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OPPORTUNITIES AND PROSPECTS FOR MAGLEV IN NORTH AMERICA

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ABSTRACT

As a result of early research in many countries, including the USA and Canada, and developments particularly in the Federal Republic of Germany and in Japan, the technologies of magnetic suspension and linear electric drives have matured to the stage at which low-speed systems are operational and high-speed systems have reached prototype test and demonstration. Maglev is now recognized as a realistic option for the 1990s and is being assessed in parallel with high-speed rail service in many corridor studies. Maglev is becoming available at a time when both road and air congestion is threatening the mobility that North America has come to expect. The fast, clean, energy-efficient characteristics should allow Maglev systems to contribute to the solution of impending transportation problems. This paper reviews the opportunities and prospects for the implementation of Maglev in North America.

INTRODUCTION

There is a renaissance of interest in high-speed ground transportation in North America. Both high-speed rail and Maglev are being proposed and evaluated for a number of routes linking major urban areas. Many such potential high-speed corridors are identified in Figure 1.

This renewed interest in high-speed ground transportation has been stimulated by problems and by perceived opportunities. Congestion of urban roadways and interurban airways is beginning to have significant impact on the convenience and reliability of personal (automobile) and public (air) transportation systems, and is limiting the mobility which North Americans have come to expect. Scientific and technological advances such as the discovery of high-temperature superconductivity (HTSC) and the development and demonstration of the TRANSRAPID and Linear Express vehicles in the Federal Republic of Germany and in Japan has given Maglev public exposure and have led to the realization that high-speed ground transportation can be a realistic option for alleviating some of the transportation problems of the continent in the 1990s and beyond.

This paper focusses on developments, opportunities and prospects for the implementation of Maglev in North America.

NORTH AMERICAN DEVELOPMENTS

While the work of Graemiger in 1911 [1] and Kemper in 1934 [2] laid the foundations for electromagnetic suspension (EMS), and while Bachelet's "Foucault Railway" demonstration in 1912 [3] used the principle of electrodynamic suspension (EDS), it is now evident that the ideas of Powell and Danby at Brookhaven National Laboratory in the mid-sixties [4] represented seminal research towards the practicality of Maglev and laid the foundations for EDS.

In North America, the work of Powell and Danby and emerging Maglev research projects in the Federal Republic of Germany and in Japan stimulated federal government and private sector funding for Maglev R&D in the late '60s and early '70s. Powell and Danby continued to refine their ideas, while other groups, including Coffey, Chilton and Hoppie at Stanford Research Institute [5], Kolm and Thornton at MIT [6], Reitz, Borcherts, Wilkie and colleagues at the Ford Motor Company [7], and Atherton, Eastham and colleagues at Queen's University [8] began detailed analyses of electrodynamic suspension and conducted transportation system design studies. A small-scale linear test track was constructed at MIT, a 500 kg test vehicle was levitated at Stanford Research Institute, and large rotating wheel facilities were constructed at Queen's University and at General Motors Research Laboratories.

By 1972, the technical feasibility of Maglev had been established. More precise analytical tools to examine suspension forces and dynamics were then developed, and high-speed transportation system design concepts were refined. At that time, tracked air-cushion vehicles (TACV) were absorbing the major portion of federal advanced transportation R&D funds in the US. Maglev and TACV suffered the same fate and financial cuts that were imposed by the Federal Railroad Administration, and plans for a high-speed electrodynamic Maglev test track at China Lake in California were terminated in 1975. This administrative decision was justified by the belief that by using ever larger aircraft the United States would have adequate air transportation and highway infrastructure to accommodate the anticipated growth in intercity travel at least for the next decade. That decade has now passed, saturation of the system is approaching and alternatives are not being developed.

