N94- 35841

Transrapid – The First High-Speed Maglev Train System Certified "Ready for Application": Development Status and Prospects for Deployment

Reinhard F. -Luerken
Thyssen Henschel America, Inc.

Contents

1. History: Milestones of Development

Starting point of the Transrapid development more than two decades ago was the idea to create a

- contact-free
- cost effective
- energy efficient
- environmentally sound and
- comfortable

system for high-speed ground transportation which is superior to competing modes. (→ chart: Transrapid Development Chronology)

In the development history of the Transrapid maglev system a great number of highlights are worth mentioning, among others

- the demonstration of the first long-stator-propelled vehicle (HMB 2) in 1976

- the first public maglev service by the TR05 vehicle during the IVA in Hamburg 1979

- the first full-size maglev vehicle TR06 to go into testing and demonstration in 1984

- several world records for manned maglev vehicles (most recently 450 km/h [280 mph] clocked by the TR07 vehicle).

On the other hand it must not be forgotten how difficult, time consuming and costly it was to overcome all the problems that arose during all stages of the development. Several times the program was endangered for lack of funds and political support. All the more the personal commitment, engagement and sacrifice of the people involved in the program has to be appreciated. Nobody should ever underestimate the difficulties and risks related to the development process of a completely new transportation system!

2. Technology

2.1 Function

The Transrapid maglev system basicly features electronicly controlled attractive electromagnetic forces to provide

- vertical and horizontal support functions

- and (by interaction with an electric synchronous long-stator motor in the guideway) both propulsion and regenerative braking
  (→ chart: Vehicle/Guideway Components)

The levitation system consists of electromagnets (and related control systems) integrated in the vehicle structure in a way that they attract the vehicle to the guideway from below by interacting with ferromagnetic reaction rails attached to the underside of the guideway.

The guidance system holds the vehicle laterally on the track also by means of a second sort of electromagnets. These magnets and the related control systems are integrated on both sides in the vehicle structure so that they attract towards the lateral flanges attached to the guideway structure.

Both levitation and guidance magnets are fed from the on-board power system and controlled by means of electronic choppers so that a gap of 8 - 10 mm (approx. 3/8") is safely maintained ["safe hovering"].

The propulsion system consists of a linear motor featuring the long-stator component with two three-phase windings with laminated iron core in the guideway and the levitation magnets of the vehicle providing an excitation field so that the vehicle travels synchronously with the AC wave of variable fredquency fed into the long-stator winding.

2.2 Benefits

Due to its technical features, Transrapid maglev technology is superior to other transportation systems, particularly in terms of

- safety and ride comfort
- acceleration and travel speed
- grade capability and alignment flexibility
- cost effectiveness and operational versatility

(→ chart: Performance Capability)

It is interesting to see that despite the current success of advanced wheel-on-rail projects there is more and more initiative worldwide to make maglev technology available for the future replacement of conventional railroads.

In order to justify Transrapid consideration for public service, the German Government requested an unbiased evaluation whether or not the maglev technology is ready for application. This evaluation focused on the following questions:

- Is the development and testing status of the system sufficiently advanced to consider the technology for concrete application cases and project planning procedures?

- Are there any inherent safety risks in the entire system or in any of the subsystems?

- As far as specific solutions have not yet been demonstrated, will these solutions be available by the time of application?

- Is there sufficient certainty in the calculation of specific investment costs at the time of assessment?

A special task force under leadership of the German Federal Railways conducted thorough investigations of the comprehensive documentation and additional experiments on the test facility, altogether more than two years of intensive study work. The team ended up with fully positive answers to the above questions: Transrapid maglev technology is technically ready for application as a public transportation system!

2.3 Performance Highlights

During an extended test period early in June 1993, the opportunity was taken to demonstrate again the performance capabilities of the Transrapid technology.

The outstanding result of these demonstrations was a new world record for manned maglev vehicles at 450 kph (280 mph). This peak velocity was reached several times, first on June 10, 1993.

The numerous endurance runs during the same testing period may be even more significant to prove the system's suitability for commercial high speed long distance operation; the longest non-stop run was 1,674 km (1,040 miles) at top speeds up to 380 kph (236 mph).

