and goods - on environmentally friendly, narrow guideways. The cost of moving people and goods by Maglev will be considerably less than by the present modes of auto, truck, rail, and air.
2. TECHNOLOGY AND WORKING OF MAGLEV TRAINS

The Levitation System

Support electromagnets built into the undercarriage and along the entire length of the train pull it up to the guideway electromagnets, which are called ferromagnetic reaction rails. The guidance magnets placed on each side of the train keep it centered along the track and guide the train along. All the electromagnets are controlled electronically in a precise manner. It ensures the train is always levitated at a distance of 8 to 10 mm from the guideway even when it isn't moving. This levitation system is powered by onboard batteries, which are charged up by the linear generator when the train travels. The generator consists of additional cable windings integrated in the levitation electromagnets. The induced current of the generator during driving uses the
propulsion magnetic field's harmonic waves, which are due to the side effects of the grooves of the long stator so the charging up process does not consume the useful propulsion magnetic field. The train can rely on this battery power for up to one hour without an external power source. The levitation system is independent from the propulsion system.

**System**

Electronically controlled support magnets located on both sides along the entire length of the vehicle pull the vehicle up to the ferromagnetic stator packs mounted to the underside of the guideway.

Guidance magnets located on both sides along the entire length of the vehicle keep the vehicle laterally on the track. Electronic systems guarantee that the clearance remains constant (nominally 10 mm). To hover, the Maglev requires less power than its air conditioning equipment. The levitation system is supplied from on-board batteries and thus independent of the propulsion system. The vehicle is capable of hovering up to one hour without external energy. While travelling, the on-board batteries are recharged by linear generators integrated into the support magnets.
Vehicles

Maglev vehicles comprise a minimum of two sections, each with approx. 90 seats on average. According to application and traffic volume, trains may be composed of up to ten sections (two end and eight middle sections).

However, the Maglev is suitable for transporting goods as well. For high-speed cargo transport, special cargo sections can be combined with
Passenger sections or assembled to form dedicated cargo trains (payload up to 15 tons per section). As the propulsion system is in the guideway, neither the length of the vehicle nor the payload affect the acceleration power.

Fig 2.6 Maglev vehicle in Action

**Propulsion System**

The synchronous longstator linear motor of the Maglev maglev system is used both for propulsion and braking. It is functioning like a rotating electric motor whose stator is cut open and stretched along under the guideway. Inside the motor windings, alternating current is generating a magnetic traveling field which moves the vehicle without contact. The support magnets in the vehicle function as the excitation portion (rotor). The

Fig 2.7 Process of Propulsion and the traveling field
propulsion system in the guideway is activated only in the section where the vehicle actually runs.

The speed can be continuously regulated by varying the frequency of the alternating current. If the direction of the traveling field is reversed, the motor becomes a generator which brakes the vehicle without any contact. The braking energy can be re-used and fed back into the electrical network. The three-phase wound stator generates an electromagnetic travelling field and moves the train when it is supplied with an alternating current. The electromagnetic field from the support electromagnets (rotor) pulls it along. The magnetic field direction and speed of the stator and the rotor are synchronized. The Maglev's speed can vary from standstill to full operating speed by simply adjusting the frequency of the alternating current. To bring the train to a full stop, the direction of the travelling field is reversed. Even during braking, there isn't any mechanical contact between the stator and the rotor. Instead of consuming energy, the Maglev system acts as a generator, converting the breaking energy into electricity, which can be used elsewhere.

Fig 2.8 Repulsion of magnets

Fig 2.9 Stator Winding for Propulsion

Fig 2.10 Stator Windings Below the Guideway
The Operation Control System

The operation control system controls the operation and guarantees the safety of the Maglev system. It safeguards vehicle movements, the position of the switches, and all other safety and operational functions. Vehicles location on the track is accomplished using an on-board system which detects digitally encoded location flags on the guideway. A radio transmission system is used for communication between the central control center and the vehicles.
The Guideway

The Maglev hovers over a double track guideway. It can be mounted either at-grade or elevated on slim columns and consists of individual steel or concrete beams up to 62 m in length. Guidance or steering refers to the sideward forces that are required to make the vehicle follow the guideway. The necessary forces are supplied in an exactly analogous fashion to the suspension forces, either attractive or repulsive. The same magnets on board the vehicle, which supply lift, can be used concurrently for guidance or separate guidance magnets can be used. They use Null Flux systems, also known as Null Current systems, these use a coil which is wound so that it enters two opposing, alternating fields. When the vehicle is in the straight ahead position, no current flows, but if it moves off-line this creates a changing flux that generates a field that pushes it back into line.

![Alt-grade guideway](image)

![Elevated guideway](image)

Fig 2.13 Guideway Specifics

The Maglev system changes tracks using steel bendable switches. They consist of continuous steel box beams with length between 78 m and 148 m (256 ft - 486 ft) which are elastically bent by means of electromagnetic setting drives and securely locked in their end positions.

In the straight position, the vehicle can cross the switch without speed restrictions, in the turnout position, the speed is limited to 200 km/h (125 mph) (high speed switch) or 100 km/h (62 mph) (low speed switch).
The propulsion in the guideway is activated only the section where the vehicle actually is.
The magnetized coil running along the track, called a guideway, repels the large magnets on the train's undercarriage, allowing the train to levitate between 0.39 and 3.93 inches (1 to 10 cm) above the guideway. Once the train is levitated, power is supplied to the coils within the guideway walls to create a unique system of magnetic fields that pull and push the train along the guideway. The electric current supplied to the coils in the guideway walls is constantly alternating to change the polarity of the magnetized coils. This change in polarity causes the magnetic field in front of the train to pull the vehicle forward, while the magnetic field behind the train adds more forward thrust.
3. IMPLEMENTATIONS OF MAGLEV TRAINS

