EIR Science & Technology

Mag-lev train will allow us to fly at zero altitude

There are two revolutions in Europe. The new political unity must be consolidated with the first new form of ground transportation since the invention of the wheel. Germany's Ralf Schauerhammer explains.

The following article motivates the urgent need for the German government to implement the leading edge of a high-speed transportation system based on magnetic levitation technologies. German researchers have investigated mag-lev, as it is known, intensively for over a decade, and the only roadblock to implementation has been the persistent capitulation of the government to Anglo-American dictates. As Schauerhammer documents, one form of this technology can, and must, be immediately put into place, before the transportation "heart attack" so hoped for by the Anglo-Americans, kills continental Europe.

Meantime, the Japanese, less politically timorous, have laid out and approved right-of-ways for a more advanced magnetic levitation system, whose development is not yet completed. Nonetheless, the Japanese recognition of the vital economic importance of the first breakthrough in ground transportation since the invention of the wheel, is the principle Germany must look to, and not the "good opinions" of the ancien régime *of Adam Smith-Karl Marx neanderthals in Washington, London, and Moscow.*

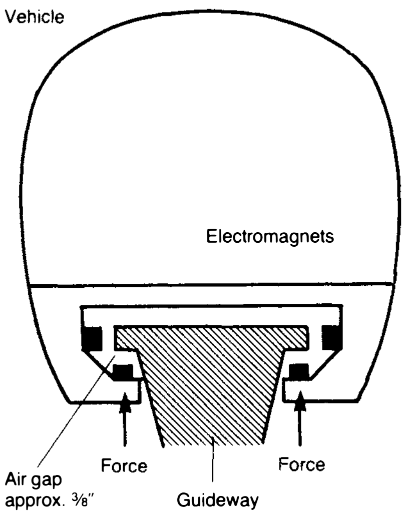
When Lyndon LaRouche first elaborated his European Productive Triangle on Jan. 2, 1990, the dream of German reunification was barely beginning to become reality. LaRouche's proposal, to base a newly freed, unified Europe on a concentration of infrastructure whose vertices were marked by Paris, Berlin, and Vienna, provided the unique economic basis for turning the continent into a locomotive for new development, consigning both Karl Marx and Adam Smith to the dustbin.

What a paradoxical situation! Experts warned that in 1992 there would be a "traffic heart attack" on Europe's roads and in its air space. But their warning was too late, and transportation chaos is already here. Congestion on the highways, holding patterns over airports, and train connections off schedule are now the order of the day. On the other hand, there exists in Germany a revolutionary transportation technology that is suitable to prevent the "heart attack": the magnetic levitation (mag-lev) train, Transrapid. This technology has been under development for 20 years. All the components are developed, and the overall system tested to the point that it is ready for commercial introduction. The detailed planning of large stretches of track could be begun today, with construction of European-wide mag-lev train routes beginning after the approximately five years that is customarily necessary. And yet the mag-lev train has been blocked for years. What is lacking is the competence of those politically responsible to plan and approve the introduction of this technology.

In Japan, the country in which the age of high-speed trains was introduced in the 1960s with the Shinkansen ("Bullet") train, the political decision for a mag-lev train has already been made. Even the planning of routes on the magnetic "Super Shinkansen" is under consideration. There, however, a different technological variant of the mag-lev trains has been selected than in Germany, and the technological development of that variant is not yet sufficiently advanced for the already politically approved lines to be installed. The Japanese experimental vehicle MLU002 on its test track in Miyazaki is 5 to 10 years behind Transrapid 07. When German politicians awaken some years from now from their enchanted transportation-policy sleep, they are sure to lament about how aggressively Japan is carrying on the competitive fight for high-technology markets.

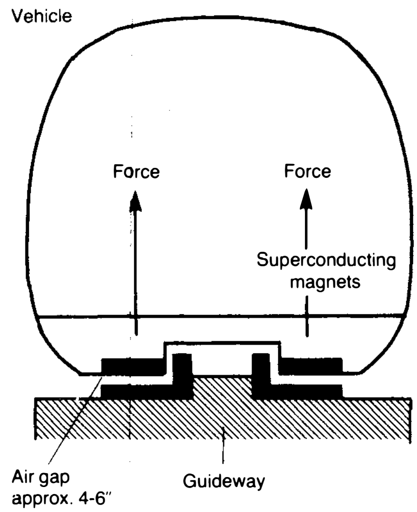
FIGURE 2
Attractive and repulsive mag-lev

Electromagnetic mag-lev (attraction)



System: Germany's Transrapid 07

Superconducting mag-lev (repulsion)



System: Japan's Linear Express ML-002

Electromagnetic, attractive maglev (left) uses conventional magnets aboard the vehicle which are attracted to a ferromagnetic guideway. This design creates a small air gap between the vehicle and the guideway of only a fraction of an inch. On the right is the superconducting, repulsive maglev design. Here, the magnets onboard the vehicle interact with induced magnetic fields from eddy currents produced in a light-weight aluminum guideway. The air gap is greater, and the vehicle is inherently stable.

