Implementation of Cargo MagLev in the United States

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ABSTRACT: Numerous studies have been completed in the United States, but no commercial MagLev systems have been deployed. Outside the U.S., MagLev continues to attract funding for research, development and implementation. A brief review of recent global developments in MagLev technology is given followed by the status of MagLev in the U.S. The paper compares the cost of existing MagLev systems with other modes of transport, notes that the near-term focus of MagLev development in the U.S. should be for cargo, and suggests that future MagLev systems should be for very high speed cargo. The Los Angeles to Port of Los Angeles corridor is suggested as a first site for implementation. The benefits of MagLev are described along with suggestions on how to obtain funding.

1 INTRODUCTION

The concept of magnetic levitation (MagLev) is not new. In fact, the idea has been explored since at least 1902. The first attempt to build a MagLev train was in Paris in 1906. In 1912, French engineer Emile Bachelet, built a model vehicle that was levitated and propelled by magnetic forces using a principle that later came to be known as the linear induction motor (Bachelet 1912).

There have been many articles and summaries written about the history and technological development of MagLev over the ensuing years (Hochhausler 1971; Laithwaite 1977; Luu & Nguyen 2005; Powell & Danby 1967; Taniguchi 1992; Vuchic & Casello 2002). Although commercial, passenger-carrying MagLev systems have been deployed around the world, the fact remains that there is no comparable system in operation in the U.S.

In this paper, we show that the most practical and likely the best first application for MagLev in the US market is for cargo transport for short to medium haul distances, and at medium speeds. The paper is organized as follows: section 2 is a brief background of MagLev technology; section 3 reviews the present status of MagLev projects around the world; section 4 discusses the present status of MagLev in the US; section 5 describes how cargo-based MagLev in the US can be successful in the near term, and describes the future of enhanced cargo MagLev; section 6 offers suggestions on how to get it implemented; and section 7 summarizes the findings of the paper.

2 BACKGROUND

There are two, primary competing MagLev technologies—electromagnetic suspension (EMS) and electrodynamic suspension (EDS). These are shown in Figure 1 in simplified diagrams. EMS levitation technology, which "pulls up," is represented by the German conventional-magnet-based Transrapid system (Wahl 2004) and EDS technology, which "pushes down," is represented by the Japanese JR low-temperature superconducting system (Miyamoto 2004). Both the German and Japanese governments have supported and funded the development and demonstration of their respective technologies by several billion US dollars each.

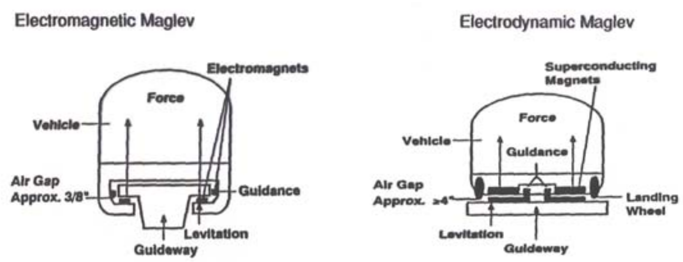

Figure 1. Comparison of EMS and EDS magnetic levitation systems.

EMS-type trains use room temperature, normal conducting magnet technology. EDS-type trains, use both room temperature and superconducting magnets.

3 STATUS OF MAGLEV OUTSIDE THE USA

The Chinese government, with Transrapid GmbH of Germany as a partner, constructed the first commercial MagLev line which runs between Pudong International Airport and Shanghai's financial district. The train is based on Transrapid's electromagnetic suspension technology, and does not use superconductivity. Figure 2 and Figure 3 show the Shanghai MagLev train. This train transverses the 30-km track in 7 minutes and 20 seconds, travelling at an average speed of 250 km/h (150 mph) with a peak speed of 431 km/h (268 mph).

The project was completed in 22 months, four months ahead of schedule, and has carried over three million passengers since its commencement in April 2004. The Chinese government recently announced the approval of a 175-km extension to the present MagLev line which will link the city of Shanghai to Hangzhou. The cost of the project is expected to be about 3.2 B $US with a completion date in 2014. This new line represents approximately a 60% reduction in cost per kilometer compared to that of the Shanghai-Pudong line. This projected cost of 16 M$/km or 25.6 M$/mile will enable MagLev to be competitive with high speed rail such as the French TGV. This represents a significant step forward for MagLev as a technology and its path to wide-scale commercialization.