3.1 History of Maglev Trains

<table>
<thead>
<tr>
<th>Year</th>
<th>Subject</th>
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<tbody>
<tr>
<td>1962</td>
<td>Research of linear motor propulsion and non-contact run started.</td>
</tr>
<tr>
<td>1970</td>
<td>Study of electrodynamic levitation systems using superconducting magnets started formally.</td>
</tr>
<tr>
<td>1972</td>
<td>LSM-propulsion experimental superconducting Maglev test vehicle (LSM200) succeeded in levitated run. LIM-propulsion experimental vehicle (ML100) succeeded in levitated run.</td>
</tr>
<tr>
<td>1975</td>
<td>LSM-propulsion experimental superconducting magnet test vehicle (ML100A) succeeded in perfect non-contact run.</td>
</tr>
<tr>
<td>1977</td>
<td>The Miyazaki Maglev Test Center opened. Test run of ML-500 inverted-T guideway started at the Miyazaki Test Track.</td>
</tr>
<tr>
<td>1979</td>
<td>Simulated tunnel run tested. Run with helium refrigerator on-board tested (ML-500R). 517 km/h run attained.</td>
</tr>
<tr>
<td>1980</td>
<td>Test run of MLU001 on U-type guideway started on the Miyazaki Maglev Test Track.</td>
</tr>
<tr>
<td>1981</td>
<td>2-car train test run started.</td>
</tr>
<tr>
<td>1982</td>
<td>Manned 2-car train test run started.</td>
</tr>
<tr>
<td>1986</td>
<td>3-car train registered 352.4 km/h run.</td>
</tr>
<tr>
<td>1987</td>
<td>Unmanned 2-car train attained 405.3 km/h. 400.8 km/h run of manned 2-car train attained. Railway Technical Research Institute reorganized as a foundation, taking over the R&amp;D work so far pursued by JNR. Test run of MLU002 started.</td>
</tr>
<tr>
<td>1988</td>
<td>Substation cross-over test carried out.</td>
</tr>
<tr>
<td>1989</td>
<td>Aerodynamic brake system tested (MLU001). 394 km/h run attained (MLU002).</td>
</tr>
<tr>
<td>1990</td>
<td>Test of traverser-type turnout started. Start of initial phase in construction of the Yamanashi Maglev Test Line celebrated.</td>
</tr>
<tr>
<td>1991</td>
<td>Test run using sidewall levitation system started. Test run energized by inverters started. MLU002 burned down in a fire accident.</td>
</tr>
<tr>
<td>1993</td>
<td>Test run of MLU002N started.</td>
</tr>
<tr>
<td>1994</td>
<td>MLU002N attained 431 km/h.</td>
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<tr>
<td>Year</td>
<td>Event</td>
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<tr>
<td>1995</td>
<td>MLU002N attained 411 km/h (manned).</td>
</tr>
<tr>
<td>1996</td>
<td>The Yamanashi Maglev Test Center opened. Tractor-pulled running test of MLX01 on the Yamanashi Maglev Test Line started.</td>
</tr>
<tr>
<td>1997</td>
<td>Running test of MLX01 on the Yamanashi Maglev Test Line started. MLX01 attained 531 km/h (manned). MLX01 attained 550 km/h (unmanned).</td>
</tr>
<tr>
<td>1998</td>
<td>Test of two trains passing each other at a relative speed of 966 km/h.</td>
</tr>
<tr>
<td>1999</td>
<td>MLX01 arranged in a five-car train set attained 548 km/h (unmanned). MLX01 arranged in a five-car train set attained 552 km/h (manned). Test of two trains passing each other at a relative speed of 1,003 km/h.</td>
</tr>
<tr>
<td>2000</td>
<td>The Committee of the Ministry of Transport of Japan concluded &quot;Maglev has the practicability for ultra high speed mass transportation system.&quot; Cumulative traveled distance exceeded 100,000 km.</td>
</tr>
<tr>
<td>2001</td>
<td>Their Imperial Highnesses Prince and Princess Akishino experienced Maglev trial ride.</td>
</tr>
<tr>
<td>2002</td>
<td>Cumulative traveled distance exceeded 200,000 km. Number of passengers for Maglev trial ride exceeded 30,000 persons. Test run of new train set including MLX01-901 started.</td>
</tr>
<tr>
<td>2003</td>
<td>Longer traveled distance 1,219 km in a day was attained. Cumulative traveled distance exceeded 300,000km and the number of passengers for Maglev trial ride exceeded 50,000 persons. Longest traveled distance 2,876 km in a day was attained. MLX01 arranged in a three-car train set attained 581 km/h (manned).</td>
</tr>
<tr>
<td>2004</td>
<td>Number of passengers for Maglev trial ride exceeded 80,000 persons. Cumulative traveled distance exceeded 400,000 km. Test of two trains passing each other at a maximum relative speed of 1,026 km/h.</td>
</tr>
<tr>
<td>2005</td>
<td>His Imperial Highness Crown Prince Naruhito experienced Maglev trial ride.</td>
</tr>
</tbody>
</table>
3.2 Cities Where Installed

The Linimo Maglev Train, Japan

The Linimo Maglev Train is the world's first commercial automated "Urban Maglev" system.

Built for the 2005 World Expo in Nagoya Japan the 8.9klm line connects Bampaku-yakusa station to Fujigaoka station. Japan has several private railway companies that can operate independent lines to each other. Transferring from one companies station to another companies station to complete your journey is a common occurrence in Japan, so the fact that the unique Maglev system is used terminating at one end of the Aichi Loop Railway and the other end of the Nagoya Subway Higashiyama Line is not a problem.

There are 9 stops on the line that goes from a highly elevated track around the hills near the Expo site to an underground track where it terminates next to the Subway line. The Linimo has a minimum operating radius of 75 m and a maximum gradient of 6%. The linear-motor magnetic-levitated train has a top speed of 100 km/h. The line serves the local community as well as the Expo 2005 fair site. The trains were designed by the Chubu HSST Development Corporation, which also operates a test track in Nagoya.

The Linimo is not the only Maglev Project in Japan, there are plans to develop a Maglev Bullet Train (Shinkansen) From Tokyo to Osaka. Bullet Trains have been used all across Japan since 1964 but these trains are a fairly standard arrangement in the fact they use the familiar steel track system. With the ability to tilt into corners these fast trains can reach speeds of up to 300Klm/h.