Even more important than the potential competition of Japan is the political revolution of the last two years. The map of Europe has been completely transformed. Even if the fact has not penetrated to all the planners in the German state bureaucracy, the "Iron Curtain" has finally collapsed. The geometry of the European economy will now be determined primarily by geography and transportation infrastructure. We must accept geography as it is, but we could shape the infrastructure with an eye to the future.

Transportation in Europe's future

In fewer than two years, Europe has grown by 50 degrees of longitude. We will soon become accustomed to thinking of distances in Europe, not in hundreds of kilometers, but rather, in thousands. Europe is suddenly broader than it is long. If the principal transportation arteries have run in a north-south direction since the Second World War, a massive additional tendency will now come into existence in the east-west direction. That has obvious consequences for transportation policy.

The complete development of this new Europe will take decades, but the crucial direction-setting decisions must be made today. These decisions are to be made by politicians whose careers and minds have been so anchored in the postwar *status quo* that they are unable to recognize the significance of their decisions and omissions today, in the framework of this new situation.

What we need today would be a European Friedrich List. The unity of Germany in the last century is not conceivable without the economic customs union created by List. But economic integration did not come into existence merely on paper and in the text of treaties; it had its material basis in the development of the railway system. Today, this same problem must be solved for all of Europe from the same broad point of view. The railway was of such infrastructural importance in List's time, because it was the most modern transportation technology. At the time, the arguments against the "expensive" and "totally superfluous" railroad sounded exactly like those that are brought up today against the mag-lev train. Who does not see the importance of the mag-lev train in the context of a new European infrastructure, will argue exactly as did the provincial stage-coach owner in the last century, who attempted to demonstrate to List that the railroad would not be profitable.

If we merely look at the development of the distribution of transportation volumes on existing carriers—ship, automobile, truck, train, and aircraft—we see at a glance that what is lacking is a system that will close the huge, yawning gap between motorized traffic and air traffic. Flying at zero altitude is the solution: The mag-lev train will do it!

This year, the green light must be given for Transrapid. Lines in the new federal German states are the obvious choice, since infrastructure investments here are unavoidable in any case.

At the very least, concrete planning must begin this year for the following routes: 1) the "backwards C," Hamburg-Berlin-Munich, with a branch to Dresden and Prague; 2) Frankfurt-Berlin, with possible continuation to Warsaw; 3) the Hanover-Berlin line should be developed with mag-lev technology. Of course, the decision has already been made for the old wheel-rail technology on this line, but because the mag-lev train can be routed more flexibly than the high-speed train ICE, we can build up from existing planning, and the decision in favor of the mag-lev train should not slow down the development of the project. 4) It can now be planned how the lines from Hanover and Frankfurt in the Cologne-Bonn area can be brought together and integrated with the mag-lev connection between the airports in Cologne and Düsseldorf, a project which has been under discussion for years.

That is the minimum of "advance work" that the Federal Republic can perform, so that the mag-lev train can become the backbone of a new transportation infrastructure in Europe. The future European transportation infrastructure should be implemented on the basis of the following clear principles: Bulk goods belong on ships; piece goods, on trains; and high-grade express freight and passengers will be transported on mag-lev lines. Only motorized transport can carry out local surface distribution, and the airplane will be Europe's connection to the world.

The mag-lev technological revolution

The mag-lev train is the only form of transportation that moves without contact. Even aircraft cannot manage without wheels in their brief but crucial take-off and landing phases. The technological history of mankind began with the control of fire and the development of the wheel. The magnetic train levitates and no longer needs wheels, and that shows what a revolution is involved here.