The Japanese High Speed Surface Transport (HSST) system low-speed MagLev supports the concept of the Urban MagLev through the successful construction and operation of the Tobu Kyuryo line which extends about 9.2 km from the Fujigaoka subway station in Meito Ward, Nagoya (Aichi Prefecture) through Nagakute Town to Yakusa Station on the Aichi Kanjo (Loop) Line in Yakusacho of Toyota City.

Figure 2. The high-speed, Chinese-Transrapid EMS-type MagLev train.

Figure 3. The Chinese-Transrapid train leaving the station on the route from Pudong to Shanghai.

This project further emphasizes the usefulness of MagLev for intermodal transportation. Figure 4 shows the Japanese urban MagLev train in operation. The HSST research was started in 1974 by Japan Airline and the JR High Speed MagLev system by Japan Railways in 1969. The HSST system is based on electromagnetic suspension technology and does not use superconductivity with a top speed of 38 mph.

In December of 2007, Japan Railways (JR Central) announced plans to build a superconducting MagLev linear-motor train between Tokyo and central Japan at a cost of 5.1 trillion yen (44.7 billion US dollars) by 2025. It will have an average speed of 500 km/h (310 mph) on a route of 290 km. This MagLev train will be the successor to the famous Japanese Shinkansen "bullet" train that runs at 300 km/h (186 mph). JR tested the first ever MagLev using high temperature superconductors attaining a world record speed for railed vehicles of 361 mph.

Figure 4. Picture of the Japanese, low-speed, EMS-type MagLev train on the Linimo line.

Other interesting MagLev development around the world include the Swissmetro MagLev concept designed to have vehicles running in small 5-m diameter tunnels under partial vacuum to reduce aerodynamic drag forces and the Brazilian concept using high temperature superconducting bulk magnets for levitation (Stephan & Nicolsky 2004).

England is considering the construction of a MagLev train line between Glasgow and London, reducing the travel time between the two cities (522 miles apart) from 5 hours to 2.5 hours. Korea also has a long history in its interest in urban MagLev and is actively pursuing a low-speed passenger-carrying MagLev line (Kim et al 1995).

Despite recent advances and continuing efforts in commercialization around the world, MagLev technology still has not realized its potential as a transport system, especially in the United States.

4 MAGLEV IN THE USA

The US has a sketchy history of research and development in MagLev beginning in 1969 with the first US patent related to this technology.

Under the High Speed Ground Transportation Act of 1965, the United States Federal Railway Agency (FRA) funded a wide range of research into all forms of HSGT continuing through the 1970s. This sponsorship led to the development of the linear induction motor that has been used in many early MagLev development efforts and some modern MagLev designs. By the mid 1970s, the U.S. work had ended with no implementation of a MagLev system.

The importance of MagLev, as an advanced transport system, was recognized in 1990 when the National MagLev Initiative (NMI) program was started with grassroots support of engineers and scientists as well as the late Massachusetts Senator Moynihan. US$ 975M were appropriated for an aggressive four-year program with the end goal of a 19-mile long demo track with MagLev vehicles running on it (Coffey 1993). Four major industrial teams, led by Foster Miller, Grumman, MIT and Bechtel, were assembled. For a time, technologists were enthusiastic about the future of MagLev in U.S. However, with a change of presidency and lobbying efforts from other competing modes of transportation, the NMI program was cancelled just after a year and a half with only $38M expended. By the mid 1990s, U.S. interest in MagLev technology had waned and funding for MagLev research had been cut.

An urban (low-speed) MagLev program was started by the U.S. Government in the early 2000s but so far, the $35M funding for that program has not produced any commercialization effort. The companies that continue trying to develop and implement MagLev in the U.S., either low speed or high speed, include MagLev 2000, American MagLev Inc. and General Atomics.