Perhaps even more impressive and meaningful than these performance highlights as such is the way they were obtained. Without any particular preparation of the vehicle or the propulsion system, the record speed could be reached repeatedly. And no limits of the technology were recognizable. The only reason why the test crew could not head for higher speeds is because the alignment of the test track does not allow it to go faster [it was originally designed for 400 kph (249 mph)].

Due to the contact-free levitation, guidance and propulsion/braking coming with the maglev technology, high-speed operation is not related to any mechanical wear. On the contrary, rail-bound trains are facing a substantial increase in wear of their mechanical components such as the wheel and rail profiles, motors and gears, brakes, overhead power catenary and pantographs. Typically, the excessive wear and tear resulting from fast railway operation and the associated dramatic increase in operation and maintenance costs are the controlling factors that limit the design speed for wheel-on-rail projects.

3. Application

Considering

- the overall acknowledged benefits of the German Transrapid maglev technology,
- its brilliant performance highlights, and
- its development status reached so far which is topped by the certification for public service in the country of origin,

there is no doubt that the time has come for commercial deployment.

3.1 Germany: The Berlin - Hamburg Project

The Federal Master Transportation Plan for Germany, currently under parliamentary discussion, features numerous projects to upgrade the infrastructure urgently needed for the fostering of the economic development of the country after unification in 1990. One of the most important projects in the plan is the high-speed passenger transportation link between Berlin and Hamburg. This project has been dedicated to maglev technology provided all conditions can be met.

An overview of the key features of this project is given in the Project Data Berlin-Hamburg chart. (→ chart: Project Data Berlin-Hamburg Maglev Link)

Up to now, intercity transportation in Germany is an issue of Federal responsibility and thus entirely publicly funded. For the first time ever, the Berlin-Hamburg maglev project is intended to be established as a public-private partnership featuring a substantial private contribution in the funding. Thyssen as the development leader of the technology was invited to come up with a feasible financing scheme to meet the governmental requirements. Together with our industrial partners of the Magnetschnellbahn Berlin-Hamburg GmbH (Siemens, Daimler Benz/AEG) and leading German banks (Deutsche Bank, Kreditanstalt für Wiederaufbau) Thyssen submitted a conceptual proposal on this matter earlier this year. Currently the proposal is being reviewed and modified to meet the imposed conditions. The whole task is particularly difficult as major portions of the rail-related legislation to be referred to are presently in a process of being restructured towards part privatization of the German railways system.

However, we anticipate getting the political go-ahead for the Berlin-Hamburg project after the final approval of the financing concept which is due by the end of this year. (→ chart: Financing Scheme Berlin-Hamburg Maglev Link)

3.2 USA: The American MagLine Group

After decades of unlimited growth of both automobile and aircraft traffic in the U.S., it has become obvious that high-speed ground transportaion is a must to further provide adequate transportation quality. Otherwise, the ever increasing mobility demand would face more and more unacceptable conditions in terms of gridlock and pollution.

Maglev technology in fact has been identified as the most promising approach to cope with this situation. As a consequence, the National Maglev Initiative (NMI) has been started to develop a system capable of meeting the requirements. However, serious evaluation of the NMI intentions has to admit that it is at least questionable whether these efforts can ever fulfill the high expectations, particularly in terms of

- safe and reliable performance,
- commercially viable operation, and
- availability for public service within less than a decade.

In May 1993, the American MagLine Group (AMG) was founded by four U.S. companies:

- Booz, Allen & Hamilton, Inc., a Delaware corporation particularly experienced in transportation systems engineering;

- General Atomics, a California corporation with broad expertise in the design of sophisticated power supply and conditioning systems;

- Hughes Aircraft Company, a Delaware corporation with great experience in systems engineering and command and control systems, and

- Thyssen Henschel America, Inc., a wholly-owned California subsidiary of Thyssen Industrie AG from Germany, which holds the lead in the development of the Transrapid maglev technology to date. (→ chart: AMG Cover Chart)

The objectives of the AMG target the development of a high-speed ground transportation infrastructure, which creates real and enduring economic and social benefits to the U.S. (→ chart: Our Objectives)

The intent is to make maglev available for application in the U.S. by Americanization of existing designs.