From primeval ox carts to the modern, high-speed Intercity Express (ICE), the principal components of transportation technology have remained the same. A load is transported from one place to another, carried on wheels. The load, which normally would produce friction with the ground over the entire support surface, is distributed on the few support points of the wheels or the axle bearing. The force of the load, and especially its sliding friction in locomotion, is now concentrated in those points, but can be deliberately controlled there with high-grade materials. As soon as it was possible, axle bearings and wheel rims on wooden vehicles were made of iron. Moreover, the load in sideways motion must be carried in the right direction. With ox carts, that is accomplished by means of the driver's whip; with the ICE, the tracks on which the guiding rims run are machined to millimeter precision. Finally, the entire system must be propelled. The oxen accomplish that with muscle power through the frictional force of their hoofs, the ICE by means of its electric motors through the frictional force of the wheels on the tracks. The ICE must distribute the application of force very exactly, so that the steel wheels do not spin on the steel tracks. It moves rather like an ox on ice.

The energy supply reveals the first principal difference between the ICE and the ox cart. The ox carries its energy supply around in fat and muscle tissue, as well as its stomach, and must be "filled up" in the stall or pasture. The same is true for almost all transport types: auto, airplane, powered ships, rocket, and steam and diesel locomotives. They carry around their transportation energy in a tank or tender. How decisive a smaller and lighter tank is for the economy of a type of transportation is seen in the attempts to drive autos with "environmentally friendly" hydrogen or electric engines. The engines have been around for a long time; the problems now, and probably for quite some time in the future, concern tank and battery, and relate to the fact that the weight and volume of the stored energy is not comparable to the normal gasoline tank. Best of all would be a form of transportation that used no tank at all. Transrapid is such a vehicle; it needs no "tank" for its drive energy.

The energy supply for the engine is also not carried around with the vehicle for street cars, trolleys, subways, and electrified train lines, since the drive energy can be supplied continuously via electrical conductors from overhead wires. That allows a significantly more rational operation, as can been seen, for example, from the fact that the German national railroad, the Bundesbahn, could reduce its energy use by one-half by electrifying its principal routes. With increasing travel velocities, this advantage becomes, however, a problem, since the current collector must exert great pressure on the live contact lines to maintain the contact. Tearing the contact line, as has already happened on the French high-speed train TGV, is not a harmless accident.

With the magnetic train, support, guiding, and drive are all completely frictionless. The load is simply lifted up 1 centimeter by magnets and guided along the track. Nothing rolls, nothing turns, and nothing rubs. Everything is provided by magnetic fields. Drive energy need be supplied to the vehicle neither from a fuel tank nor through supply lines or a current collector, since there is no motor in the driver's cabin of the magnetic train that would use such energy. The active part of the drive on the Transrapid is the rail. Transrapid needs no electric motor; it is driven along on the electromagnetic waves from the roadway by its support magnets, somewhat like a surfer on a surfboard, only, in distinction from natural water currents, electromagnetic waves can be controlled precisely down to the millimeter in order to allow the train to arrive at the right place at the right time.

Transrapid cars require only a minimum of protection for the passengers, namely, the cabin itself and its magnetic "mounting installation" to the roadway. As a result, the vehicle is light and gains in structural flexibility. Both the drive and the energy supply are present completely without contact. It is a revolution in the millennia-old history of transportation technology.

If magnetic levitation is such a brilliant solution, why wasn't it implemented long ago? After all, magnetism has been known since antiquity, and electromagnetic effects have been exhaustively researched for at least 150 years. In fact, the idea of frictionless transport is nothing new. In the last century, it was proposed that vehicles move without friction on water cushions or with permamagnets. Another kind of frictionless transport has been achieved in air-cushion vehicles, which are used only in the military, and there only for specialized amphibious deployments. As a means of universal transportation, they are inappropriate.

What is the advantage of a magnetic train? Compare it to the air-cushion vehicle, which must not only produce the drive energy, but also, like an aircraft, must produce the additional support energy, or lift, which is provided to a vehicle with wheels "free of charge."

The crucial point with the Transrapid magnetic train is that the energy necessary for lift support is negligible. That sounds improbable, but it is easy to understand on closer examination. On the experimental track in Emsland, Germany, measurements showed that the electrical energy to produce levitation is only 110 kW, that is, 1 kW per ton of vehicle weight, and less than is used by Transrapid's air-conditioning system. This low energy use is possible because the magnetic fields of Transrapid can be so precisely controlled that there is an air gap of only a few millimeters between the magnets of the track and those on the vehicle. As a result, the support magnetic fields can be kept small, and the leakage of magnetic fields in the cars is no greater than the terrestrial magnetic field, even though the vehicle is levitated by the fields. An individual using an electric hair dryer is exposed to a magnetic field 10 times greater than when traveling on Transrapid.

