EIR Science & Technology

Opening the age of electromagnetic flight

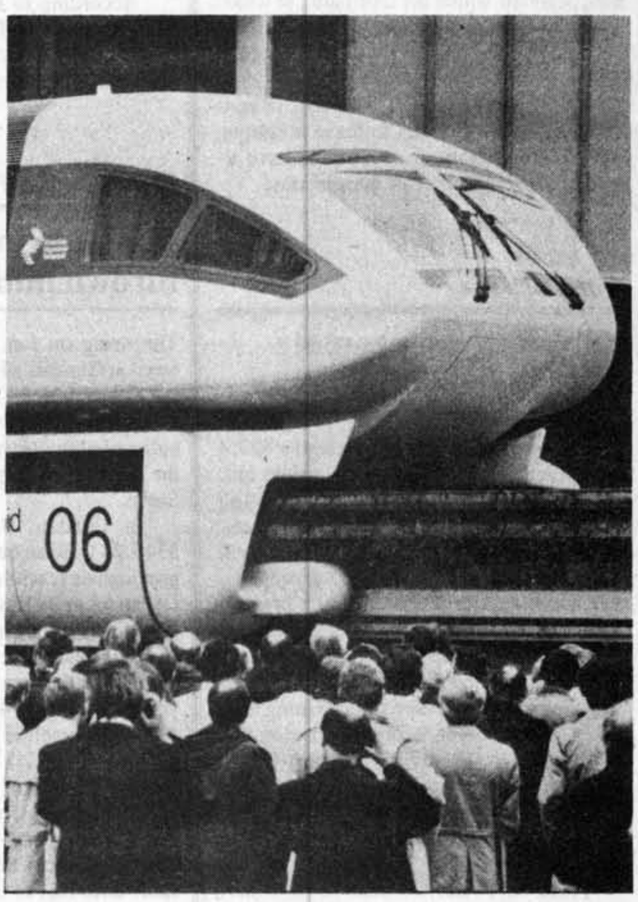
Marsha Freeman reports on the 'maglev' trains that make train transport more like flying, and whose potential speed is virtually unlimited.

Inaugurating a series on modern transportation technologies in last week's EIR, *Lyndon H. LaRouche, Jr. argued that current reliance on passenger cars for transport of persons is increasingly, savagely, counterproductive. We can transport commuters and goods more cheaply, more comfortably, and faster, by public rapid-transit systems. This article examines one of the best technologies for doing this, now reaching the stage of commercial development in Japan and West Germany.*

A maglev train could travel from Washington to New York in less time than it currently takes to fly, because it could go faster than a plane. In addition, as every airplane passenger knows, the real time for an air journey is much greater than the scheduled flight time, once traffic jams to and from the airport are taken into account, plus the hours of delay in the terminal and on the runway. A well-run mass transit system can be fast, non-polluting, quiet, and run on a more frequent schedule than either autos or planes.

Future articles in this series will discuss other transportation technologies of the future, including those which will boost the efficiency and durability of the automobile. As LaRouche emphasized, to the extent that the family automobile is still used in the future, it should be built to last at least 20 years. The forthcoming EIR Quarterly Economic Report *(fourth quarter 1985) will include an in-depth examination of technologies which will make this possible, such as the ceramic heat engine.*

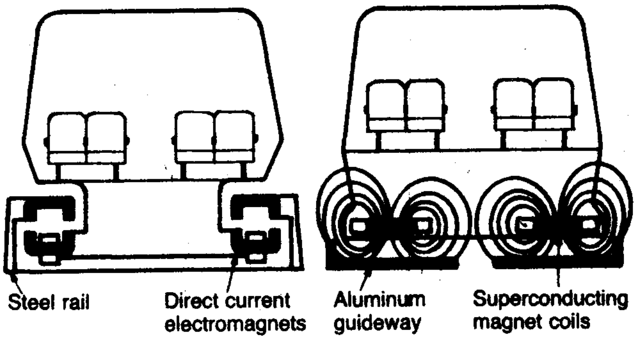
Imagine traveling from New York to Los Angeles in only 21 minutes—by train. Impossible? Not according to feasibility studies for the mass-transportation system of the future, the



The Budd Company

Government and transport officials in West Germany inspect the Transrapid 06 Maglev vehicle in Emsland.

