Pennsylvania High Speed Maglev Project

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Abstract
This paper discusses the implementation plans for the Pennsylvania High Speed Maglev Project in the United States. Western Pennsylvania’s rugged terrain, rivers and geographic features provide multiple challenges to the technology supplier as well as in the fabrication, construction and installation of the guideway for the maglev system. The impact of these challenges on the development of the project is discussed. Currently the Pennsylvania Project is developing the Environmental Impact Statement (EIS) for the project with various alignment alternatives having been identified and studied. Alignment alternatives, EIS status, planned construction techniques as well as operating plans, safety methodology, support facilities, and advanced manufacturing and fabrication required to meet the guideway and rider comfort requirements are discussed.

1 INTRODUCTION
The Federal Railroad Administration (FRA) has proposed the deployment of high-speed transportation systems using maglev technology in the United States. The purpose of this action is to promote the development and construction of an alternative transportation system in the United States, employing magnetic levitation technology capable of safe use by the public at speeds in excess of 386 kilometers per hour (240 miles per hour). The maglev technology utilizes non-contact electromagnetic forces to levitate, guide and propel vehicles over a fixed, elevated guideway.

The Magnetic Levitation Transportation Deployment Program was authorized by the Transportation Equity Act for the 21st Century (TEA 21: Pub. L. No. 104-178, 112 Stat. 107, 216). This legislation identified federal funding of $950 million for the deployment of the first high-speed maglev system in the US. This legislation has currently been extended through mid 2004 and will be replaced by new legislation as part of the transportation and infrastructure planning for the entire country. It is anticipated that multiple high speed maglev projects will be identified for implementation.

The planning for the Pennsylvania Project has been under development since 1984 by MAGLEV, Inc., a for profit company, as part of a public/private partnership with the local transportation authority, the Port Authority of Allegheny County (PAAC) and the Pennsylvania Department of Transportation (PENNDOT).
The Pennsylvania Project includes the guideway, vehicles, passenger stations, maintenance and operation control facilities and related roadway infrastructure required to support the system.

MAGLEV, Inc. is a dynamic, and mature organization composed of some of the most advanced and prestigious companies and organizations in Pittsburgh, including Bombardier Transportation Company, Carnegie Mellon University, Duquesne Light Company (DQE), Michael Baker Corporation, Pittsburgh Building and Construction Trades, U. S. Steel, United Steelworkers of America, and Wheeling-Pittsburgh Steel Corporation. There are additional contributing board members including PriceWaterhouseCoopers and Reed Smith LLP, as well as city and county governmental agencies that have been involved in the project since its inception.

MAGLEV, Inc. has two objectives in the development and support of the Pennsylvania Project. The first objective is to install the first high speed maglev system in the USA. The second objective is to establish the precision fabrication technology required to implement the Transrapid technology in the USA.

2 Project Description

The Pennsylvania Project is an 87-kilometer (54 mile) high-speed ground transportation system from the Pittsburgh International Airport in Allegheny County, located approximately 29 kilometers (18 miles) west of Downtown Pittsburgh to the suburb of Greensburg in Westmoreland County. Illustration 1 shows the alternative alignments that have been studied during the Environmental Impact Study (EIS) process.

Illustration 1: Overview of Alignment Alternatives Studied

The east/west corridor the maglev system will serve is a highly congested transportation corridor with no light rail or other rail or transit services available. The maglev system will provide an alternative to the region’s most highly congested highway, I-376. Auto travel times from the airport to downtown range from 25 minutes to more than 45 minutes. Travel time from Greensburg to the airport is
approximately 45 to 60 minutes during non rush hour periods and 75 to 90 minutes during rush hours. Auto travel times are greatly impacted by the limitations of two tunnels (the Fort Pitt tunnel in the trip segment from the airport to downtown and the Squirrel Hill tunnel in the segment from downtown to the eastern suburbs). Both tunnels have been at capacity for more than 10 years and remain congested through the day. Illustration 2 provides a comparison for the travel times for auto, bus and maglev.

![Comparison of Travel Times](image)

Illustration 2: Comparison of Travel Times

Maglev travel time from the airport to Greensburg including stops will be approximately 35 minutes with speeds in excess of 386 kilometers per hour (240 miles per hour) being reached with the average speed of approximately 145 kilometers per hour (90 miles per hour). The planned system consists of five stations including a dual station configuration at the airport to serve air travelers at the terminal and a commuter station located approximately two miles from the air terminal. The downtown Pittsburgh station will be located within a 15 minute walking distance from most major businesses and employers. Suburban and rural stations in Monroeville and Greensburg complete the initial 87 kilometer (54 mile) system.