The New Maglev Shinkasen is being tested on a test track in Yamanashi prefecture where test trains have reached 581 km/h (363 mph), These trains use superconducting magnets which allow for a larger gap, and repulsive-type "Electro-Dynamic Suspension" (EDS). In comparison the 100khr Linimo train uses conventional electromagnets and attractive-type "Electro-Magnetic
Suspension" (EMS). These "Superconducting Maglev Shinkansen", developed by the Central Japan Railway Co. ("JR Central") and Kawasaki Heavy Industries, are currently the fastest trains in the world, achieving a record speed of 581 km/h on December 2, 2003. If a proposed Chuo Shinkansen is built, connecting Tokyo to Osaka by maglev, this test track would be part of the line.

The long term benefits of a maglev system not only begin with a safe smooth and quiet ride. It is suggested that because there is no friction between the train and the track operating costs are much lower along with less ware and tear costs associated with the moving parts of a traditional train. perhaps as the initial outlay costs of these 21st century trains reduce more and more may be seen all across the world.

The Japanese have spent over $1 billion developing both attraction and repulsion maglev systems. The HSST attraction system, developed by a consortium often identified with Japan Airlines, is actually a series of vehicles designed for 100, 200, and 300 km/h. Sixty miles-per-hour (100 km/h) HSST Maglevs have transported over two million passengers at several Expos in
Japan and the 1989 Canada Transport Expo in Vancouver. The high speed Japanese repulsion Maglev system is under development by Railway Technical Research Institute (RTRI), the research arm of the newly privatized Japan Rail Group. RTRI's ML500 research vehicle achieved the world high-speed guided ground vehicle record of 321 mph (144 m/s) in December 1979, a record that still stands, although a specially modified French TGV rail train has come close. A manned three-car MLU001 began testing in 1982. Subsequently, the single car MLU002 was destroyed by fire in 1991. Its replacement, the MLU002N, is being used to test the sidewall levitation that is planned for eventual revenue system use. The principal activity at present is the construction of a $2 billion, 27-mile (43 km) maglev test line through the mountains of Yamanashi Prefecture, where testing of a revenue prototype is scheduled to commence in 1994.

The Central Japan Railway Company plans to begin building a second high-speed line from Tokyo to Osaka on a new route (including the Yamanashi test section) starting in 1997. This will provide relief for the highly profitable Tokaido Shinkansen, which is nearing saturation and needs rehabilitation. To provide ever improving service, as well as to forestall encroachment by the airlines on its present 85 percent market share, higher speeds than the present 171 mph (76 m/s) are regarded as necessary. Although the design speed of the first generation maglev system is 311 mph (139 m/s), speeds up to 500 mph (223 m/s) are projected for future systems. Repulsion maglev has been chosen over attraction maglev because of its reputed higher speed.
potential and because the larger air gap accommodates the ground motion experienced in Japan's earthquake-prone territory. The design of Japan's repulsion system is not firm. A 1991 cost estimate by Japan's Central Railway Company, which would own the line, indicates that the new high-speed line through the mountainous terrain north of Mt. Fuji would be very expensive, about $100 million per mile (8 million yen per meter) for a conventional railway. A maglev system would cost 25 percent more. A significant part of the expense is the cost of acquiring surface and subsurface ROW. Knowledge of the technical details of Japan's high-speed Maglev is sparse. What is known is that it will have superconducting magnets in bogies with sidewall levitation, linear synchronous propulsion using guideway coils, and a cruise speed of 311 mph (139 m/s).

Maglev Test Line, Yamanashi

![Fig 3.2.4 Test Center of the Yamanashi Maglev Test Line](image1)

![Fig 3.2.5 Route of the Yamanashi Maglev Test Line](image2)
On the Yamanashi Maglev Test Line extending 42.8 km between Sakaigawa and Akiyama of Yamanashi Prefecture, various confirmation tests are being performed to obtain a final perspective of Maglev feasibility. The Test Center was officially opened on July 1996, to start on the program of test runs and complete the developmental activities, aimed at the realization of Maglev by the end of 1999.
The followings are major test items to take place on the Yamanashi Maglev Test Line:

- Confirmation for possibilities of safe, comfortable, and stable run at 500 km/h
- Confirmation of reliability and durability of the vehicle, wayside facilities, and equipment as well as the Superconducting Magnets
- Confirmation of structural standards including the minimum radius of curvature and the steepest gradient
- Confirmation of center-to-center track distance for safety of trains passing each other
- Confirmation of vehicle performance in relation to tunnel cross-section and to pressure fluctuations in the tunnels
- Confirmation of performance of the turnout facilities
- Confirmation of environmental impact
- Establishment of multiple-train operation control systems
- Confirmation of operation and safety systems and track maintenance criteria
- Establishment of inter-substation control systems
- Pursuit of economic issues, construction and operation costs.
Shanghai Transrapid Maglev Line, China

The Shanghai Transrapid Maglev Line is the world's first high-speed commercial commuting system using the state-of-the-art electromagnetic levitation technology. The 30 km (19.5 miles) and double-track project started on March 2001 and it is now on trial operation. It will be on commercial operation in late 2003.

With a top speed of 430 km per hour (267 miles per hour), it only takes eight minutes for a one-way trip, which connects the Pudong International Airport and the Longyang Road Station, a downtown subway station. The total cost of the project is about 10 billion yuan (1.2 billion US dollars).

The high-speed train takes about 2 minutes and 15 seconds to reach 300 km/h and about 4 minutes to reach its peak speed, 430 km/h. The ride of the train is comfortable and quiet due to the maglev technology and the specially designed window. Its noise level is less than 60 decibels at a speed of 300 km/h.

China's economy is on the fast track, so is the project. It only takes two and a half years to complete such a
large and complex project.

The line runs from Longyang Road station in Pudong, on the Shanghai subway line 2 to Pudong International Airport. The journey takes 7 minutes and 20 seconds to complete the distance of 30 km. A train can reach 350 km/h (220 mph) in 2 minutes, with the maximum normal operation speed of 431 km/h (268 mph) reached thereafter.

The line is operated by Shanghai Maglev Transportation Development Co., Ltd. As of May 2008, the line operates daily between 06:45–21:30, a one-way ticket cost ¥50 (US$7.27), or ¥40 ($5.81) for those passengers holding a receipt or proof of an airline ticket purchase. A round-trip return ticket cost ¥80 ($11.63) and VIP tickets cost double the standard fare.