Overall, Transrapid, at speeds around 200 kilometers per hour (kmh), uses less energy than the ICE: First, the Transrapid, at 0.58 ton per seat, is very light in comparison with the ICE, at 1.11 tons per seat. Second, energy consumption at velocities over 200 kmh is primarily determined by aerodynamic resistance, and Transrapid also has the advantage here. Third, the rolling friction in wheel-on-rail systems such as ICE increases at higher speeds, whereas, with Transrapid, the resistance of the guide magnets and linear generators (that is, "magnetic rolling friction") decreases at speeds over approximately 150 kmh. Even a normal Intercity Express train at 160 kmh uses 40% more energy per passenger than the Transrapid. To see how that is possible, we must more closely consider the Transrapid's magnet system.

Magnetic levitation: How is it done?

There are two different magnetic train systems. The electromagnetic system (EMS), or attractive mag-lev, was employed in the Transrapid in Germany. In Japan, this system was researched, but research there has concentrated primarily on the electrodynamic system (EDS), or repulsive mag-lev, and testing has been done with the experimental vehicle MLU002. In the Federal Republic of Germany, a concept for electrodynamic levitation was developed in 1977. At that time, Project Group Magnetic-Levitation Train, which was supported by the firms AEG, BBC, and Siemens, attempted to combine wheel-on-rail technology with the electrodynamic system. The concept was crushed by the wheel-on-rail lobby. When, in the same year, the development of the electrodynamic system was begun in Germany, Japan immediately embarked resolutely upon this development.

Electrodynamic levitation seems, at first glance, to be more promising. In repulsive mag-lev systems, strong magnetic fields are produced in superconducting magnetic spools installed in the vehicle. Aluminum guide plates are mounted along the roadway. When the vehicle travels over these guide plates, an eddy current is induced that works against the magnetic fields in the vehicle, in accord with Lenz's Law. Vehicle and roadway repel one another, and the vehicle levitates. Since the repulsive force is increased with increasing velocity of the vehicle, the electrodynamic system needs wheels for standing still and slow motion, thus, "taking off" and "landing."

For electromagnetic systems, the attractive force between an electromagnet and a ferromagnetic rail is employed. However, this requires the distance between the electromagnet and the rail to always be held constant by rapid control technology. Every second, Transrapid's control system determines thousands of times—that is, at 500 kmh, every 1.4 millimeter along the route—whether the support magnets are at precisely the right distance from the rail. The control electronics ensure that current in the support magnets is properly adjusted quickly. If the support magnet approaches the rail too closely, the current, and therefore the magnetic field, is reduced; if the support magnet moves too far from the rail, the current in the support magnet is increased, and the vehicle is more powerfully attracted to the rail. The rapid pace of technological development in high-performance transistors enabled Transrapid to be controlled far better than was originally assumed, and for that reason, very little support energy is needed.

The electrodynamic system can do without this control in principle, and it was originally assumed that it could be operated with far more energy efficiency than the electromagnetic system. In practice, however, it turns out that the eddy current losses in the electrodynamic system are greater than assumed. In addition, there is the energy expenditure for cooling the superconducting magnets; this will improve only through the use of high-performance magnets built on the principle of new developments in high-temperature superconductors. Third, it was possible through the unexpectedly rapid development of control technology to transform the disadvantage of necessary control with Transrapid into an advantage. This is even more true since, in the meantime, it turns out that electrodynamic systems cannot operate without active control, which is necessary to achieve the lateral load stability and pitch stability for passenger transport at speeds over 350 kmh.

In any case, the "German" EMS today has a clear developmental head start on the "Japanese" EDS, but that should not lead to an undervaluation of the great developmental potential of the EDS, especially in connection with further happy surprises in the development of superconductors (see *EIR*, May 11, 1990, "Mag-lev Technology Could Rebuild U.S. Transportation," and May 18, 1990, "U.S. Could Leapfrog Europe, Japan, in Mag-lev Technology.").

The support system of Transrapid consists of a chain of support magnets that attract the rail from below. The vehicle completely surrounds the rail, which contributes to traffic safety since the magnet train cannot be derailed. Because the chain of magnets distributes the weight of the vehicle along the entire length of the car, only a technically advantageous load area has to be dealt with, and not a point load, with which rail-wheel systems load the roadway. How decisively this roadway-protecting construction can affect operational costs can be seen in the fact that the operational velocity of the Japanese Shinkansen was reduced from 280 kmh to 220 kmh, in order to keep repair times and costs within tolerable limits.

Guidance of the Transrapid is ensured by laterally mounted magnets. The drive system is integrated with these support and guidance magnets.