5 POTENTIAL CARGO MAGLEV IN THE US

Numerous articles have been written comparing MagLev to other modes of transport (Coffey 1993; Janic 2003; Lever 1998; Luu & Nguyen 2005; Rose et al. 2007; Suppes 1995; Vuchic & Casello 2002). Building on that work, we offer a two pronged approach in order to implement cargo MagLev in the U.S.: 1) address the issue of cargo MagLev now in the present based on present-day technology; and 2) by further research and development, implement enhanced cargo MagLev in the future.

5.1 Cargo MagLev Now

In 2006, the Office of Naval Research (ONR) sponsored a consortium of experts led by the Superconductivity Technology Center at Los Alamos National Laboratory to study and determine the status of present-day MagLev and Electromagnetic Launch technology and describe the key technology areas which need further investment to enhance performance and reduce system costs. The report summarized all major aspects of MagLev systems, described the costs of those systems, and suggested research and development efforts including expected costs and time lines in which strategic research could be done to enhance MagLev technology. One conclusion of the report, is that present-day technology, even without further research, could be successfully implemented in select applications and select transportation corridors. However, strategic investment in areas such as superconductivity, guideway technology, and advanced materials would significantly reduce system costs while drastically improving operating performance (Rose et al. 2007). Based on that research, we suggest that the first implementation of cargo MagLev in the U.S. have the following characteristics:

- Use EMS or EDS levitation technology
- Use conventional magnets at room temperature
- Operate at low to medium speed, less than 100 mph
- Transport over a short distance, a few miles
- Operate in a highly congested area to mitigate congestion, reduce noise and atmospheric pollution.

Although MagLev technology can directly compete with all modes of transportation for both cargo and passenger travel, it does have some distinct advantages. In general, the advantages of MagLev systems consist of the following:

- Low noise, very quiet in urban settings
- Frictionless travel, low maintenance costs
- Clean, non polluting due to electricity use
- Sharper turn negotiation
- Steeper grade climbing capability
- Higher acceleration and deceleration rates
- High speed, over 350 mph

In spite of these advantages as a transportation system, MagLev in the United States suffers in terms of its development and implementation. This is due mainly to several misconceptions:

- it is too expensive with construction and operational costs unknown
- it is not a proven technology
- it is unsafe
- it unfairly competes with other modes of transport.

Of the many factors that determine adoption of any new technology, one of the most important is the economics including the capital and operational costs plus projected revenue. A cost comparison study was performed comparing MagLev to other modes of transportation. The findings for both low-speed and high-speed MagLev are summarized in Tables 1 and 2.

Table 1. Low-Speed MagLev is cost effective as compared to other forms of low speed transport.

	Length (miles)	Cost/mile ($M/mile)	Oper. Cost ($/pg-mile)	Cost Basis	Max. Speed (mph)	Max. Grade (%)
British Birmingham Maglev	0.6	22.7	0.19	Actual	50	10
Las Vegas Strip	3.9	166.7	0.45	Actual	50	6
San Diego Trolley (blue line)	25.2	33.2	0.43	Actual	50	6
Bay Area BART	21.5	175	0.33	Estimate	80	3.5
Vancouver SkyTrain	17.9	63.3	0.92	Actual	56	6

Table 2. High-Speed MagLev is cost competitive with High Speed Rail.

	Length (mile)	Capital Cost ($M/mile)	Cost Basis	Max. Speed (mph)	Max. Grade (%)
Shanghai Int. Airport to PuDong	19	60	Actual	269	10
Transrapid Berlin-Hamburg	181	32	Estimate	313	10
French TGV	> 100	18-30	Average	210	4

Table 1 and Table 2 list actual and projected costs for several types of rail and MagLev transportation systems. Based on the numbers, MagLev is comparable in cost to other forms of transportation. With a commercial high speed line between Pudong and Shanghai that has carried over three million passengers over the last three years, one can no longer say that MagLev is an unproven technology. MagLev is safe and comfortable as noted by those who have travelled on the Shanghai-Pudong line.

The Shanghai-Pudong line had an actual cost of $ 60M/mile. The cost estimate for the construction of the next section of 175 km from Shanghai to Hangzhou is about $25M/mile. It would be comparable to the cost per mile for the French TGV which travels at 40% lower speed.

For low-speed MagLev, the Birmingham line, even without the benefit of modern advanced technology compares favorably with monorails, trolleys and subways (essentially light trains).