For study purposes, segments “A”, “B” and “C” have been used to refer to the alignments between each station. The “A” segment refers to the alignment alternatives from the airport to downtown Pittsburgh. The “B” segment refers to the alternatives from downtown Pittsburgh to the Monroeville/ Penn Hills area. And the “C” segment refers to alternatives from Monroeville/ Penn Hills to Greensburg.

2.1 Segment A - Alternative Alignment A5 South

Referring to Illustration 3, alternative alignment A5 South is approximately 17.62 miles (28.4 kilometers) in length and provides service from a station at the Pittsburgh International Airport (PIA) to a station in downtown Pittsburgh near the Mellon Arena and Steel Plaza light rail transit (LRT) station. Airport passengers (air travelers) would board maglev at the Landside Terminal station while commuter passengers would board at the Enlow Road station located along Pennsylvania Route 60 south of the Airport entrance. The Alternative Alignment A5 South would leave the proposed station at PIA and follow Pennsylvania Route 60 in an eastwardly direction.

The alignment then leaves the Pennsylvania Route 60 corridor where it converges with business Route 60 and follows the Chartiers Valley eastward through Moon, Robinson and Kennedy Townships to McKees Rocks Borough and the City of Pittsburgh. In Pittsburgh, it follows the south shore of the Ohio and Monongahela Rivers to a new river crossing between the existing Panhandle and Liberty bridges.
After crossing the Monongahela River, it continues into Pittsburgh over the Cross-town Expressway to a proposed Steel Plaza station near the Mellon Arena and the existing Steel Plaza transit station.

Illustration 3: Segment A, Airport to Downtown Pittsburgh

2.2 Segment B - Alternative Alignment B4 West

Referring to Illustration 4, alternative alignment B4 West is approximately 17.5 miles (28.2 kilometers) in length and extends from the proposed station in downtown Pittsburgh to the proposed Thompson Run station in the municipalities of Penn Hills/ Monroeville.

Utilizing the existing East Busway, the Alternative Alignment B4 West leaves Pittsburgh, proceeds northeast through the Strip District and use the Allegheny Valley Railroad corridor along the south side of the Allegheny River to the Borough of Verona. The alignment leaves the existing rail corridor at Verona, heads eastward, through Plum Borough and Penn Hills, follows the west side of the Pennsylvania Turnpike to the Union railroad corridor to the Thompson Run station in Penn Hills.
Illustration 4: Segment B: Downtown Pittsburgh to Monroeville/ Penn Hills

2.3 Segment C - Alternative Alignment C6

Referring to Illustration 5, alternative alignment C6 is approximately 19.3 miles (31.1 kilometers) of single track guideway and extends from the Thompson Run station site to a proposed station near the Pennsylvania Route 136 and Toll Route 66 interchange in Westmoreland County.

The alignment would leave the Thompson Run station following the north side of I-376 and follow the northeast side of the Pennsylvania Turnpike. It would cross to the southwest side of the Pennsylvania Turnpike near Trafford Road and then cross back to the northeast side, east of Nike Site Road just south of Arbor Court in Penn Township.

The alignment then continues through Penn Township and Manor Borough to North Huntingdon Township. It would cross U.S. Route 30 in North Huntingdon Township just east of the Irwin interchange of the Turnpike. It would continue to parallel the Turnpike to SR 3071 (Henry Long Road) where it would generally follow Pennsylvania Route 136 east to the proposed station in Hempfield Township near Toll Route 66/PA Route 136.
The Pennsylvania Project has a distinct advantage in that it can be constructed in phases permitting operation of a revenue service system without completion of the total 87-kilometer (54 mile) system. This approach permits all aspects of the construction and operation to be fully demonstrated and evaluated.

Implementing the project in phases also permits a more detailed assessment of the project requirements to be made during the initial construction phase, thereby reducing risk and contingency in bidding and allows contractors to more effectively plan the construction methods and costs for the remainder of the project.

The basic planned operating and implementation features of the Pennsylvania Project including distances, trip times, stations, fare structure, major facilities, guideway and superstructure are summarized in Table 1.