What drive system a magnetic train uses can be solved in two different ways, and the most promising of the two was chosen for Transrapid. To make that clear, it is best to consider the manner in which a normal electric motor functions. It consists of two components: a fixed magnetic field and a mobile magnetic field, which is pulled step-by-step along the stationary field, like a hamster on its exercise wheel. At first, the magnetic north pole of the mobile magnet is attracted to the south pole of the stationary field, and moves in that direction. When it reaches that point, the electromagnetic field of the mobile field is reversed, so that the stationary north pole is next to a repulsing north pole, and the next south pole of the mobile field can be attracted.

A linear motor functions in much the same way, as the name suggests, "linearly," and not in a circle. Our hamster runs around on a long, linear exercise ladder extending through the entire house. With linear drive systems, the decision can be made whether the active mobile field will be on the vehicle or on the roadway. For the hamster, the second solution seems paradoxical, since it would appear that many hamsters, one placed beside the other, would represent the active part of the route, and a short piece of linear ladder would be passed along beneath each, which gives it a few shoves with its feet as it comes by. Technically, however, the choice of the active roadway is very interesting, since it allows us to shift the drive out of the vehicle to the roadway.

With Transrapid, therefore, it is not necessary, as it is with the ICE, to install a drive motor in the vehicle, which has the advantage that drive energy does not have to be carried on board the vehicle. Current collectors such as the ICE needs are thus no longer necessary. Ferromagnetic stator packets with three-phase mobile field windings are attached to the underside of the roadway as the drive component of the Transrapid. These mobile fields draw the magnets, which are in any case necessary for lift-support of the Transrapid, along the roadway. The Transrapid thus actually "surfs" with its support magnets on the alternating magnetic field generated in the roadway. Braking is also performed without contact, with the mobile field simply reversing in polarity, and, finally, the energy necessary for on-board systems can be drawn by induction from the mobile field. Everything fits together.

This construction concept is convincing. On the other hand, the speed records of wheel-rail systems on specially prepared tracks are about as convincing as the habit that aging U.S. Presidents have of jogging in public to prove their fitness. The magnetic train can travel at more than 500 kmh, and without any structural changes. The operational speed of the Transrapid was limited in previous plans to 500 kmh, because the sharply increasing energy costs made that kind of self-limitation seem sensible. Since the energy use of the magnetic train is clearly below that of an airplane, it can be

Robert H. Goddard's 'High-Speed Bet'

Our story begins in 1904. On Dec. 20 of that year, Robert H. Goddard—freshman physics student at Worcester Polytechnic Institute in Massachusetts and future great American rocket scientist and pioneer—read an essay before the freshman class, responding to the assigned English theme of Prof. Zelotes W. Coombs, "Traveling in 1950." Goddard's essay created considerable discussion and a good deal of skepticism. Enough interest was shown, however, to give Goddard the courage to present the idea in the form of a story, and send it in 1906 to prominent magazines, such as *Scientific American*. The editors, however, were fully as skeptical as some of the students, and "The High-Speed Bet"—as Goddard titled his story—did not find its way into print.

What method of travel did the young Goddard propose in his essay? He presented a scheme for Earth travel, addressing the three impediments to rapid surface transit:

- Friction between the rails—to be eliminated by raising the cars off the rails by electromagnetic repulsion roadbeds;
- Friction against the air—to be eliminated by propelling the cars through at least a partial vacuum;

• The time of transit—to be reduced to a minimum by speeding the cars faster and faster up to the middle of the journey, and then reversing the power and slowing down until the destination has been reached.

The train Goddard projected for the year 1950 seemed fantastic to his engineering classmates. Cars were suspended inside a steel vacuum tube, floating and driven by the attraction and repulsion of electromagnets—what is now referred to as magnetic levitation.

At the time of Goddard's essay in 1904, no patents had been issued for mag-lev rapid transit schemes. In fact, it was not until April 2, 1910, that Emile Bachelet applied for a patent on the use of alternating-current electromagnets in a car for purposes of levitation, and of solenoids at intervals along a road-bed for purposes of propulsion.

In Goddard's scheme, the train's electromagnetic speed would be limited only by the force of acceleration on the passengers, who would be strapped securely in reclining and reversible seats—the idea he patented some 40 years later. At the outset, the train would accelerate rapidly, reaching maximum velocity of two times the average velocity at mid-journey, then would decelerate at the same rate as the initial acceleration for the last half of the journey. Some 200 miles between New York and Boston would be covered in 10 minutes, an average speed of 1,200 miles per hour. Goddard's mag-lev train was to compete against conventional trains "running at the frightful speed of 180 miles an hour, but with great waste of energy and much danger. The people were not satisfied; greater speed and greater safety was their demand. Most insatiable were the rich and influential men."