The service operates once every 15 minutes. It can be easier and faster for those passengers with destinations in west (Puxi) Shanghai to use a taxi directly from Pudong International Airport—although missing out the “thrill factor” of riding on the high-speed Maglev.

When discussing the practicality of other means of transport to the airport it is important to remember the name of the line Demonstration Operation Line. Hans-Dieter Bott, vice president of Siemens when they won the contract to build the rail link stated that "Transrapid views the Shanghai line, where the ride will last just eight minutes, largely as a sales tool. This serves as a demonstration for China to show that this works and can be used for longer distances, such as Shanghai to Beijing". However, the decision was eventually made to implement the Beijing-Shanghai Express Railway with conventional high-speed technology.

Of all the world’s Airport rail links, the Demonstration Operation Line is by far the fastest. In comparison the Heathrow Express link is a nonstop 26.5 km from central London to Heathrow airport. This distance is similar to the Shanghai link, but the Heathrow Express takes 15 minutes (average speed 66 mph and top speed 100 mph). The Shanghai train is more than twice as fast, but it takes a full 4 minutes to reach its top speed of 431 kmh, and then must immediately begin slowing down for the final 3 minutes and 20 seconds. Because the Shanghai maglev was built before the connection to the local mass transit subway, it is often described as of little benefit to many people trying to get to the airport.
In 13 June, 2007, *Asia Times* reported that it "could hardly be called a commercial success", in part because "it virtually goes nowhere".

**Operation**

Following the opening, overall maglev train ridership levels were at 20% of capacity, the levels were attributed to limited operating hours, the short length of the line, high ticket prices and station at the upmarket financial hub of China in Pudong at Longyang Road Terminus.

![The train en-route its journey](image)

In normal operation, the speed and journey time vary depending upon the time of day. Considering the short length of the track, increasing the maximum speed from 300 kmh to 431 kmh only saves 10% of the travel time (or 50 seconds).

<table>
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<td>301 km/h (187 mph)</td>
<td>224 km/h (139 mph)</td>
<td>20 minutes</td>
</tr>
</tbody>
</table>
Construction

The Shanghai Transrapid project took ¥10 billion (US$1.33bn) and two and a half years to complete. The line is 30.5 km (19.0 mi) track and has a further separate track leading to a maintenance facility.

The Transrapid, Emsland, Germany

The German TR07 is the high-speed Maglev system nearest to commercial readiness. If financing can be obtained, ground breaking will take place in Florida in 1993 for a 14-mile (23 km) shuttle between Orlando International Airport and the amusement zone at International Drive. The TR07 system is also under consideration for a high-speed link between Hamburg and Berlin and between downtown Pittsburgh and the airport. As the designation suggests, TR07 was preceded by at least six earlier models. In the early seventies, German firms, including Krauss-Maffei,
MBB and Siemens, tested full-scale versions of an air cushion vehicle (TR03) and a repulsion maglev vehicle using superconducting magnets. After a decision was made to concentrate on attraction maglev in 1977, advancement proceeded in significant increments, with the system evolving from linear induction motor (LIM) propulsion with wayside power collection to the linear synchronous motor (LSM), which employs variable frequency, electrically powered coils on the guideway. TR05 functioned as a people mover at the International Traffic Fair Hamburg in 1979, carrying 50,000 passengers and providing valuable operating experience.

The TR07, which operates on 19.6 miles (31.5 km) of guideway at the Emsland test track in northwest Germany, is the culmination of nearly 25 years of German Maglev development, costing over $1 billion. It is a sophisticated EMS system, using separate conventional iron-core attracting electromagnets to generate vehicle lift and guidance. The vehicle wraps around a T-shaped guideway. The TR07 guideway uses steel or concrete beams constructed and erected to very tight tolerances. Control systems regulate levitation and guidance forces to maintain an inch gap (8 to 10 mm) between the magnets and the iron "tracks" on the guideway. Attraction between vehicle magnets and edge-mounted guideway rails provide guidance. Attraction between a second set of vehicle magnets and the propulsion stator packs underneath the guideway generate lift. The lift magnets also serve as the secondary or rotor of a LSM, whose primary or
stator is an electrical winding running the length of the guideway. TR07 propulsion is by a long-stator LSM. Guideway stator windings generate a traveling wave that interacts with the vehicle levitation magnets for synchronous propulsion. Centrally controlled wayside stations provide the requisite variable-frequency, variable-voltage power to the LSM. Primary braking is regenerative through the LSM, with eddy-current braking and high-friction skids for emergencies. TR07 has demonstrated safe operation at 270 mph (121 m/s) on the Emsland track. It is designed for cruise speeds of 311 mph (139 m/s).

Fig 3.2.15 The futuristic design of the Transrapid
4. MAGLEV: THE BEST OPTION

• What are the attributes of maglev which commend its consideration by transportation planners?

• Faster trips

High peak speed and high acceleration/braking enable average speeds three to four times the national highway speed limit of 65 mph (30 m/s) and lower door-to-door trip time than high-speed rail or air (for trips under about 300 miles or 500 km). And still higher speeds are feasible. Maglev takes up where high-speed rail leaves off, permitting speeds of 250 to 300 mph (112 to 134 m/s) and higher.

• High reliability

Less susceptible to congestion and weather conditions than air or highway. Variance from schedule can average less than one minute based on foreign high-speed rail experience. This means intra- and intermodal connecting times can be reduced to a few minutes (rather than the half-hour or more required with airlines and Amtrak at present) and that appointments can safely be scheduled without having to take delays into account.

• Petroleum independence

With respect to air and auto as a result of being electrically powered. Petroleum is unnecessary for the production of electricity. In 1990, less than 5 percent of the Nation's electricity was derived from petroleum whereas the petroleum used by both the air and automobile modes comes primarily from foreign sources.

• Less polluting
With respect to air and auto, again as a result of being electrically powered. Emissions can be controlled more effectively at the source of electric power generation than at the many points of consumption, such as with air and automobile usage.