**Table 1: Operation and Implementation Features**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Distance</td>
<td>~54 Miles (86.9 km)</td>
</tr>
<tr>
<td>Airport to Downtown</td>
<td>~17.6 miles (Trip time ~10 minutes)</td>
</tr>
<tr>
<td>Downtown to Monroeville</td>
<td>~17.5 miles (Trip time ~11 minutes)</td>
</tr>
<tr>
<td>Monroeville to Greensburg</td>
<td>~19.3 miles (Trip time ~10 minutes)</td>
</tr>
<tr>
<td>Total Trip Time</td>
<td>~ 35 Minutes (including stops)</td>
</tr>
<tr>
<td>Peak Headway</td>
<td>8.5 minutes (Designed for 7.5 minutes)</td>
</tr>
<tr>
<td>Non-Peak Headway</td>
<td>10 minutes (15 and 20 minutes also available)</td>
</tr>
<tr>
<td>Dwell Time (Intermediate Stations)</td>
<td>1 minute</td>
</tr>
</tbody>
</table>


3 Construction Challenges

The Pennsylvania Project area is part of the Appalachian Plateaus Province and consists of hilly topography bisected by numerous streams and rivers with elevations between 213 meters (700 feet) and 457 meters (1,500 feet). Areas of steep slopes can be found along many of the waterways with local relief in these areas up to 152 meters (500 feet). The rugged topography presents a challenge for the implementation of additional roadways or other forms of transportation in the area.

The Transrapid maglev however represents an effective alternative solution to the congested east/west corridor. The Project serves as an ideal example for the implementation of high-speed maglev in the US since it demonstrates performance under varied terrain and climatic conditions as well as the advanced guideway fabrication and construction techniques described later.

Construction of any Transrapid system in the US will present various challenges. However, MAGLEV, Inc. has developed processes in various areas that will be utilized to fully address these challenges.

3.1 Construction Planning

The maglev system demands a significantly difference approach to fabrication and construction of the guideway and supporting substructure. Maglev is a total system. This means building of an 87 km (54-mile) long set of linear motors, one on each side of each guideway. Tolerances demanded by such a motor system are extremely tight, and must be met to guarantee the performance. This calls for a re-evaluation of both the fabrication and construction techniques from beginning to end. The fabrication

<table>
<thead>
<tr>
<th>Stations</th>
<th>Five (Dual station serving the airport area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fare</td>
<td>$5 between stations</td>
</tr>
<tr>
<td>One-way passenger trips</td>
<td>~14.2 Million/Year (47,449 one way trips/ day)</td>
</tr>
<tr>
<td>Vehicle Sets</td>
<td>8 x 3 Sections (Designed for 5 section)</td>
</tr>
<tr>
<td>Passengers/ Vehicle</td>
<td>344 (3 section), 600 (5 section) (~50% seated)</td>
</tr>
<tr>
<td>Maximum Grades</td>
<td>6 - 8 Percent (Dependent on Alignment)</td>
</tr>
<tr>
<td>Hours of Operation</td>
<td>18 hrs/ day</td>
</tr>
<tr>
<td>Max. Speed, Average Speed</td>
<td>~250 mph (400 km/h), ~90 mph, (161 km/h)</td>
</tr>
<tr>
<td>Guideway Configuration</td>
<td>Dual Dedicated-35 miles, Single-19 miles</td>
</tr>
<tr>
<td>Number of Substations</td>
<td>5</td>
</tr>
<tr>
<td>Maintenance Facility</td>
<td>1</td>
</tr>
<tr>
<td>Major River Crossings</td>
<td>1 (300 meters, 985 feet)</td>
</tr>
<tr>
<td>Million train Miles/ yr</td>
<td>3.47</td>
</tr>
<tr>
<td>Guideway</td>
<td>Primarily Type I, Steel, 96% Elevated</td>
</tr>
<tr>
<td>Substructure</td>
<td>Primarily – Caisson Foundation</td>
</tr>
<tr>
<td>Planned Operational Start</td>
<td>2010 (Airport to Downtown)</td>
</tr>
</tbody>
</table>

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and construction are inexplicably connected. This connection is created by the design for the basic electric motor and control system along an alignment in the field that is driven by ride comfort criteria.

The typical construction processes used in Germany and in China for columns and setting the beams onto the columns involved building a construction road adjacent to the columns. This process is costly and potentially damaging to the environment.