According to biographer Milton Lehman, Goddard barely concealed himself in "The High-Speed Bet" as his hero, Maurice Sibley, who proposed the bet on a rainy afternoon in late November 1948 during an animated discussion at the Engineers' Club in New York. Sibley wagered $1,000 that by 1958 he would build a rapid transit system which would permit travel from Boston to New York in 10 minutes. The bet was accepted by another engineer, Charles Adams, who was invited to ride on the maiden voyage of Sibley's rapid transit wonder. The train reached New York a full three seconds faster than the wagered 10 minutes.

Eventually, *Scientific American* paid Goddard $5 for the use of his article based on "The High-Speed Bet," titled "On Future Rapid Transit," which the magazine converted into an unsigned editorial, "The Limit of Rapid Transit," for the Nov. 20, 1909 issue—four months before Bachelet applied for his patent.

—Robert D. Allen

Robert D. Allen, a mechanical engineer with experience in nuclear energy and aerospace development projects, contributed a fuller discussion on Goddard's mag-lev project to the Fall 1991 issue of 21st Century Science & Technology.

expected that it will be driven on some routes at more than 500 kmh. If we wanted to technically soup up the magnetic system, as is done with the wheel-rail system today, it could even be faster than air traffic, for example, by laying some of the track inside a vacuum tunnel.

The development history of the magnetic train

Mag-lev technology is very new, and yet, as with every important development, there were brilliant anticipations of it long before (see box). For example, the Frenchman Emile Bachelet experimented in 1912 with a model of a levitation train that worked according to electromagnetic principles. The energy use was so great, however, that the project necessarily failed. The German engineer Hermann Klemper began to work with mag-lev technology in 1922, and demonstrated in 1935 that levitation must be achievable with economical power input, and on Aug. 11, 1934 received national patent No. 643316 for a "levitation train with wheel-less cars that travels by means of magnetic fields on iron guide tracks."

Then came the Second World War, and nothing happened then or afterward for quite some time. Only in 1969, after the success of the Japanese Shinkansen astonished the world, did the German Federal Transportation Ministry issue a contract for the HBS study, and research on rail-bound rapid transport was again picked up. In the same year, Krauss-Maffei presented the first basic model with magnetic support and guidance systems and with a linear motor, and in October 1972, the experimental vehicle Transrapid 02 was conceived on the basis of the electromagnetic system. At the MBB firm, a test magnetic sled was put into operation.

At that time, the electrodynamic system was also being researched in Germany. In 1973, AEG, BBC, and Siemens began work on Project Group Mag-Lev Train with the test vehicle EET 01 in Erlange. In the following year, Krauss-Maffei and MBB formed the Transrapid-EMS Corporation. In 1975, this corporation operated the magnetically supported and guided component test vehicle KOMET, which was accelerated on a short experimental track with a hot-water drive system. The vehicle attained even at that time a speed of 401.4 kmh. In the same year, the construction of Transrapid 04 could begin. This vehicle was a "purebred" magnetic train, and in 1977 set the world record of 253.2 kmh for a mag-lev train with linear motor carrying passengers.

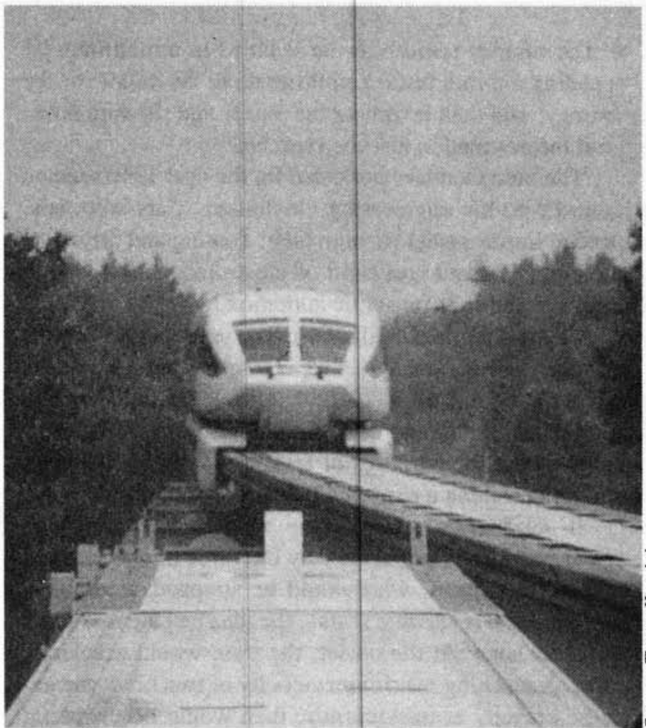
As already mentioned, in 1977, the development of electrodynamic (repulsive) levitation was halted in the Federal Republic, and in 1978, the firms participating in the development of the magnetic train formed the Magnetic Train Transrapid Consortium, in order to construct and operate the experimental facility at Lathen in Emsland. The construction of the 31 km-long track in the form of a figure eight, with approximately 10 km of straightaway in the middle section, was begun in 1979.