FIGURE 1a FIGURE 1b



Attractive levitation

Repulsive levitation

The attractive levitation system operates on the basis of pull between the steel rail and the train's electromagnet. With the electrodynamic or repulsive levitation, superconducting magnets create a repulsive force against the current induced in a conducting nonmagnetic aluminum guideway.

magnetically levitated train. A maglev system operating underground in a vacuum tube would have virtually no limit to its speed, with no steel-on-rail friction and no aerodynamic resistance. At a steady rate of acceleration, the passenger leaving New York would feel a gentle acceleration pull for about half the trip, then a steady deceleration. And this at an average speed of about 8,500 miles per hour!

Tests are now underway in West Germany and Japan which will soon lead to the commercial development of such trains without wheels, operating on the principles of interaction of electrical and magnetic fields. The first generation will not use vacuum tubes, and so, slowed by aerodynamic drag, will run at 250-300 mph.

More akin to flight than conventional ground transportation, these maglev systems have been under development for 20 years. In the United States, where an effort to develop such systems was active at the Massachusetts Institute of Technology and in industry until the early 1970s, research was abandoned by the federal government, so that anyone considering building such systems in the United States today, will have to import the technology from West Germany or Japan.

Tests on the maglev test track in Emsland, West Germany, detailed in the accompanying article, have proven that people can be safely and comfortably transported at speeds over 250 mph. Maglev offers noiseless, pollution-free, energy-efficient mass transit, most effective along routes where it generally takes more time to get to the airport than it does to make the flight once you are in the air.

In the near future, maglev systems should connect the major cities and population centers across Western Europe. By the 1990s, islands in Japan will also be connected by magnetically levitated trains.

This is in stark contrast to the situation in the United States, where even our barely functional conventional passenger rail system is under threat of abandonment, as the Gramm-Rudman "balanced budget" bill may cause the shutdown of the Amtrak passenger rail system. A nation without an efficient rail system is no longer an industrialized nation.

The limits of wheeled trains

Even the most advanced wheel-on-rail trains have an inherent speed limit of less than 200 miles per hour, due to problems of loss of traction, frictional heating, and difficulties in the transmission of power through wheel-rail contacts. Wheel-on-rail trains operating at very high speeds are expensive to maintain, noisy, and very sensitive to climate and weather changes.

For example, the Japanese bullet trains, or Shinkansen, which have been operating since 1964, necessitated the construction of sound barriers in populated areas. The line is shut down every night, as men and equipment are sent along the lines to realign the track, which must be near-perfect. In 1979 the system set a world speed record of 198 miles per hour for wheel-on-rail trains, but averages a speed of only 130 miles per hour.

The 1,100-mile Shinkansen system is computerized, and is monitored and controlled from a central control room in Tokyo. Since 1964, over a billion passengers have ridden on the 2,200-car system, with no fatalities. But the 130 mph average speed of the trains means they cannot compete with less energy-efficient air travel. To get from Tokyo to Osaka, the two largest cities in Japan, takes 3.5 hours with the bullet train. With a maglev system, this could be reduced to about one hour.

The French railway also operates a high-speed wheel-on-rail system—the TGV. In 1981 it broke the Japanese record, hitting 238 mph, though it regularly runs at about 165 mph. Though various cities and states in the United States have considered high-speed rail systems to replace aging and obsolete trackage, only an all-electric maglev system could successfully compete with petroleum-dependent automobiles, buses or airplanes.

In the first couple of decades of this century, experimenters in Europe and the United States developed and demonstrated small-scale magnetically levitated systems. Before the first World War, the Frenchman Emile Bachelet demonstrated the concept at an exposition in Paris. Hermann Kemper, known in Germany as "the father of electromagnetic levitation," conducted successful tests with the technology in the 1930s, and at about the same time, Edwin Northrup built a successful test model in the United States.

By the 1960s, conventional rail systems were reaching their technological limit, and maglev development began in earnest in America, Germany, Britain, Canada, Japan, and other nations. Only West Germany and Japan have continued this work, now nearing the point of commercial introduction.

Attractive versus dynamic maglev

The fundamental principle involved in using the interaction of magnetic and electrical fields to levitate anything, is that bodies of like polarity repel, and those of opposite polarity attract.