Based on a transfer of the original design and manufacturing know-how, "Americanization" means (→ chart: Americanization of Transrapid)

- to create subsystems based on U.S. state of the art: operation control, communications, propulsion, power distribution, etc.

- to establish the American subcontractor/supplier infrastructure and American manufacturing base

- to develop the data needed to facilitate DOT certification of the system.

Taking advantage of the expertise of the AMG partners, a preliminary assignment of work has been agreed on. (→ chart: AMG Partners and Work Assignment)

The AMG program plan allows use of the readily developed Transrapid technology to quickly implement a maglev project and to create a large number of jobs. (→ chart: AMG Program Plan)

Thus, the technology can be made available very soon, allowing a fast start on a commercial U.S. project (→ chart: System Upgrade and Conversion)

The time factor is particularly interesting with regard to the jobs resulting from such a project. The example of a LAX - Palmdale connection based on Transrapid technology shows how soon construction can start, as preparatory work does not significantly exceed the amount involved in conventional train projects. (→ chart: Maglev Project Example)

There are plenty of both potential U.S. and overseas candidate projects for maglev application as offered by AMG, including California, Florida, Pennsylvania and the DOT High-Speed Corridors as well as in the Pacific rim. (→ chart: Potential Transrapid-based Projects)

The effect of job creation in AMG's maglev system program is particularly impressive compared to alternative approaches. (→ chart: Job Creation in Maglev System Program)

Considering the current decrease of the defense sector, conversion to civilian technologies is most time-critical to avoid serious damage to the economy. Assuming the overall volume of jobs generated by a maglev project is independent of the specific technology, it is most important to come up with a concept providing occupation in the field of high tech development and manufacture the sooner the better. Under this criterion the AMG approach is obviously superior to other alternatives as it takes advantage of the Transrapid state of development reached so far.

4. Summary

The Transrapid maglev technology is at the threshold of commercial deployment and technologically all prerequisites for the successful operation of the system in public service are given.

In post unification Germany the domestic maglev technology is envisioned to be applied in the Berlin-Hamburg project. At present, a public-private funding concept is being prepared and the lengthy planning process is about to be initiated.

In the USA the AMG has presented a program to Americanize the technology and to make it available for commercial use in the U.S. in the very near future.
(→ chart: AMG Program Summary)

The paramount features of this program

- generate economic development
- provide a basis for transportation technology development
- create opportunities for U.S. industry
- improve the U.S. transportation infrastructure and
- improve the environment and traveler safety.

Maglev is ready for the U.S.; is the U.S. ready for maglev?

TRANSRAPID DEVELOPMENT CHRONOLOGY

1976 - FIRST LONG STATOR VEHICLE (HMB2) DEMONSTRATED

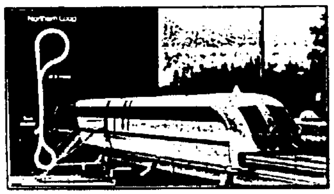
1977 - EMS SYSTEM SELECTED OVER EDS SYSTEM

1979 - TR05 DEMONSTRATED AT HAMBURG EXPOSITION

1980-87 - CONSTRUCTION OF THE EMSLAND TEST TRACK

1984 - FULL SYSTEM DEMONSTRATED BY TR06 ON EMSLAND TEST TRACK

1989 - TR07 BEGINS FULL PERFORMANCE & RELIABILITY TESTING



1991 - TRANSRAPID SELECTED BY FLORIDA FOR ORLANDO PROJECT

1992 - TRANSRAPID TECHNOLOGY APPROVED FOR PUBLIC USE BY THE GERMAN GOVERNMENT

1993 - HAMBURG TO BERLIN LINE USING TRANSRAPID TECHNOLOGY INCLUDED IN GERMAN MASTER TRANSPORTATION PLAN

1993 - FORMATION OF THE AMERICAN MAGLINE GROUP TO BUILD TRANSRAPID BASED HIGH SPEED GROUND TRANSPORTATION SYSTEMS IN THE U.S.