In the same year, the public at the Transportation Exposition in Hamburg was able to travel for the first time on a magnetic train. It was the 36 ton Transrapid 05 car, which carried more than 50,000 visitors over a 900 meter line. On this short route, a maximum velocity of 90 kmh was achieved.

The test vehicle Transrapid 06 served as the technical test for the entire system. In 1988 at Lathen, it achieved the record speed of 412.6 kmh on the 10 km straight track, at the end of which the vehicle had to be again braked down to 200 kmh, in order to safely take the oncoming curve. In so doing, it achieved an average acceleration of 0.51 m/sec^2. Parallel to these drive tests, the entire vehicle was reconstructed and further developed into the Transrapid 07, which was able to demonstrate the operational maturity of the system in the following year. In December 1989, a speed of 435 kmh was reached. Small delays occurred for the program, when it turned out that, under permanent load, the screw coupling of the stator packet on the roadway had to be slightly altered. Through heat, cold, fog, and ice, the Transrapid has accumulated over 100,000 km in operational experience at its test track in Emsland over the years. Today, Transrapid stands ready for commercial use as a tested technology, and stressed ICE riders may be assured that even the toilets function.

In Japan, Japan Airlines (JAL) began the development of High-Speed Surface Transportation (HSST) in 1974, and in 1978 attained a speed of 307.8 kmh with the test vehicle HSST-01. In the same year, the drive tests began for the successor system, HSST-02, and from 1985-87, the HSST-03, a vehicle based on the earlier version, carried 1.4 million persons at three world expositions. At the Saitama Expo 1988, the HSST-04 ran, outfitted with 70 passenger seats, and in 1989, demonstration of the HSST-05 began on a route just over 500 meters in Yokohama.

Overall, however, the emphasis in Japan is on work on electrodynamic (repulsive) levitation. As early as December 1979, an unmanned experimental vehicle using this system attained a speed of 517 kmh. In 1980, technical testing of the manned experimental vehicle, the MLU 001, was begun on an approximately 7 km test track, and in 1987 it reached 400.8 kmh. The successor project, MLU 002, has so far reached only 354 kmh with an average acceleration of 2.24 m/sec^2. It is to be supposed, and not merely as a result of that, that some unanticipated problems have appeared in the development of the electrodynamic system that are connected with the stability of the vehicle. To improve the lateral wind stability of the vehicle, support magnets were installed, not directly under the vehicle, but rather to the side. That improved the lateral stability, but pitch stability, that is, the vertical component in vibration, became worse.


Courtesy: Thyssen Henschel

Germany's magnetic levitation train, Transrapid.

Transrapid wins on points

If we look at the history of rapid train systems development in Germany, we must admit that a fundamental error was made in the last decade. In the 1960s and 1970s, development was more or less dormant. Nothing proves that more clearly than the rapid increase of continentwide freight transport on highways. For this volume of transport, a modern rail system was technically necessary. The avalanche of trucks that today clogs the freeways is the result of national conceit, bureaucratic ossification, and the technological obsolescence of European railroads.

When, at the end of the 1960s, it was recognized in France that the national railway company SNCF was threatening to bring everything to an end, the creation of a new rail infrastructure was begun with the *train à vitesse* (TGV), at least for France, if not for Europe. Then people finally woke up in the Federal Republic. But no one thought in European terms. Instead of deciding that a good step had been made in France with the TGV, which should be adopted for the immediate future, in order to immediately concentrate on mag-lev trains as the next technological step, we Germans made the mistake of developing our own "German" TGV—the Intercity Express. The ICE is certainly just as good as the TGV, perhaps a bit faster and a bit better. But, fundamentally, it is superfluous. Putting the same research dollars into the mag-lev trains would have been more useful to our national economy and to Europe as a whole. Well, the decisions were made, and the situation is as it is. But why don't we finally stop making unfavorable comparisons between Transrapid and the ICE, merely to justify the wrong decisions made in the past? We should be happy that we have Transrapid, should seek partners and aggressively exploit this opportunity. With the daunting economic and transportation tasks that stand before us, neither of the two systems will come up short.