The German group of aerospace, steel, and electronics companies that makes up the Transrapid Maglev Train Consortium is testing an attractive maglev system. In this approach, the levitation of the vehicle above the track, or guideway, is accomplished through the use of 32 electromagnets mounted on the train's undercarriage, below the guideway beam (**Figure 1a**).

The guideway beam is a nonenergized ferromagnetic steel-conducting surface, which is attracted to the magnets on the train, and pulls the vehicle up about one-half inch from the guideway, the way a magnet attracts iron filings. Each vehicle also has a set of 28 magnets facing the outer edges of the guideway, to provide guidance and keep the train from swaying from side to side.

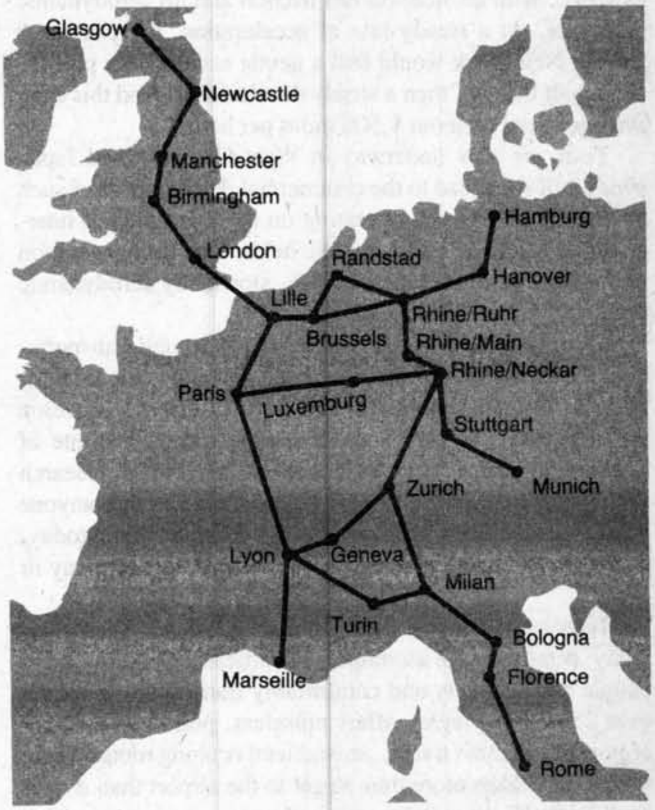
The gap between vehicle and guideway is very small in the attractive maglev system, because the levitation force is inversely proportional to the distance. If the distance were increased, the force required would be so large that the use of conventional iron-core magnets would not be possible. The attractive maglev system requires very precise and constant electronic feedback mechanisms to make sure the gap between vehicle and guideway remains constant. Any irregularities in the guideway will interfere with levitation, which means that a near-perfect guideway must be maintained at all times.

Because the gap in the attractive system is small, the power needed for levitation is also smaller than the dynamic repulsive design. There is less magnetic drag, which also reduces the propulsion requirements, although at high speeds, 80% of the energy loss is from aerodynamic drag, affecting both systems.

The alternative to the small-gap attractive maglev design, has been developed in Japan. In the electrodynamic or repulsive design, two energized electromagnets are needed, to produce the magnetic fields of opposite polarity. On board the vehicle are high-powered superconducting magnets, which induce eddy currents in coils in the guideway as the vehicle moves (**Figure 1b**).

The guideway itself is not conducting, and is made out of a continuous sheet of aluminum that can be unrolled along the road bed. The attractive system needs to have a steel rail guideway. Unlike the attractive system, where there is no motion required to produce the levitation, the dynamic systems must have auxiliary wheels, similar to airplane landing and take-off gear, until a speed of about 60 mph is attained. At that point, the magnetic force exceeds the vehicle weight, and produces levitation.

Potential maglev lines in central Europe



The greatest advantage of the repulsive maglev design, is that the gap between vehicle and guideway is about four inches. Tests done at the Miyazaki test track in Japan have shown that since the repulsive magnetic force naturally increases if the train nears the guideway, it is automatically stabilized. No electronic feedback control is necessary. The vehicle was tested with a 1.5-inch vertical irregularity in the guideway, and the four-inch gap was found sufficient to keep the train running normally. There was also found to be an increase in aerodynamic pressure on the vehicle when it goes through tunnels. Here, too, the larger gap is an advantage, since the vehicle did go up or down three-quarters of an inch with the changes in pressure.