- **Higher capacity than air**
  
  At least 12,000 passengers per hour in each direction with potential for even higher capacities at 3 to 4 minute headways. Provides sufficient capacity to accommodate traffic growth well into the twenty-first century and to provide an alternative to air and auto in the event of an oil availability crisis.

- **High safety**
  
  Both perceived and actual, based on foreign experience.

- **Convenience**
  
  Due to high frequency of service and the ability to serve central business districts, airports, and other major metropolitan area nodes.

- **Improved comfort**
  
  With respect to air due to greater roominess, which allows separate dining and conference areas with freedom to move around. Absence of air turbulence ensures a consistently smooth ride.

- **Maintenance**
  
  Due to the non-contact technology, the cost of vehicle and guideway maintenance is very low.

  In the event of a malfunction of one of the propulsion and control components, the remaining components can assume its responsibilities, thereby ensuring a high overall system availability. If an electronic component group in the vehicle fails, the high redundancy concept guarantees that the vehicle will reach the next destination.
Here the vehicle can be taken out of operation, the defective component quickly replaced, and then be available as reserve.

The guideway is inspected and monitored by maintenance vehicles from the guideway. These are provided with measuring systems to detect any changes in the position of the guideway equipment (such as stator packs, cable windings, and guidance rails) and with optical systems using digital photo interpretation to check the condition of the surfaces, e.g. for corrosion. In addition, evaluation of the sensor data obtained in daily operation allows the maintenance personnel to detect any changes in the position of the guideway and to implement corrective measures in a timely, efficient manner. An access road along the guideway is not required for maintenance purposes.
4.1 Pros and Cons

Compared to conventional trains

Major comparative differences between the two technologies lie in backward-compatibility, rolling resistance, weight, noise, design constraints, and control systems.

- **Backwards Compatibility**
  Maglev trains currently in operation are not compatible with conventional track, and therefore require all new infrastructure for their entire route. By contrast conventional high speed trains such as the TGV are able to run at reduced speeds on existing rail infrastructure, thus reducing expenditure where new infrastructure would be particularly expensive (such as the final approaches to city terminals), or on extensions where traffic does not justify new infrastructure.

- **Efficiency**
  Due to the lack of physical contact between the track and the vehicle, maglev trains experience no rolling resistance, leaving only air resistance and electromagnetic drag, potentially improving power efficiency.

- **Weight**
  The weight of the large electromagnets in many EMS and EDS designs is a major design issue. A very strong magnetic field is required to levitate a massive train. For this reason one research path is using superconductors to improve the efficiency of the electromagnets, and the energy cost of maintaining the field.

- **Noise**
  Because the major source of noise of a maglev train comes from displaced air, maglev trains produce less noise than a conventional train at equivalent speeds. However, the psychoacoustic profile of the maglev may reduce this benefit: A study concluded that maglev noise should be rated like road traffic while conventional trains have a 5-10
dB "bonus" as they are found less annoying at the same loudness level.

- **Design**

Comparisons Braking and overhead wire wear have caused problems for the Fastech 360 railed Shinkansen. Maglev would eliminate these issues. Magnet reliability at higher temperatures is a countervailing comparative disadvantage (see suspension types), but new alloys and manufacturing techniques have resulted in magnets that maintain their levitational force at higher temperatures.

As with many technologies, advances in linear motor design have addressed the limitations noted in early maglev systems. As linear motors must fit within or straddle their track over the full length of the train, track design for some EDS and EMS maglev systems is challenging for anything other than point-to-point services. Curves must be gentle, while switches are very long and need care to avoid breaks in current. An SPM maglev system, in which the vehicle permanently levitated over the tracks, can instantaneously switch tracks using electronic controls, with no moving parts in the track. A prototype SPM maglev train has also navigated curves with radius equal to the length of the train itself, which indicates that a full-scale train should be able to navigate curves with the same or narrower radius as a conventional train.

- **Control Systems**

EMS Maglev needs very fast-responding control systems to maintain a stable height above the track; this needs careful design in the event of a failure in order to avoid crashing into the track during a power fluctuation. Other maglev systems do not necessarily have this problem. For example, SPM maglev systems have a stable levitation gap of several centimeters.

**Compared to aircraft**

For many systems, it is possible to define a lift-to-drag ratio. For maglev systems these ratios can exceed that of aircraft (for example Inductrack can approach 200:1 at high speed, far higher than any aircraft). This can make maglev more efficient per kilometre. However,
at high cruising speeds, aerodynamic drag is much larger than lift-induced drag. Jet transport aircraft take advantage of low air density at high altitudes to significantly reduce drag during cruise, hence despite their lift-to-drag ratio disadvantage, they can travel more efficiently at high speeds than maglev trains that operate at sea level (this has been proposed to be fixed by the vactrain concept). Aircraft are also more flexible and can service more destinations with provision of suitable airport facilities.

Unlike airplanes, maglev trains are powered by electricity and thus need not carry fuel. Aircraft fuel is a significant danger during takeoff and landing accidents. Also, electric trains emit little carbon dioxide emissions, especially when powered by nuclear or renewable sources.

- How much will it cost to travel by Maglev compared to airplanes? Will it be faster or slower, more comfortable?

The average cost for air travel is about 13 cents per passenger mile. This includes labor, airplanes, fuel, and other costs, and corresponds to a ticket price of about $600 round trip, for a coast-to-coast flight. Some tickets cost less, some more, for a particular flight, depending on the discount offer, date of purchase, age, and so on. The 13 cents per passenger mile does not include government subsidies for airports, highway access, FAA operations, etc.

Maglev operational costs for vehicles, energy, and labor total about 4 cents per passenger mile, not including the amortization cost for the guideway. Projecting guideway amortization cost is difficult since it depends on ridership and whether the guideway carries freight as well as passengers. For a MAGLEV guideway cost of 10 million dollars per 2-way mile, that carries only passengers, amortization cost is about 10 cents per passenger mile, assuming a 30-year payback period and 10,000 passengers daily. If the guideway carries 1000 trailers daily and allocates 3 cents per ton mile (30 tons per trailer) of revenue to guideway amortization, the passenger share for guideway amortization is zero cents per passenger mile. Total cost for passengers is then only 4 cents per passenger mile, about 1/3 of that for air travel. If Maglev guideways carry both passengers and truck type freight, Maglev will be much cheaper than air travel.