While both low and high-speed MagLev are cost competitive in comparison with existing forms of transportation, there are other intangible advantages such as reduced air and noise pollution, tighter turns, and higher grade negotiating capability, which are essential characteristics for carrying cargo, that will eventually help gain the deployment of MagLev in U.S.

If MagLev systems were employed for medium speed, 75 – 150 mph, and short (5-50 miles) to medium distances (50-500 miles), then it competes favorably with automobiles, trucks, short haul commuter airlines, inter-urban passenger and cargo trains, and buses. Costs for cargo MagLev are expected to be less than what would be incurred for passenger MagLev as are noted in the tables.

Medium-speed cargo MagLev could be successfully implemented in a highly congested, urban corridor such as the busy corridor between the Ports of Long Beach and Los Angeles and an inland distribution center. A small step to show viability of this concept is to build a pilot or demonstration line. The Port of Los Angeles Electric Cargo Conveyor (ECCO) project is a good example and supports the ONR conclusion. In this situation, two parallel, bidirectional systems each equipped with 36 vehicles are required to meet the throughput. This 4.7-mile-long system links the ports with a cargo distribution center further inland hence avoiding the bottleneck around the port itself. Initial studies show that it is a viable concept (California State University at Long Beach 2007) and more detailed information is available on its website. Figure 5 shows a map of the area of interest with the MagLev route running from an inland hub to the Port of Los Angeles.

At the present time, the ship cargo is primarily moved on Los Angeles freeways by big-rig trucks with assistance by steel-wheeled train lines. The city of Los Angeles has great interest in reducing the noise, pollution and congestion in that corridor and has funded studies and work to assess MagLev technology for that type of setting. Note that the city of Los Angeles corridor is only one example. Many other highly congested urban corridors exist around the U.S. and would benefit from an urban-type cargo MagLev system. Recently, UP (the United Port of Los Angles and Long Beach) announced that they will start working with two manufacturers, Skytech Transportation Inc., and American MagLev Technology, to study the feasibility of a MagLev-based container-conveyance system.

MagLev trains have significant advantage over other modes not only in a crowded urban setting, but also can facilitate the movement of troops and equipment rapidly from an inland naval or marine base to the ports where they have to depart.

Given the technological, economic, convenience and perceived advantages and disadvantages of MagLev over other competing modes of transport, the application and situation in which MagLev has clear advantages over all other modes of transport is in a congested, urban environment, relatively short haul, where noise and atmospheric pollution abatement are significant concerns.

Figure 5. Map showing the proposed route for the cargo MagLev system between the Port of Los Angeles and an in-land distribution center. The route is about 4.7 miles long.

5.2 Cargo MagLev in the Future

After having established short-haul cargo MagLev, efforts should then be focused on its improvement. We suggest that the future implementation of cargo MagLev in the U.S. have the following characteristics:

- Use EDS levitation technology
- Employ high-temperature superconducting magnets for greater lifting capability and reduced energy consumption,
- Operate at high speed, over 1000 mph
- Operate over medium to long distances, greater than 500 miles
- Operate in partially evacuated tubes.

The concept, "MagLev-Tube Cargo Transport," is a new method of efficiently transporting cargo by MagLev trains through partially evacuated tubes. The pneumatic tube technology is at least 200 years old and has been used to move many products ranging from coal and limestone to mail and telegrams. It is time to re-evaluate the viability of this concept since intercity trucking is projected to dramatically increase over the next decade. This MagLev tube approach has the potential to replace the majority of the long-haul trucks on the nation's roads and highways, dramatically improving energy efficiency, safety, reliability, and reducing pollution in the environment. A national tube transport system could operate automatically under computer control and unmanned enabling precise delivery times not affected by weather, accidents or surface traffic and would be especially valuable to move goods during national emergencies. Levitating and propelling heavy cargo capsules through partially evacuated tubes with reduced air pressure, reduces air resistance and friction and allows for transport rates at hypervelocity rates in excess of 1000 mph. Relying on electricity produced by renewable sources eliminates the need for any oil to for transporting goods greatly reducing our reliance on petroleum and alleviating traffic congestion, and significantly increasing the safety and life expectancy of our highways. Traffic delays add billions of dollars to the cost of doing business. This approach would greatly reduce air pollution from both trucks and planes as well as increase the capacity of our ports with costly expansion. Goods including perishable food and medical supplies could be rapidly moved from the source into highly congested cities for further efficient distribution.