The challenge in developing the dynamic or repulsive maglev system, is to master the new technology of superconductivity. Certain metals and combinations of materials lose their resistance to the flow of electricity when they are kept at temperatures near absolute zero. This superconductivity means that if a magnet is energized with electrical power, it will remain an electromagnet and not dissipate its energy as heat and require continual energy in-puts, if it is kept at cryogenic—very low—temperatures.

Regular iron core magnets, when they reach a large size, have to be cooled with circulating water, because of the energy that is lost through resistive heating. Therefore, more energy-efficient superconducting magnets have already been developed for large-scale applications such as fusion energy research, and magnetohydrodynamics energy conversion, but such magnets are not yet off-the-shelf commercial technology.

Means of propulsion

No matter which method is used to levitate the vehicle, it must also have a unique propulsion system. The German attractive maglev design uses a synchronized electric induction motor, which consists of continuous ferromagnetic stator elements with three-phase windings which are in the guideway. These elements are mounted under both sides of the guideway beam, along the entire length of the system.

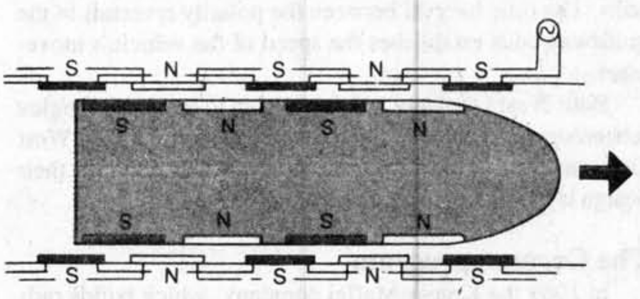
Alternating electrical current from transformers and frequency converters along the roadbed create a traveling magnetic wave that interacts with the car-mounted levitation magnets, and drives the train. This induction motor recharges the batteries on board the vehicle, which power the iron core magnets. It provides the electricity for heating, air conditioning, and other purposes.

The linear motor also serves as the braking system. By varying the voltage, frequency, and polarization of the power from the commercial electric grid, the converters control the driving force of the motor, to create either foward or braking motion without frictional contact with the guideway.

The entire track is divided into several power feed switches, which are automatically energized when the train is approaching, and are shut off after the train passes. This increases the system's energy efficiency.

FIGURE 2

The Japanese-built linear synchronous motor



In this propulsion system designed in Japan, the vehicle is propelled by the interaction of magnetic forces between its on-board magnets and the magnetic coils on the sides of the guideway. Each magnet on the vehicle is attracted by a guideway coil of different polarity immediately ahead of it, and repulsed by the same polarity immediately behind it. The polarity of the guideway coils is reversed at frequent intervals, propelling the vehicle forward. The time interval between these reversals establishes the speed of the vehicle movement.

Source: Japanese National Railways

A maglev route from Los Angeles to Las Vegas

Extensive studies have been conducted to determine the economic feasibility of connecting the approximately 230-mile corridor between these two large western cities. While both high-speed rail and maglev were found to be technically feasible, only the maglev could compete economically with the existing modes of transport, because of its greater speed.

Using a 160-mph wheel-on-rail train, the trip would take approximately two hours, taking a route along existing railroad right-of-way. A 250 mph maglev train could make the trip in almost half the time, along a shorter route.

Because the maglev system does not depend upon traction between wheels and rail, it can climb steeper grades. In the Los Angeles to Las Vegas example, the train can go over, rather than around, the Clark Mountains west of Las Vegas, shaving 24 miles off the route, compared to the 254 miles a high-speed train would have to travel.

One study indicates that with a four-car maglev train departing on the hour from Los Angeles, and on the half hour from Las Vegas, train crews could make two round trips per eight-hour shift. This compares with just 1.5 trips per shift using seven-car high-speed trains, to provide the same level of service.

Either new rail system would divert thousands of travelers from existing modes of transportation, but the maglev system would attract 3.7 million passengers per year, which is more than double that of the high-speed rail, due to the time difference and the novelty of the technology.

The cost, in 1982 dollars, of building the maglev system for the route, was estimated at $1.85 billion. With a round-trip fare of $65, which is well below the $100 commercial air fare, it was determined that the system would generate enough revenue to pay operating and maintenance costs, repay the debt with interest, and return a profit. Flying is the only way to make this trip now in less than five hours.