The Pennsylvania Project objectives include the development of alternative column construction and beam installation methods that do not require development of permanent construction roads. This requires a total evaluation of all disciplines and techniques for construction and transport, techniques both in and out of the traditional highway and bridge construction industry. The Type I, 62 meter (203 feet) beams will be the primary beams used for construction. Other lengths will be used, but they will be shorter and lighter. Transporting a 62 meter (203 feet) beam to the construction sites poses many challenges. The Pennsylvania Team has discussed beam transport with local and international hauling and rigging companies, barge companies and railroads. Plans have been developed for the safe and efficient movement of the beams.

Railroads and rivers are also located along much of the alignments making movement by rail or barge a preferred method that will be utilized by the Project.

3.2 Beam Transport and Setting

Where applicable transport of guideway beams will utilize the tried and true methods of special highway transport trailers, and special rail cars. Specialized multi axle flat bed trailers with trailing dollies and support cradles similar to the one shown in Illustration 6 are available to transport the beams from the fabrication facility to the construction site as was done in Emsland during the construction of the test facility. There will also be areas that are available to use standard double crane setting procedures. This method is well proven and is applicable to many areas where access is not limited due to terrain or other natural barriers. However, due to the varying terrain, existing structures, and remote access, many beams for the Project will be erected with girder launching equipment as shown in Illustration 7. The concept involves a launcher that travels on the guideway. The launcher can place two beams at a time and progresses along the alignment setting new beams by traveling on the previously placed beams.

Illustration 6: Typical Beam Transport for Test Track at Emsland, Germany
To feed the launcher, two beams will be lifted by cranes or a gantry and placed on a cart at a staging area near the alignment. The self-propelled cart and launching assembly will move along the guideway to the next launch position. The launching equipment will be designed and fabricated to meet the specific needs of this project including curves and grades.

Theoretically all girders could be placed with one launcher and the girder cart could travel the entire 80 km (50 miles) or more with each pair of girders. However it is likely that schedule considerations will necessitate multiple carts and launchers.

Illustration 7: Beam Launching Systems

Other more innovative methods for construction of columns and beams have also been investigated and discussed with various companies and construction teams. One method under consideration includes the use of lifting or tow balloons to position column drilling platforms and equipment. This process is being developed for gas pipeline construction in Canada and is also applicable to the construction of the maglev system as shown in Illustration 8.

Illustration 8: Tow Balloon Concept for Beam Transport and Placement
3.3 Preparation and Column Installation

Maglev is not a highway construction project. Balancing of cuts and fills is not desirable, since no significant fill is required during the construction of the system. Removal of cut materials therefore becomes paramount. The availability of open areas for trucks and haulers to move material will not always exist along the right of way. Material movement via conveyors and off road vehicles similar to rough terrain quarry vehicles will be employed in these situations. Movement of excess earth by rail cars to other construction projects will also be developed and coordinated for the Project.

The elevated guideway substructures will be primarily made of reinforced concrete and are constructed on site using conventional construction techniques. They consist of a foundation below ground level with or without pilings, and one or more columns with column head or reinforced concrete. Poured-in-place concrete or pre-cast, post-tensioned pier structures may also be used to address construction challenges in several areas of the project.

Geologic conditions along the alignments require a variety of suitable foundations to support the guideway and pylons. Maglev structures share the same criteria that affect the design of highway and railroad structures, which can tolerate little settlement. However, highway pavement and railroad tracks at grade can often tolerate gradual settlement over long intervals. Maglev is less tolerant of gradual changes, which require structures to be designed to undergo “zero” vertical movement due to ground settlement. The depth to bedrock from the support base below the pylons will vary. The appropriate foundation type will depend primarily on bedrock, and, to a lesser extent, groundwater depth.

The typical foundation types include:

- Spread Footing
- Driven Piling
- Drilled Piling
- Drilled Shafts
- Large River Piers on Bedrock

Close tolerance GPS technology will be used in setting the columns and guideway. The tolerance range is 3mm (0.12 inches). “Millwright GPS” technology have been used on other close tolerance work and has been proven reliable in setting items within one millimeter horizontally and three millimeters vertically over a distance of four kilometers. This eliminates normal field surveying techniques and allows setting beams in their final position. Illustration 9 shows a concept for a precision GPS application for the maglev installation.

Illustration 9: Precision GPS Application for Maglev
The minimum pier height for the elevated guideway system is primarily driven by safety guidelines and has been set at a minimum clearance height to the underside of the beam of five meter (16.4 feet).