Although jet aircraft speed is greater than Maglev (500 mph compared to 300 mph) the actual trip time will be much less for Maglev. First,
access to Maglev stations will be much easier and faster than airports. With the National Maglev Network, over 70% of the population will live within 15 miles of a Maglev station, which they could reach in a few minutes. Second, the departure frequency of Maglev vehicles will be much greater than for aircraft. Most airports have only a few flights daily to a given destination: Maglev stations will typically have dozens. Third, Maglev schedules will not be upset by bad weather or congestion, which is often the case for air travel.

Finally, because Maglev vehicles are much cheaper than airliners - a few million dollars per vehicle, compared to a 100 million dollars or more for an airliner - and because their operating cost is very low, Maglev travel will be much more comfortable than air travel. There is no need to pack riders in like sardines to save money - passengers will travel in first class style, for lower cost than economy air. Moreover, the vibration and noise experienced on airliners are completely absent on Maglev vehicles.

- **Why is Maglev better than the High-Speed Trains already operating in Europe and Japan?**

Maglev is better than high-speed trains for many reasons. First, rather than the point-to-point service between city centers characteristic of high speed rail, Maglev will have many more stations, distributed so that people have easy and fast access to the Maglev Network. Second, individual Maglev vehicles will hold 100 people at most, compared to the 500 to 1000 people on a high-speed train. This enables more frequent and convenient service. Third, Maglev vehicles travel at 300 mph, compared to 180 mph for high-speed trains. The faster Maglev vehicles, plus their ability to accelerate and decelerate much more quickly, cut the travel time for Maglev by at least a factor of 2, as compared to high speed rail. Fourth, the Maglev noise is much less than steel wheels on rail. Finally, Maglev vehicles travel on elevated guideways, something that the much heavier trains cannot do. Elevated Maglev guideways enhance safety and reduce environmental impact, compared to an on-grade rail track.

- **Why don't we already have Maglev systems? If they are as good as you say, why aren't they being built?**
There is a tremendous investment, both in money and human experience, in our present modes of auto, truck, air, and rail transport. The US spends almost a trillion dollars annually on these transport systems. Until recently, they have functioned adequately. Moving into a new transport mode like Maglev is difficult and takes time, because of the large capital investments required, and the need for people to acquire new job skills and change their ridership habits.

**Public Benefits of Maglev**

The economic evaluation of maglev should include not only its financial viability but also its other public benefits and costs in areas such as congestion, petroleum consumption, emission, and safety. The estimated values of such public benefits and costs can, at least conceptually, be added to the corridor revenues and used to compute a societal benefit/cost (BC) ratio.

**Airport Congestion Relief Benefit**

**Analysis of airport congestion relief indicated that:**

- Passengers diverted to maglev from air reduce demand and congestion at airports.
- The congestion reduction benefit is received by remaining air passengers, i.e., airport users.
- Maglev would have a sizable congestion relief benefit when aggregated over many cities, corridors, and years.

Diversion of air traffic to Maglev trains will potentially reduce delays at congested airports. Although this benefit may be reduced by having new flights at popular departure times, having more air travelers, or by canceling or postponing airport/air traffic control improvements, the direct congestion reduction benefit can still be a good first approximation of the size of estimated benefit. However, the estimate is highly dependent on the assumptions that are made about airport capacity increases during the period of analysis.
4.2 Safety

- Are super-conducting magnets really dependable? Will it be safe to travel by Maglev?

Superconducting magnets are highly reliable. High-energy accelerators routinely operate with many hundreds of superconducting magnets positioned along the path followed by particles that travel in precise orbits along miles of evacuated tubes. If only one of these many hundred magnets failed, it would shut down the accelerator for a long period while the magnet was repaired or replaced. Such a situation could not be tolerated, and in fact, does not occur in practice. In the proposed superconducting super collider (SSC), for example, over 10,000 superconducting magnets would have been positioned along the 76-kilometer circumference of the SSC. Failure of one of these magnets would have shut down the SSC.

The Maglev vehicles are designed with multiple (typically 16) superconducting magnets that operate separately and independently of each other. The vehicle will remain levitated and operate safely even if several of its magnets were to fail. Because the failure rate of superconducting magnets is very low, the probability of two magnets failing in a period of few minutes, the time needed to reach a stopping point, would be less than once in a million years of operation.

Such a failure rate is much smaller than the engine failure rate in jet aircraft. Furthermore, the Maglev vehicle would continue to operate, while the jet aircraft would not. In fact, it would take the simultaneous failure of at least 6 independent magnets to compromise levitation capability -a probability that is infinitesimally small compared to other modes of transport.

- What happens if the electric power is cut off to a Maglev guideway? Will the vehicles on it crash?

The Maglev vehicles are automatically and passively stably levitated as long as they move along the guideway. The electric power fed to the guideway magnetically propels the vehicles and maintains their speed. If the guideway power were cut off, the vehicles would coast for several
miles, gradually slowing down due to air drag. When they reach 30 mph, they settle down on auxiliary wheels and brake to a stop on the guideway. When power is restored to the guideway propulsion windings, the vehicles can magnetically accelerate back up to their cruising speed. Because the vehicles are automatically levitated and stabilized for speeds greater than 30 mph, there is no chance of a crash if guideway power is cut off.

**Are there any health or environmental hazards from the magnetic fields of a Maglev vehicle?**

There are no health and environmental hazards from the magnetic fields around the Maglev vehicle. The magnetic fringe fields from the quadrupole magnets on the vehicles drop off much faster with distance than do the fringe fields from dipole magnets. This rapid decrease in fringe fields allows the magnetic fields in the passenger compartment to be at Earth ambient level, ~ 0.5 Gauss. All humans live constantly in Earth's magnetic field and are adapted to it. They will experience no difference in field strength when they ride in a Maglev vehicle.