In the dynamic system being developed in Japan, the guideway already has coils in it for levitation, but the bulk of the energy needed for both the levitation and propulsion is provided by the powerful superconducting magnets on the vehicle. Only a small amount of electricity is needed for the guideway coils, to provide a north or south polarity under the train, as it passes over the guideway (**Figure 2**). This linear synchronous motor is not needed to produce electric power for the train itself.

The speed of the forward movement of the train varies with the frequency of the power supplied to these ground coils. The time interval between the polarity reversals in the guideway coils establishes the speed of the vehicle's movement.

Both West Germany and Japan plan to turn their maglev technology into commercial transport systems. It is in West Germany that developers are closest to that goal, as their design is based on more conventional technology.

The German program

In 1969 the Krauss-Maffei company, which builds railroad locomotives, tested a scale model of their Transrapid 01 maglev vehicle. At the same time, the aerospace giant MBB began developing the sophisticated control systems needed for the attractive maglev concept.

Then in 1974 these two corporations joined together to form Transrapid EMS, and in 1976 they tested the 10-ton Komet vehicle on a one-mile guideway. Five years later, the steel manufacturer Thyssen joined the consortium, and the full-sized Transrapid 05 vehicle was built and tested. It transported tens of thousands of visitors, at a speed of 50 mph, around an International Transportation Fair in Hamburg in 1979. The vehicle weighs 80,000 pounds, and can carry 75 passengers.

In 1978 the federal minister for research and technology decided that the maglev technology should be evaluated under practical operating conditions, including temperature fluctuations between $-13°$ and $+104°$F., in all weather conditions, and in 60-mph winds. The goal was to provide enough data on operating and maintenance costs, for industry to be able to produce a fixed price for a commercial system by 1986.

The Magnetbahn Transrapid consortium, now including seven major industrial firms, began construction of the Emsland Test Track and the Transrapid 06 vehicle in 1980; it began operations two years later. The track is designed for 18 hours a day of testing, with a six-hour break. The top speed the vehicle and guideway are designed for is 250 mph.

Japan: setting speed records

In Japan, the Japanese National Railways (JNR) has been involved in maglev development since the late 1960s. In 1978, the first couple of miles of guideway at the Miyazaki test track opened, and the ML-500 test vehicle reached a speed of about 180 mph. In December 1979, the vehicle set the world's speed limit for a maglev system, of 321 mph, without any people on board.

With the completion of the ML-500 program, the MLU-001 vehicle began testing in 1980, after the guideway design was altered. This is a three-section vehicle which is more representative of a full-sized commercial vehicle. Though the goal of the German maglev system is to reach a speed limit of 250 mph, the Japanese plan to design their system for a 300 mph average speed.

In a presentation made at the First International Convention on High Speed Rail in May 1984 in the United States, Dr. Ichiroh Mitsui stated that the JNR is considering three routes for its commercial maglev system in the 1990s. One would connect Tokyo and Osaka, another Tokyo and Sapporo on Hokkaido island, and the third between Tokyo and Hakata on the island of Hokkaido.

The problems that remain to be solved in the superconducting Japanese system include capturing and recycling the evaporated liquid helium coolant for the magnets on board the train, and studying the fatigue on the magnets from severe stress and strain from the propulsion forces generated by them.

What will the United States do?

In the United States, a number of states and municipalities are interested in building high-speed ground transport systems. A company called Transit America was established in January 1985, a sister company of the Budd Company, which is a subsidiary of Thyssen. Transit America is licensed to sell German maglev technology in the United States. Feasibility studies have already demonstrated that at 250 mph, maglev systems could compete with much automobile and air transport.

But the cut-back in federal funding for such public transportation systems made it virtually impossible for them to be initiated, even before the Congress voted up the Gramm-Rudman bill.

Three much-studied projects are links between Los Angeles and Las Vegas, various cities in Florida, and connecting Chicago and Milwaukee or Detroit. A spokesman for Transit America reported that the proposed elimination of federal subsidies for Amtrak, and proposed cuts in the budget of the Urban Mass Transit Authority of the Department of Transportation, has recently left these promising projects in the lurch.

Economic studies done by German, Japanese, and American contractors have shown that the maglev systems, which substantially reduce the energy cost per passenger-mile of service, can take as much as two-thirds of the business away from air traffic in trips of a couple of hundred miles.