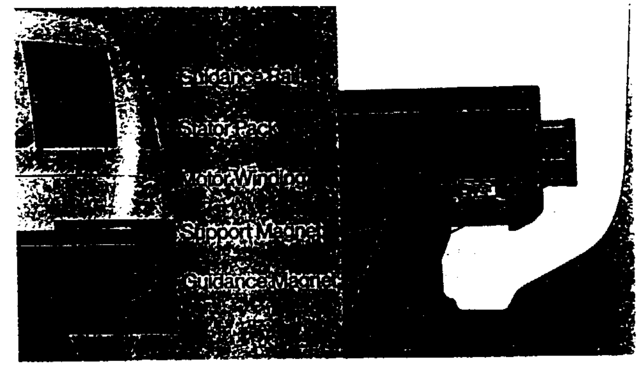
TRANSRAPID TECHNOLOGY REPRESENTS TWO DECADES OF CONTINUOUS COMMITMENT TO REVOLUTIONIZING HIGH SPEED GROUND TRANSPORTATION

C-2.

TRANSRAPID SYSTEM PERFORMANCE CAPABILITY

OPERATING SPEED	300 MPH
GRADE CAPABILITY	10%, REDUCES NEED FOR TUNNELS AND BRIDGES
SAFETY	WRAPS AROUND GUIDEWAY, CANNOT DERAIL
ELECTRO-MAGNETIC EMISSIONS	WELL BELOW EXISTING STANDARDS (U.S. REPORT DOT/FRA/ORD-92/09)
MAINTENANCE	LOW DUE TO CONTACTLESS OPERATION AND NO ROTATING MACHINERY
ALIGNMENT	EASILY ELEVATED, TIGHT RADII, HIGH GRADE CAPABILITY, SMALL FOOT PRINT - OFFERS FLEXIBILITY IN URBAN & ROUGH TERRAIN ALIGNMENTS

Vehicle/Guide-way components



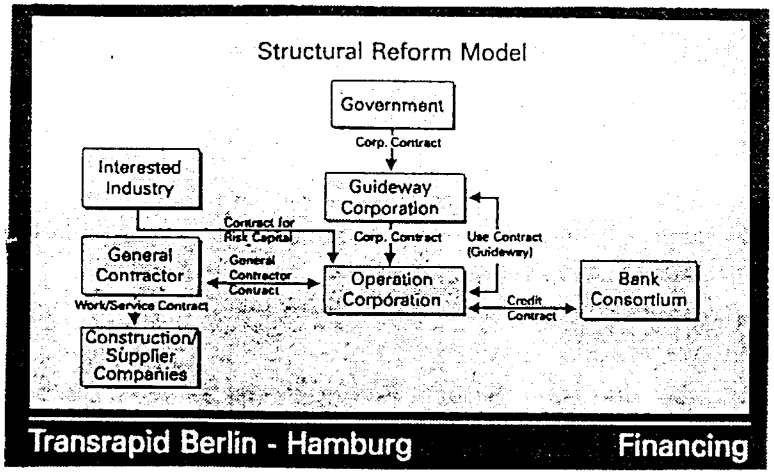
Project Data Berlin - Hamburg Maglev Link

Distance Berlin - Hamburg	283 km	(176 mi)
Design Speed	400 km/h	(250 mph)
Trip Time	approx. 55 min.	
Service Concept	96 roundtrips per day, 10 min. service interval (peak)	
Ridership Volume	14.7 million pax per year	
Investment Cost		
- fixed facilities	6.6 bill.DM = 23.3 mill.DM/km (23.3 mill.$ per mi)**	
- vehicles (trains, cars e.a.)	0.6 bill.DM	
TOTAL	7.2 bill.DM = 25.4 mill.DM/km (25.4 mill.$ per mi)	
Operating Costs*	0.05 DM/pass.km (0.05 $ per pass.mi)**	
Construction Time (provided the availability of r-o-w and building permits)	1994 - 2002	

*) Standard basis of all Fed. Master Transportation Plan Projects: 1989 DM

**) Conversion: 1 DM per km = 1 $ per mile

1 mile = 1.609 km
1 $ = 1.61 DM (June 1993)