In Canada, the large-scale wheel facility was used to conduct full-scale tests (at speeds up to 100 km/h) on

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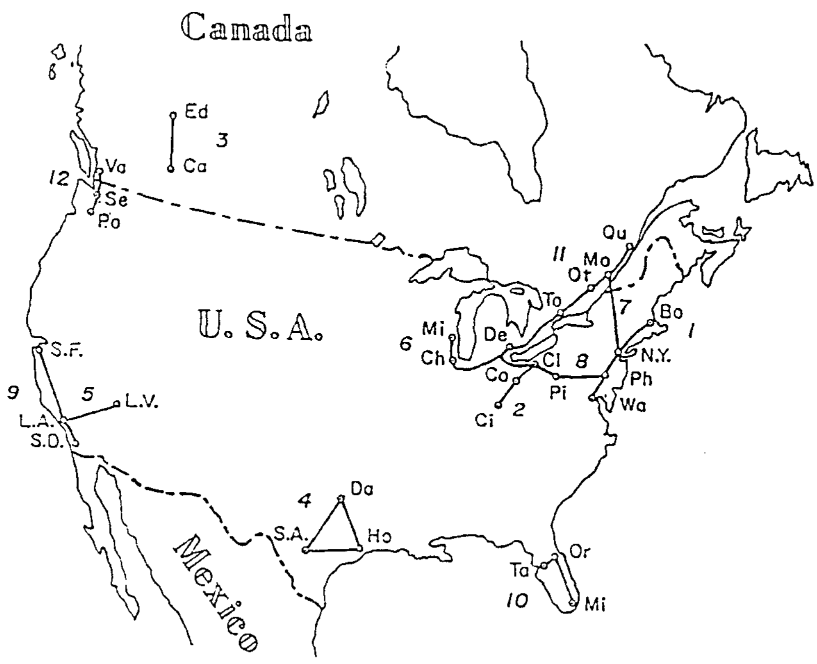

1. Boston-New York-Philadelphia-Washington (in operation with Metroliner service at 200 km/h)
2. Cleveland-Columbus-Cincinnati
3. Edmonton-Calgary
4. Dallas-Houston-San Antonio
5. Las Vegas-Los Angeles
6. Milwaukee-Chicago-Detroit
7. Montreal-New York
8. Pittsburgh-Philadelphia
9. San Francisco-Los Angeles-San Diego
10. Tampa-Orlando-Miami
11. Quebec-Montreal-Ottawa-Toronto-Detroit
12. Vancouver-Seattle-Portland

Figure 1 **Candidate corridors for high-speed ground transportation in North America.**

levitation, guidance and linear synchronous propulsion elements of the proposed superconductive electrodynamic Canadian Maglev system. These results allowed analyses to be validated, leading, by 1977, to engineering design studies of a vehicle system suitable for operation at 450 km/h in the Toronto-Ottawa-Montreal corridor.

North American groups maintained an active involvement in Maglev R&D efforts up to the late '70s. Over the last decade, however, contributions to the worldwide Maglev technology base have been very modest. The renewed interest in high-speed ground transportation has not yet been accompanied by a renewed commitment to technological development. It is recognized that any near-term implementation will need imported technology. It should be noted, however, that U.S. Senator Moynihan introduced legislation seeking $300 million for the development of high-speed systems in the United States towards the end of the Reagan administration. The FAST (Federal Advanced Superconducting Transportation) Act would have provided funding to NASA for research and would have aided state high-speed rail agencies through a federal Office of High-Speed Ground Transportation. Revised legislation is currently being prepared for consideration by the Bush administration.

OPPORTUNITIES FOR THE INTRODUCTION OF MAGLEV IN NORTH AMERICA

Current interest in the implementation of high-speed systems for intercity transportation was born with the energy crises of the mid-70s, when it was realized that the world could no longer rely on low-cost, readily available petroleum fuels. Fuel supplies for automobiles, trucks, buses, diesel-electric trains and aircraft were suddenly vulnerable. While these concerns have receded (for the time being), there are other emergent threats to mobility in North America. Congestion is becoming an acute problem in and around many urban areas, as traffic continues to grow at a faster rate than new infrastructure can be provided. A similar situation exists in the air, and many airports will reach saturation capacity over the next decade [12]. The Federal Aviation Administration forecasts that air traffic will nearly double by the year 2000 over 1985 levels, which in turn represented a doubling over 1970 levels.

In a companion paper at this conference, Rote et al. [9] discuss the market for Maglev in North America. They note the increasing delays caused by congestion at hub airports and the lack of political and public enthusiasm for new airport construction. They consider that Maglev should evolve as an element of the airline market, serving the intermediate distance (200-1000 km) travel demand to and from regional airports and between nearby urban centres. Maglev thereby becomes an energy-efficient extension of airline service, rather than competing as an upgraded super-speed "railway" service linking city centres.