By the turn of the century, magnetically levitated trains could criss-cross all of Western Europe, as shown in the accompanying map, to provide speedy service between major population centers. In the United States, heavily traveled corridors, such as the Boston-to-Washington route, going through New York City, could have maglev spurs, that would eventually be connected to neighboring corridors, in the same way that the transcontinental railroads were linked up a century ago.

As the speed of the "flying" train increases, so does the aerodynamic drag. For distances of thousands of miles, such as long stretches across the United States, it would be worthwhile to put the trains inside underground evacuated tunnels, to eliminate the drag and limits on speed. In that case, the only limit to the speed, would be the amount of time the train has to accelerate at a comfortable rate. The more distance and time there is to travel, the faster the train could go.

The technology is ready. According to Transit America, if a U.S. entity ordered a maglev system today, the West German consortia would have the equipment ready for export by the time the road bed were ready, in four or five years.

But over the past decade, U.S. policymakers have acted from the standpoint that the once-industrialized United States did not any longer need public transport. The trucking and airline industries were deregulated, with disastrous results. The railroad system was allowed to fall into disrepair and contraction, with funding for development of advanced technologies eliminated.

This decline could still be reversed; all it would take would be a return to the American System of economics, which recognized that for a nation to be a great economic power, it must have infrastructure, including transportation. The United States is too far behind Japan and Germany to develop maglev technologies from scratch as rapidly as required; but it can import from those nations that recognized the importance of developing 21st-century transport technology.

The collapse of the U.S. railroads

Not only has the United States terminated all research programs to develop a magnetically levitated train system—even its conventional railroads are now threatened with drastic cuts, if not shut-down.

On Dec. 23, the federal government-supported passenger railroad system, Amtrak, announced plans to reduce rail service to seven American cities, and temporarily cut routes in three regions, because of a 10.5% budget reduction. Amtrak spokesman John Jacobsen blamed the cuts on the just-signed Gramm-Rudman balanced budget law.

The reductions took effect on Jan. 12, and involve lines between Philadelphia and Harrisburg, Pennsylvania; Albany and Niagara Falls, New York; Chicago and Champaign-Urbana, Illinois; Chicago and Detroit; St. Louis and Chicago; Valparaiso and Chicago, Illinois; and Portland and Seattle.

Amtrak also announced that it plans to reduce overhead costs and slash its capital budget to zero. Tens of thousands of former train passengers will likely have to resort to their automobiles.

For the past two years, the Reagan administration has threatened to totally eliminate the more than $600 million per year federal Amtrak subsidy. The continuing resultion passed by the Congress before its Christmas recess, cut Amtrak's funding 10%, from $684 million to $616 million.

Amtrak spokesman Jacobsen said in an interview that another cut, between 4-5% is expected, in this year's funding, due to Gramm-Rudman. For fiscal year 1987, Jacobsen fears that the reductions "could be four to five times this year's cut" or about 25% over the two years.

He stated that last year when Congress queried an Amtrak witness at budget hearings, on the impact of a proposed 25% cut in federal funding, the witness said that this would force the nation's only passenger rail system to "close its doors and go into Chapter 11 bankruptcy."

These cut-backs merely continue a trend that began with the bankruptcy of the Penn Central Railroad in the mid-1970s. Since 1976, the miles of track owned by the nation's railroads have declined every year. That year, there were over 300,000 miles of Class 1 trackage. By 1984, this had dropped to 255,748 miles. This drop is catastrophic, when it is compared to the fact that in 1929, the nation had over 100,000 more miles of rail than it does today! In 1929, there were over 61,000 cars just for passenger service on the rails. In 1984, this number had fallen to less than 4,000.

The picture is not any better for freight. In 1953, this nation had over 80,000 rail cars hauling freight. This had declined to just over 12,000 by a year ago. Although the amount of freight carried by each car has increased, it has only doubled, meaning a drastic decline in rail freight transport.

Costs of constructing various rail systems

Type	Speed (miles/hr)	Examples	Cost/mile (million $)
Conventional	125+	Amtrak	3-5
High-speed rail	160+	French TGV Japanese Shinkansen	8-12
Maglev	250	German, Japanese	9-13

Source: *High Speed Rail Compact Background Report*, May 1984.