OUR OBJECTIVES

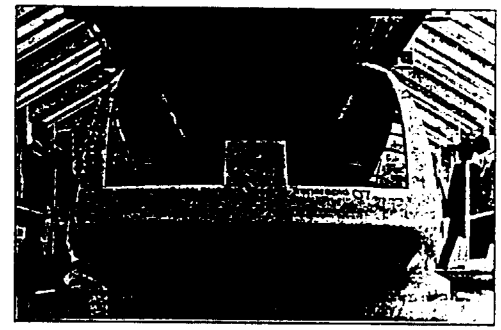
- CREATION OF TENS OF THOUSANDS OF HIGH SKILL, HIGH WAGE U.S. JOBS THAT WILL BE LONG LASTING
- MINIMIZING THE DEVELOPMENT TIME AND COST BY LEVERAGING THE $3 BILLION GERMAN TRANSRAPID INVESTMENT
- INCORPORATING ADVANCED U.S. TECHNOLOGIES INTO THE SYSTEM TO MAINTAIN THE MARKET LEAD OF THE U.S. PRODUCT
- CREATION OF TECHNOLOGY AND BUSINESS SPIN OFFS THAT WILL ENHANCE AMERICAN COMPETITIVENESS
- EXPORTING PRODUCTS WORLDWIDE

DEVELOPMENT OF A HIGH SPEED GROUND TRANSPORTATION INFRASTRUCTURE WHICH CREATES REAL AND ENDURING ECONOMIC AND SOCIAL BENEFITS TO THE U.S.

THE AMERICAN MAGLINE GROUP

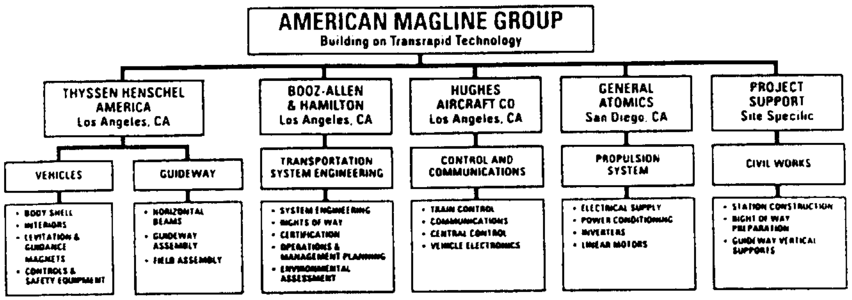
OUR VISION IS THE CREATION OF A NEW AMERICAN INDUSTRY THAT WILL REVOLUTIONIZE THE GROUND TRANSPORTATION INFRASTRUCTURE IN THE UNITED STATES AND THE WORLD BASED ON MAGLEV TECHNOLOGY

BOOZ ALLEN & HAMILTON INC THYSSEN HENSCHEL AMERICA, INC. HUGHES GENERAL ATOMICS

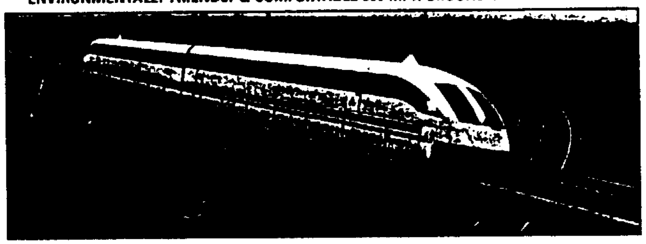


OUR INTENT IS TO AMERICANIZE THE TRANSRAPID SYSTEM

- TRANSFER THE BASIC DESIGN AND MANUFACTURING KNOW-HOW
- CREATE SUBSYSTEMS BASED ON U.S. STATE OF THE ART: OPERATION CONTROL, COMMUNICATIONS, PROPULSION, POWER DISTRIBUTION
- ESTABLISH THE AMERICAN SUBCONTRACTOR/SUPPLIER INFRASTRUCTURE AND AMERICAN MANUFACTURING BASE(S)
- DEVELOP THE DATA NEEDED TO FACILITATE DOT CERTIFICATION OF THE SYSTEM



TRANSRAPID, THE ONLY-PROVEN & CERTIFIED MAGLEV SYSTEM, PROVIDES QUIET, SAFE, ENVIRONMENTALLY FRIENDLY & COMFORTABLE 300 MPH GROUND TRANSPORTATION



"WE WILL BRING THIS SYSTEM TO THE U.S. TO BE BUILT BY U.S. COMPANIES USING U.S. ENGINEERS"