In fact, people presently experience stronger magnetic fields than the Earth ambient value when they ride subways and electrified trains, when they operate electrically powered equipment in the home or when they walk down city streets. The magnetic fields in vehicles will be lower than in the above examples.
5. ACCIDENTS

August 11, 2006 fire in Shanghai Transrapid

On August 11, 2006 a fire broke out on the Shanghai Transrapid, shortly after leaving the Longyang terminal. This was the first accident on a maglev train in commercial operation. Train operation was shut down immediately. Passengers were able to disembark the train safely and no casualties were reported. Operations resumed on one line after some days.

The fire was thought to have originated below the passenger compartment, possibly as a result of battery malfunction.

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Fig. 5.1 Men trying to extinguish the fire in Shanghai Transrapid
Accident of Lathen Transrapid, Germany

The 2006 Lathen Maglev train accident occurred on 22 September 2006 when a Transrapid magnetic levitation (maglev) train collided with a maintenance vehicle near Lathen, Germany. 23 people were killed, making this the first fatal accident on a maglev train.

The Transrapid

The Transrapid 08 was doing trial runs, carrying passengers along a 19.8 mile (31.8 km) test track to demonstrate the maglev technology. The track runs from Lathen, Germany, to Dorpen, Germany, with a loop at each end. The Transrapid 08 was capable of reaching speeds of up to 280 mph (450 km/h) on the test track.
Fig 5.4 A German magnetic levitation train has crashed at high speed into a maintenance vehicle in north-western Germany

The Accident

The accident occurred on the morning of 22 September 2006 about 0.6 miles (1 km) away from Lathen at about 09:30 local time. A maintenance vehicle was checking the track for debris when the Transrapid hit it at about 125 mph (200 km/h). The Transrapid was partially derailed. Both vehicles suffered severe damage. Wreckage was spread over a section of track 437 yards (400 m) long. 23 people were killed and ten were seriously injured. The two men in the maintenance vehicle survived.

Fig 5.5 The train was travelling at 200km/h when it hit the vehicle, and was left hanging from the rail
Aftermath

Firefighters used turntable ladders and aerial platforms to reach the scene, which was about four meters above the ground. 150 personnel were involved in the rescue.

Fig 5.6 Emergency workers tried to rescue passengers from the train, but were hindered by it balancing on the elevated track

Conclusion

Until this accident, the train had safely carried a half million passengers on demonstrations rides. The crash has been blamed on human error by the train controllers and train operator, and therefore is not directly attributable to the train's design or technology.

Fig 5.7 Wreckage of the maglev train, which floats above a rail and can reach speeds of 450km/h, was scattered around the impact zone

It is a basic fact of trains that the tracks must be kept clear in order to prevent crashes. An accident of this type may have been preventable by design - the
Shanghai Transrapid line uses a computerized control system which prevents two trains from sharing the same track and shuts down a train if an obstacle is detected ahead. The maintenance vehicle carried out routine sweeps of the track to remove debris, fallen branches, etc. and is supposed to report back to the control centre via voice radio once it has cleared the track. The compounding technical flaw was that although Transrapid vehicles on the guideway are automatically tracked and controlled by the OCS, the maintenance vehicle did not operate in the same way and thus was not known to the computerized control system. Had the maintenance vehicle reported its position electronically as all Transrapid trains do, redundant computerized safety systems would never have allowed the passenger vehicle to approach.
The Miyazaki Fire incident

The MLU002 (Japan) test train was completely consumed in a fire in Miyazaki. As a result, the political opposition claimed maglev was a waste of public money. New designs were made.

Fig 5.9 Water being sprayed to douse the fire

Fig 5.10 Engineers checking the cause of the fire
6. CONCLUSION

This report gives us an insight about the principle of maglev as well as its application in running maglev trains. Also, the intricate complexities of the maglev technology have been explained. Its implementation in the various cities of the world and its innumerable advantages just take it a step closer to being the future of transportation. Maglev trains are soon going to be the new way of transportation. Just a few obstacles are in the way, but with some more improvisations nothing is impossible. With no engine, no wheels, no pollution, new source of energy, floating on air, the concept has taken tens of years to develop and just recently its true capabilities have been realized. Competing planes with speed, ships with efficiency, traditional trains with safety, and cars with comfort, it seems like a promising means of transport. Maglev trains are environment friendly; noise pollution is minimized because there is no wheel to rail contact (frictionless). A maglev train operating at 150mph is inaudible to a person standing 25 miles away. The system encourages land conservation, which is especially useful where land is costly or unavailable. Tracks for the trains are easily built on elevated platforms; this provides opportunity for construction and development underneath and prevents land dissection and also reduces animal collisions. This assertion can prove useful in constructing guide ways for maglev trains across residential areas, schools, religious places, tourist spots, etc. However, the cost of construction of these trains runs into billions of dollars. The high cost of these trains is the only deterrent factor which is preventing the train from being executed everywhere. Continued research in this field along with active interest from the various governments in the world can reduce the costing considerably with cheaper options not compromising on the safety.

Future Expansions

In the far future Maglev technology are hoped to be used to transport vast volumes of water to far regions at a greater speed eliminating droughts.

- Far more, space is an open door to maglev trains to propel space shuttle and cargo into space at a lower cost. Artist’s illustration of Star Tram, a magnetically levitated low-pressure tube, which can guide spacecraft into the upper atmosphere.
Scientists hope future technologies can get the train to operate at a 6000km/h, since theoretically the speed limit is limitless. But still it’s a long way to go.

Toshiba Elevator and Building Systems Corp have developed the world’s first elevators controlled by magnetic levitation available as early as 2008. Using maglev technology capable of suspending objects in mid-air through the combination of magnetic attraction and repulsion they promise quieter and more comfortable travel at up to 300m per-minute, some 700m per-minute.

Thus, active collaboration and future joint ventures from all international bodies holds the future of these trains.
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Magnetic levitation or maglev is a transportation technology.

**AC Current**
In alternating current (AC, also ac) the movement (or flow) of electric charge periodically reverses direction. An electric charge would for instance move forward, then backward, then forward, then backward, over and over again.

**Aichi Loop Railway**
Aichi Loop Line is a Japanese railway line between Okazaki Station, Okazaki and Kōzōji Station, Kasugai, operated by Aichi Loop Line Company.