Transrapid is so flexible that it can be integrated into existing railway stations, as well as be connected to airports, most of which are outside cities. In a time when we vociferously attempt to keep auto traffic outside of city centers with "park and ride" lots, artificial limitation of parking spaces, and subsidies to local mass transit, the construction of new mag-lev train stations on the edge of cities will be a positive step for municipal planning. From the standpoint of traffic safety, rational use of energy, and environmental soundness, Transrapid would be an excellent replacement for domestic German air traffic. Why have screaming jets climb to an altitude of 3,000 meters, adding much stink, simply to immediately begin landing, when we can "fly" with the Transrapid at an altitude of zero from Frankfurt to Berlin and achieve the same end just as quickly? And riders can also enjoy the lovely landscape on a trip on the Transrapid, since its flexible roadway configuration makes unnecessary the many tunnels through which the ICE must travel.

In addition, we can foresee that Transrapid will be able to run at least as economically as the ICE. Transrapid will balance its somewhat higher investment costs through lower operational costs. But even the investment cost advantage of ICE is negligible. An investigation by the national Ministry for Technology determined, for example, that, for a 200 km model track through Germany's typical, low mountain ranges, the investment costs for ICE are DM 4.9 billion ($2.88 billion) and DM 5.4 billion ($3.17 billion) for Transrapid. That is only 10% more. Considering the total of operating management and capital costs, the Transrapid is more advantageous for this model route. The ICE, with a cost of 7.95 pfennigs per passenger-kilometer, cannot match Transrapid, which is clearly ahead with 7.40 pfennigs. Comparing energy usage in terms of kilowatt-hours, at a speed of 200 kmh, the ICE needs somewhat more than 0.1 kWh per passenger-kilometer; the Transrapid, at 0.08 kWh, is 20% less. The difference is even more striking at 300 kmh. The ICE, at 0.19 kWh, is almost twice the Transrapid, at 0.12; and even at 400 kmh, the Transrapid at 0.15 kWh clearly uses less energy than the ICE at 300.

Finally, Transrapid, with its more flexible routing capabilities and its elevated type of construction, offers a unique advantage in the dense traffic spaces of Europe. The area needed for the route is only half as much as for the ICE on the model route in low mountains, and the amount of earth that has to be moved during construction is only one-fourth as much. Transrapid will go easily through the landscape—a further example of how modern, advanced technology is more environmentally friendly than old technology. Cows can safely graze underneath Transrapid's elevated roadway or, in cities, automobiles and streetcars could drive underneath without crossings.

All attempts to compare the ICE favorably with Transrapid are destined to fail. For example, the technical journal *ETR* reported in December 1989 that the ICE "narrowly missed its desired transit time" on the Cologne-Frankfurt route. The intention had been to make that route, including a stop in Bonn, in exactly one hour. Since the ICE has a peak speed of 250 kmh, that transit time should be possible theoretically. In practice, it didn't manage to do it because it cannot achieve that speed going up mountainous inclines. Giving the ICE more power by adding a second locomotive would be too expensive. *ETR* made the brilliant proposal to achieve the desired travel time by adding magnets to the ICE and building linear motors into stretches of incline and acceleration, with which the ICE will have more thrust. This mixture of the ICE and the mag-lev train is a good idea, second to Transrapid.

Europe will grow together

The calculations of the Federal Ministry of Transportation are only momentary snapshots that regard the economic potential of the mag-lev train from a limited point of view. These "economic calculations" are gladly used by politicians to lend "scientific" support to their decisions. The reality is that these calculations will soon be outdated, once construction of the mag-lev train begins. Infrastructure measures, such as the introduction of the revolutionary mag-lev train technology, effect a topological transformation of the entire national economy that changes the coefficients of the price matrix entered into the cost-benefit analysis.

Above all, the mag-lev train, and not the airplane or the ICE, will allow Europe to grow together. By the beginning of the new millennium, magnetic routes will connect the center of Europe and handle high-volume transportation at speeds of 500 kmh or higher. Business people will leave Paris at 9 a.m. and arrive in Berlin at 12 noon; perhaps they will go on to St. Petersburg, where they will arrive on the mag-lev train at 2:15.

Furthermore, the construction of a mag-lev train network would be a quite decisive indication for the new federal states of Germany, that we can establish the foundation of a development that will allow eastern and western Europe to grow together. Transrapid is a technological, political, and economic opportunity for German and Europe; if we are clever enough, we will immediately seize that opportunity.