SYSTEM UPGRADE AND CONVERSION ACTIVITIES

ACTIVITY	DESCRIPTION	MONTHS 0 6 12 18 24
SYSTEM COMMAND AND CONTROL DESIGN	DEVELOPMENT OF THE BASIC ARCHITECTURE OF THE COMMUNICATIONS AND CONTROL SYSTEM FOR A REVENUE SERVICE NETWORK INVOLVING MULTIPLE VEHICLES, MULTIPLE LINES AND O&M FACILITIES.	
PROPULSION POWER SYSTEM	DESIGN AND MODULAR PROTOTYPING OF THE PROPULSION POWER SYSTEM INVERTERS AND ITS CONTROL UNIT. APPROACH WILL BE BASED ON CURRENT STATE-OF-THE-ART- SWITCHING DEVICES.	
MANUFACTURING PLANNING	DEVELOP INFRASTRUCTURE INCLUDING INITIAL QUALIFICATION OF U.S. VENDORS & SUPPLIER FOR THE SYSTEM. PRELIMINARY MANUFACTURING PROCESS DESIGN AND SITING STUDIES. INCLUDES VEHICLE & GUIDEWAY DESIGN CONVERSION & UPGRADE	
PERMITTING AND CERTIFICATION	GENERATE TECHNICAL INFORMATION REQUIRED TO OBTAIN FRA CERTIFICATION OF THE SYSTEM. GENERATE DATABASE OF INFORMATION REQUIRED FOR ENVIRONMENTAL AND OTHER PERMITS WHICH WILL BE REQUIRED FOR A PROJECT.	
PROJECT PLANNING	DETAILED PLANNING BY THE GROUP OF A SPECIFIC PROJECT DONE IN CONCERT WITH THE SPONSOR OF THE PROJECT	

THESE ACTIVITIES AND THE TECHNOLOGY TRANSFER WILL ALLOW A FAST START ON A U.S. PROJECT

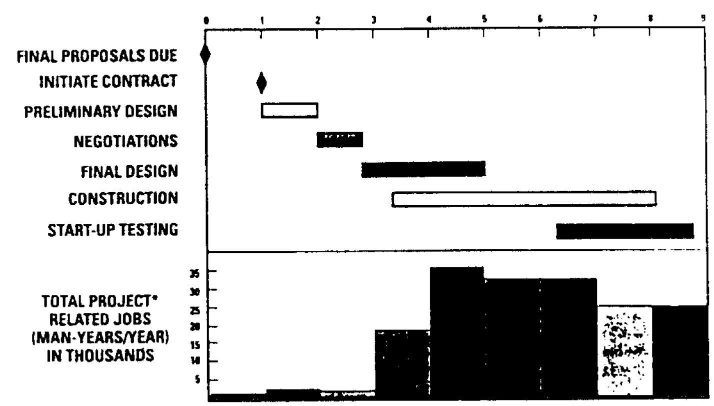
AMERICAN MAGLINE GROUP PROGRAM PLAN

- OBJECTIVES - DEVELOP A NEW U.S. MANUFACTURING BASE AND A NEW U.S. HIGH SPEED GROUND TRANSPORTATION SYSTEM
- ENABLING TECHNOLOGY ACTIVITIES FOR THE PROGRAM
  - TRANSFER IN DETAIL THE TRANSRAPID TECHNOLOGY TO U.S. FIRMS
  - AMERICANIZE THE SYSTEM, ADAPTING IT TO U.S. REQUIREMENTS & INCORPORATING STATE OF THE ART U.S. TECHNOLOGIES
  - PLANNING FOR THE U.S. MANUFACTURING INFRASTRUCTURE
  - INITIAL PLANNING OF PROJECTS INCLUDING PERMITTING REQUIREMENTS
- IMPLEMENTATION OF A MAGLEV SYSTEM PROJECT
  - PROJECT DETAILED DESIGN
  - ESTABLISH MANUFACTURING BASE
  - SYSTEMATIC BUILDING OF THE HIGH SPEED GROUND TRANSPORTATION NETWORK

USE OF THE TRANSRAPID TECHNOLOGY ALLOWS US TO QUICKLY IMPLEMENT A PROJECT & CREATE A LARGE NUMBER OF JOBS

MAGLEV PROJECT EXAMPLE (LAX-PALMDALE)