In a second companion paper at this conference, Uher [10] argues that the market for Maglev should be established by linking the regional airport to downtown and to major suburban areas. Using Pittsburgh as a design model, he shows how Maglev could serve the needs of commuters and airline passengers in the greater Pittsburgh community, and generate short-term cash flow while being extended to provide intercity service to adjacent urban areas.

In another ongoing study, a Maglev committee established by Senator Moynihan is evaluating the use of interstate highway rights-of-way for Maglev routes. This study recognizes the high cost and likely public outcry associated with the alignment and construction of a high-speed guideway along corridors with high population density (e.g. Boston-New York-Philadelphia-Washington, D.C.) and with environmental sensitivity. However, while the width of freeway rights-of-way (outside cities) could accommodate the

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alignment of a high-speed Maglev line, the profile of the highway and the number of bridge crossings are such that the Maglev guideway would need to be elevated by perhaps 10-15 metres.

IMPACT OF HTSC

The introduction to this paper made mention of the role of high-temperature superconductivity (HTSC) in raising public consciousness about the potential of Maglev. Soon after the discovery by Wu et al. [11] that a ceramic compound ($Y_1Ba_2Cu_3O_7$) had a critical temperature of 90K, *TIME Magazine* (on May 11, 1987) ran a cover story under the headline "Superconductors: the startling breakthrough that could change our world." This article, like many others, was prominently illustrated with a block of permanent magnet levitated over a disk of Yttrium-Barium-Copper Oxide, and with an artistic high-speed Maglev train under the caption "trains that literally fly between cities on cushions of electromagnetism could become commonplace -- if the new high temperature superconductors make it out of the laboratory."

Maglev is not, of course, a technology which is suddenly made feasible by the discovery of HTSC. As a result of evolutionary research and development in several countries over the past twenty years, the technologies of magnetic suspension and linear electric drives have matured to the stage at which low-speed shuttle and urban transit systems are operational and at which high-speed systems have reached prototype test and evaluation.

The likely impact of the new high critical temperature superconductors is quite distinct for the two modes of magnetic suspension.

Electromagnetic suspension (EMS) systems use iron-cored electromagnets, with copper or aluminum strip windings operating at ambient temperatures. There is no requirement for high mmf, as the airgap flux density and lift force is limited by saturation of ferromagnetic components of the magnetic circuit on both sides of the airgap. Superconductivity is not needed and would offer no operational advantages for EMS vehicles. HTSC is not likely to have any impact on this Maglev technology.

Electrodynamic suspension (EDS) systems, on the other hand, need superconductivity. Electrodynamic suspension, being repulsive in nature, cannot use ferromagnetic materials. Each Maglev vehicle must carry several coils of high mmf (500-800 kA) to create airgap flux densities of sufficient magnitude for suspension and linear synchronous propulsion. Superconductive coils, operating in the persistent mode, are an essential element of EDS.

In spite of the impressive developments in superconductive magnets in Japan, the use of liquid helium is a specialized technology for a ground transportation environment. Refrigeration components still require development to gain necessary long-term reliability. The replacement of coils, multilayer cryostats, helium refrigerator and compressor by a unit operating at liquid nitrogen temperature would result in a substantial reduction in complexity and would enhance the operational viability of EDS Maglev. However, EDS Maglev need not wait for HTSC. Vehicles could use liquid helium-cooled magnets for initial revenue service and HTSC units could be retrofitted if and when they become available.

Cost must also be considered in evaluating the impact of HTSC on Maglev. The dominant component in the cost of any transportation system is infrastructure (ground preparation, guideway construction, terminal facilities, electrification, etc.). Vehicles represent less than 5% of the total capital cost of a typical intercity EDS installation. The suspension magnets, in turn, represent less than 1% of the total capital cost. The implementation of HTSC technology will therefore have minimal impact on the initial cost of the Maglev system. The impact on operating costs is likely to be more significant; Johnson et al. [12] have estimated savings of up to 10%. Even so, HTSC is clearly an "enhancing rather than enabling" element of EDS Maglev technology.