The tubes could be placed above, on, or below ground level. Underground transport pipelines would be useful in environmentally sensitive areas and much right-of-way potentially exists below our present highway system. Although the infrastructure cost of a nation-wide MagLev tube system to transport cargo would be substantial, it is likely to be less than cost of expanding the present highway system to allow for increased future truck traffic. The Federal Highway Administration conducted a comprehensive review of tube freight transport in 1994 and concluded that it has great potential (Vance & Mills 1994).

It is expected that the US will need to rely on several energy sources in the future including the rapid transport of large quantities of clean coal. The MagLev tube would enable efficient distribution of the coal resource from the source to the power plant. This concept would also enable under water transport of goods across large distances.

A national MagLev system running from New York City to Los Angeles would enable making the 3000 mile trip in fewer than 10 hours with no problems relating to weather cancellations or rising hydrocarbon-based fuel costs. In would be even faster (~ 3 hours) if this system can be installed in a partially evacuated tunnel.

Advances continue to be made with high temperature superconductors (HTSs). The manufacturing processes are continually being improved to reduce the cost per unit length while increasing the current-carrying capacity. Using HTS magnets, high-speed MagLev could be employed that uses less energy, with higher speed (Rote & Leung 2004).

Switzerland has conducted a comprehensive study of a MagLev tube transport system for passengers called the SwissMetro connecting major cities within Europe. The MagLev tube concept is revolutionary offering a long-term and affordable solution to our current problems of traffic congestion and air pollution. Incidentally, this concept is similar to the Electromagnetic Launch To Space (EMLTS) approach (Leung & Landon 1989) proposed in the late 1980s except that in the former, the MagLev tube system is built along side of a mountain and in this case, horizontally underground.

6 APPROACHES TO MAKE CARGO MAGLEV INTO REALITY

Given that cargo MagLev in congested urban corridors is superior to other modes of transport, the question remains about how to get a system funded, installed and operating. In a situation like the one described in the Los Angeles corridor, funding would need to come from multiple partners and sources including city government, the port authority, state government, and the military, and private sources.

Because of the uncertainty over final installation and operational costs, it is most likely that the first cargo-MagLev system would predominately be funded by government sponsors.

MagLev can be viewed as a complimentary mode of transportation that can be more secure against terrorism, more friendly to the environment, and more energy efficient.

It is important to get the military to sponsor a cargo MagLev demonstration line because of its applicability to other MagLev-based military applications. There have been many efforts in the U.S. to get MagLev funded. This additional alliance with the military might be all that is needed to push it over the top since the myths of MagLev not being very useful, expensive, and untimely are all being dispelled.

7 CONCLUSIONS

Federal commitment is needed to develop MagLev networks for passenger and freight transportation, with the government as infrastructure provider and private sector as operator. Federal support is required for 2-3 demonstration projects including funding for guideways with private financing for the MagLev trains. Successful operating systems are required to convince the public that the technology is practical. Development of new electronics, magnetic and light weight materials, vehicle designs, and innovative construction techniques will increase the operational efficiency of MagLev. It will also be necessary to establish a national test facility where innovations affecting system cost and performance can be evaluated under carefully controlled conditions. In fact, for MagLev to be revived in USA, a national program similar to the National MagLev Initiative (NMI) in the early 1990s is required. Opposing forces from auto and short-haul airline industries should be less strong this time around since they have been weakened by recent economic events. A new factor is introduced, namely the potential usefulness of MagLev in military applications. A significant fraction (over 40%) of the U.S. fiscal budget is directly or indirectly related to the military. This could be an innovative way to get MagLev funded.

The world as we know it is changing and the change is accelerating. Global warming, high oil cost, the need to protect against terrorism, globalization of business and a general demand for change from the American public will all play a part. The recognition of the inadequacy of the two US major transportation systems, namely, automobiles on highways and airplanes in the sky in terms of timeliness and cost-effectiveness in the delivery of passengers and cargo, as well as military needs, will ultimately revive the MagLev development effort in the States.

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