CHARACTERISTICS - 71 MILE LONG, DOUBLE TRACK
13 STATIONS
BASIC CAPACITY 6000 PPHPD



*INCLUDES 140% INDIRECT JOBS

POTENTIAL TRANSRAPID BASED PROJECTS

SPECIFIC PROJECTS BEING STUDIED INCLUDE:

ORLANDO AIRPORT DEMONSTRATION

BERLIN - HAMBURG

PITTSBURGH DEMONSTRATION

LAX - PALMDALE

POTENTIAL MARKETS INCLUDE:

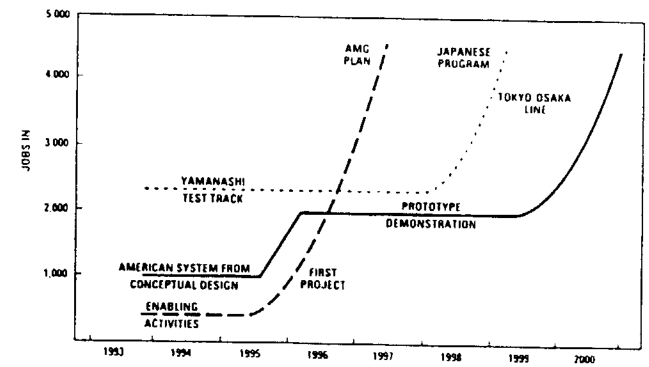
CALIFORNIA SPINE PROJECT

THE OTHER FOUR FRA DESIGNATED CORRIDORS

CHINA AND OTHER ASIAN MARKETS

THE U.S. & EXPORT MARKETS FOR MAGLEV SYSTEMS ARE VERY LARGE

JOB CREATION IN MAGLEV SYSTEM PROGRAM



AMG PROGRAM PLAN IS THE OPPORTUNITY FOR U.S. TO BE IN THE FOREFRONT OF MAGLEV SYSTEMS

AMERICAN MAGLINE GROUP PROGRAM SUMMARY

- GENERATE ECONOMIC DEVELOPMENT
  - CREATE IMMEDIATE AND LASTING JOBS
  - CREATE A U.S. MANUFACTURING BASE FOR HSGT
  - HELP THE TRADE BALANCE BY ELIMINATING IMPORTS
  - HELP THE TRADE BALANCE BY CREATING EXPORTS
- PROVIDE A BASIS FOR TRANSPORTATION TECHNOLOGY DEVELOPMENT
  - TRANSRAPID IS AN OPERATING BASIS FOR TECHNOLOGY IMPROVEMENTS
  - CONDUCT FURTHER DEVELOPMENT WORK ON THE TRANSRAPID SYSTEM
  - INCORPORATE TECHNOLOGIES AS THEY MATURE (E.G. SUPERCONDUCTORS)
- CREATE OPPORTUNITIES FOR U.S. INDUSTRY
  - SUPPLIER BASE FOR SYSTEM WILL BE FROM ALL OVER THE U.S.
  - HALF OF ANY PROJECT WILL BE BY LOCAL INDUSTRY

LOW O&M, FUEL AND ENVIRONMENTAL COSTS PLUS HIGH SPEED, PRODUCE REAL WEALTH FOR THE U.S.

AMERICAN MAGLINE GROUP PROGRAM SUMMARY

- IMPROVE THE U.S. TRANSPORTATION INFRASTRUCTURE
  - RELIEVES AIRPORT AND HIGHWAY CONGESTION
  - SUPPORTS INTERMODALISM
  - REDUCES LOST PRODUCTIVITY DUE TO TRAVEL TIME
- IMPROVE THE ENVIRONMENT AND TRAVELER SAFETY
  - SAFER THAN AUTO, STEEL WHEEL RAIL OR AIR TRAVEL
  - REDUCES SINGLE OCCUPANT AUTO TRAVEL
  - REDUCES FUEL CONSUMPTION PER TRIP
  - LOWER EMISSIONS FROM REMOTE SINGLE POINT POWER SOURCE
  - LOWER ENVIRONMENTAL IMPACT FROM ALIGNMENT (ELEVATABLE)
  - QUIETER OPERATION

MAGLEV SYSTEM WILL IMPROVE QUALITY OF LIFE: FAST, SAFE, AFFORDABLE, GREEN