PROSPECTS FOR MAGLEV

There will be a need for electrified intercity ground transportation in North America to offload short-haul flights from major airports, and to provide both business and social travellers with a safe, reliable and fast means of transportation over the intermediate distance range (200-1000 km). While not yet operational as a high-speed mode, Maglev is increasingly being recognized as a maturing technology that will be available in the nineties, and is being considered in parallel with proven high-speed rail technology in techno-economic assessment studies of many corridors such as those illustrated in Figure 1. The four corridors across the southern United States are currently the most active in terms of assessment, development potential and implementation plans.

Miami-Orlando-Tampa

The Miami-Orlando-Tampa corridor is currently the leading contender for high-speed ground transportation implementation -- not for Maglev, but for high-speed rail. A Request for Proposals (RFP), issued in January 1987, resulted in two bids eligible for the high-speed franchise:

- Florida High Speed Rail Corporation, proposing a 240 km/h ASEA Brown Boveri "Fastrain";
- TGV of Florida, Inc., proposing the 290 km/h Train à Grande Vitesse (Atlantique configuration).

Both proposals were submitted by consortia of development, technology, consulting and financing companies. These bids are currently being assessed and it is expected that a franchise will be awarded in 1991 for operation in 1995. It is the announced expectation that the high-speed line will be built and operated from private-sector sources. Residential, commercial and industrial real estate development plays a major role in both bids.

A second project in Florida, and one which is more relevant in terms of the scope of this paper, is a Maglev demonstration project. Again, an RFP was issued (in December 1988) requesting bids to implement a Maglev demonstration link at some appropriate location. Only one bid was received -- from Maglev Transit, Inc., a joint venture of C. Itoh Trading Co. and Dai Ichi Kangyo Bank of Japan and Transrapid International composed of Krauss Maffei, Messerschmitt-Bolkow-Blohm and Thyssen Henschell, all of the Federal Republic of Germany. This company proposes to build a 300 mph 32 km link from Orlando Airport to the Epcot Centre, adjacent to Disney World, using TRANSRAPID technology, for operation in 1994. This bid is also under evaluation.

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Las Vegas-Los Angeles

A preliminary Phase I study, completed in 1983, recommended TRANSRAPID technology for the Las Vegas-Los Angeles corridor. A more detailed Phase II study, which was completed in 1986, confirmed that the TRANSRAPID Maglev system is indeed technically and economically viable for this application. This study also identified the TGV as a contender, being somewhat less expensive and only marginally slower. The comparative features of Maglev and high-speed rail in the Las Vegas-Los Angeles corridor are given in Table 1.

The States of Nevada and California have proceeded to the passing of legislation to establish a bi-state commission to examine all aspects of the project, prior to the issuance of an RFP for system implementation.

Table 1: Comparative Features of High-Speed Rail and Maglev Systems in the 370 km Las Vegas-Los Angeles Corridor

	TGV	TRANSRAPID
Cruising speed	290 km	400-450 km/h
Trip time	90 minutes	75 minutes
Capital cost	$2.0 billion	$2.5 billion
Annual operating cost	$60.0 million	$76.0 million

Other Corridors

Other corridors, including Pittsburgh-Philadelphia, Toronto-Ottawa-Montreal, Chicago-Detroit and Chicago-Milwaukee, have included an assessment of Maglev as an option for high-speed service in past studies. The Texas Triangle, the central California corridor, and Cleveland-Columbus-Cincinnati are currently under study for improved ground transportation. Maglev is, however, not a serious contender for these applications, as high-speed rail speeds are considered adequate to meet local needs.

CONCLUSION

As a result of R&D commitments made to Maglev technologies over a period of twenty years both inside and outside North America, high-speed vehicles with electromagnetic suspension and with electrodynamic suspension are becoming proven options for implementation in high traffic density corridors of the world. It is becoming recognized that North America has a need for an electrified transportation system that can off-load short haul flights to and from major hub airports (and thereby becoming a ground extension of airline service) and can provide both business and social travellers with a safe, reliable and fast means of transportation over the intermediate distance range (200-1000 km).

While Maglev technology has been developed outside North America, there is clearly a need, a market, and an opportunity for implementation in North America. The first installation may well be a high-speed 32 km link between Orlando Airport and the Epcot Centre/Disney World complex in central Florida.

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