**Amortization**
To decrease an amount gradually or in installments, especially in order to write off an expenditure or liquidate a debt.

**Amtrak**
Amtrak (AMTK), is a government-owned corporation to provide intercity passenger train service in the United States.

**Baltimore**
Baltimore is an independent city and the largest city in the state of Maryland, United States.

**Chassis**
A chassis consists of a framework that supports an inanimate object.

**Consortium**
A consortium is an association of two or more individuals, companies, organizations or governments (or any combination of these entities) with the objective of participating in a common activity or pooling their resources for achieving a common goal.

**Dörpen**
Dörpen is a municipality in the Emsland district, in Lower Saxony, Germany.

**eddy current**
An eddy current is an electrical phenomenon caused when a conductor is exposed to a changing magnetic field due to relative motion of the field source and conductor; or due to variations of the field with time.
**Emsland**
Emsland is a district in Lower Saxony in north-west of Germany.

**Ferromagnetism**
Ferromagnetism is the basic mechanism by which certain materials (such as iron) form permanent magnets and/or exhibit strong interactions with magnets; it is responsible for most phenomena of magnetism encountered in everyday life (for example, refrigerator magnets).

**Flux**
The lines of force surrounding a permanent magnet or a moving charged particle.

**Flux Density**
*flux density* is the amount of magnetic flux per unit area of a section, perpendicular to the direction of flux.

**Forestall**
To prevent, delay or hinder something by taking precautionary or anticipatory measures.

**Fujigaoka Station**
Fujigaoka Station is a train station in Meitō-ku, Nagoya, Aichi Prefecture, Japan.

**Gradient**
a graded change in the magnitude of some physical quantity or dimension.

**Groove**
A long narrow furrow cut either by a natural process (such as erosion) or by a tool.

**Halbach arrays**
A Halbach array is a special arrangement of permanent magnets that augments the magnetic field on one side of the array while cancelling the field to near zero on the other side.

**Hover**
To remain floating, suspended, or fluttering in the air.

**HSGT**
High Speed Ground Transportation.
HSR
High Speed Rail.

HSST
High Speed Surface Transportation.

ICE
Intercity Express.

Intermodal
Unified, interconnected forms of transportation.

Kawasaki Heavy Industries
Kawasaki Heavy Industries, Ltd. is an international corporation based in Japan. It is a multi-industry company.

Lathen
Lathen is a municipality in the Emsland district, in Lower Saxony, Germany. It is best known in Germany as the location of the Transrapid maglev train test line.

Levitating
To rise or cause to rise into air and float in apparent defiance of gravity.

Levitation, Magnetic
Support technology that keeps a vehicle separated from its guideway by riding a surface of magnetic force.

Lenz Law
"An induced current is always in such a direction as to oppose the motion or change causing it".

LIM
Linear induction motor

Line haul time
Transportation service time between points without consideration of external time factors such as access to the system or entry and exit requirements.

Long Stator
Propulsion using an electrically powered linear motor winding in the guideway.
Longyang Road Station
Longyang Road is a station on Line 2 of the Shanghai Metro.

LS
Limited sharing of rights of way.

LSM
Linear synchronous motor.

Magnetic Levitation
Support technology that keeps a vehicle separated from its guideway by riding a surface of magnetic force.

Miyazaki
Miyazaki Prefecture is located in the South Eastern corner of the island of Kyushu (the Southernmost of the four main islands of Japan).

MLU
A Japanese maglev system employing a U shaped guideway.

Osaka
It is a city in Japan, located at the mouth of the Yodo River on Osaka Bay, in the Kansai region of the main island of Honshū, the main island of Japan.

Pantograph
A device for collecting current from an overhead conductor, characterized by a hinged vertical arm operating by springs or compressed air and a wide, horizontal contact surface that glides along the wire.

Payload
The total weight of passengers, crew, equipment, and cargo carried by an vehicle.

Propulsion
It means to push forward or drive an object forward. A propulsion system is a machine that produces thrust to push an object forward.

Psychoacoustic
A branch of science dealing with the perception of sound, the sensations produced by sounds and the problems of communication.
Pudong International Airport
Shanghai Pudong International Airport is a major aviation hub in Asia, particularly in the East Asian region, and is the primary international airport serving Shanghai of the People's Republic of China.

Quadrupole Magnets
Quadrupole magnets consist of groups of four magnets laid out so that in the multipole expansion of the field the dipole terms cancel and where the lowest significant terms in the field equations are quadrupole.

Rotem
Rotem is a South Korean company manufacturing rolling stock, defense products and plant equipment. It is part of the Hyundai Motor Group.

Rotor
The non-stationary part of an alternator or electric motor, operating with a stationary element called the stator.

Siemens
Siemens is Europe's largest engineering multi-industry company. The company deals with three main business sectors: Industry, Energy and Healthcare with a total of 15 Divisions.

Short Stator
Propulsion technology using a linear induction motor winding onboard the vehicle and a passive guideway.

Spline
Any of a series of projections on a shaft that fit into slots on a corresponding shaft.

Stator
The nonrotating part of the magnetic structure in an induction motor.

Superconducting Magnets
A superconducting magnet is an electromagnet that is built using coils of superconducting wire. Their advantages are that they can produce stronger magnetic fields than ordinary iron-core electromagnets, and can be cheaper to operate, since no power is lost to ohmic resistance in the windings.
**Superconductivity**
The abrupt and total disappearance of resistance to direct current which occurs in some materials at temperatures near to or somewhat above absolute zero (like 90 K for some high temperature superconductors).

**ThyssenKrupp**
ThyssenKrupp is a large German industrial multi-industry company, with more than 200,000 employees. The corporation consists of 670 companies worldwide.

**Train Grande Vitesse**
The French National Railway’s high speed, steel wheel on rail train.

**World Expo in Nagoya**
World Expo 2005 was the World's Fair held in Aichi Prefecture, Japan, east of the city of Nagoya. The Expo ran for 185 days between March 25 and September 25, 2005.

**Yamanashi Prefecture**
Yamanashi prefecture (Yamanashi-ken) is located in the Chubu region on Honshu island, Japan. The capital is the city of Kofu.