Except in isolated locations where special piers could be up to 25 meters (82 feet) tall, the typical maximum column height for Type I guideway beams will be 20 meters (65 feet). For heights over 25 meters (82 feet), secondary bridge structures may be required to support Type III guideway sections.

Secondary bridge structures will also be utilized for special crossings, pier heights over 25 meters (82 feet) in height and applications where it is impractical to achieve Type I or Type II beam pier placements in accordance with the system requirements of 6.2 meter (20.3 feet) increments. Deflection designs for these structures must limit the supported guideway deflection to L/4800.

The Project also requires a primary river crossing bridge across the Monongahela River. This bridge will be approximately 300 m (984 feet) in length.

4 TECHNOLOGY AND IMPLEMENTATION

There are multiple technical challenges involved with the implementation of the maglev system. One of the significant challenges involves the precision fabrication and logistics associated with the manufacture and installation of the steel guideway beams. Typical US fabrication tolerances for large box beam structures similar to the guideway beams are not sufficient to produce a beam that can meet the rider comfort criteria for the system.

4.1 Guideway Beams

An overview of the various guideway beam types is provided in Illustration 10 with characteristics of the various beam types including:

- Type I, II and III beam designs, certified by the German Government for use in Germany, have been chosen by for use on this project.
- The Type I beam is a two-span continuous steel guideway beam consisting of a trapezoidal box approximately 2 meter (6.56 feet) deep and 61.92 meter (203.14 feet) long with support span lengths of 30.96 meter (101.57 feet).
- The Type II beam is a two-span continuous steel guideway beam consisting of a trapezoidal box approximately 1 meter (3.28 feet) deep and 24.768 meter (81.26 feet) long with support span lengths of 12.384 meter (40.63 feet).
- The Type III beam is a continuous span steel guideway beam having a length of 6.192 meter (20.34 feet) consisting of three support lengths spaced at 2.752 meter (9.03 feet) and is approximately 1.4 meter (4.59 feet) in height.

The primary guideway structure planned for the project will be the 62-meter (203 foot) long Type I beam. The Transrapid system design parameters set the limits on the manufacturing processes and equipment that must be utilized to manufacture the beams.
There are two main factors that influence the geometry of the guideway:

1. The design variations in the alignment (configuration of the horizontal plane) and profile (configuration of the vertical plane), which consist of sections of tangents and curves, and

2. Deviations from the design path that arise from manufacturing and installation imperfections, structural flexing as the guideway is subjected to load application, structural expansion and contraction from thermal effects, and degradation of the various structural and mechanical components.

The vehicle and guideway interact as an integral dynamic system, as forces are transmitted at the interface between the vehicle and guideway for levitation, guidance, acceleration and braking. Variation in the guideway geometry or variations that are outside the design limits can affect the response or reduce the ride quality of the system.

The guideway system design provides data directly to the manufacturing process as well as into the control system. The software for the design and manufacturing of the guideway beams must be fully integrated to produce acceptable beams that are each geometrically unique but able to be manufactured in a mass production environment.

MAGLEV, Inc. is continuing to develop software to integrate the manufacturing process and to predict the weld distortion associated with the construction of the large box beam guideway structure. The manufacturing process is driven by the guideway alignment requirements to ensure the safety of the system and the overall rider comfort parameters for the maglev system.
The basic guideway alignment parameters for the maglev system are identified in Table 2.

Table 2: Transrapid Guideway/Alignment Parameters

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Criterion for Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cant (Super elevation)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Outside of stopping areas</td>
<td>≤ 12°,</td>
<td>Required for alignment</td>
</tr>
<tr>
<td></td>
<td>In special cases up to 16° *</td>
<td></td>
</tr>
<tr>
<td>• At stopping areas</td>
<td>≤ 12°</td>
<td>Evacuation possibility</td>
</tr>
<tr>
<td>• At station platforms</td>
<td>≤ 3.0°</td>
<td>Wheelchair and Passenger access/ egress</td>
</tr>
<tr>
<td>• Torsion</td>
<td>≤ 0.10°/m,</td>
<td>Kinematics of the vehicle</td>
</tr>
<tr>
<td></td>
<td>In special cases up to 0.15°/m *</td>
<td></td>
</tr>
<tr>
<td><strong>Longitudinal inclination or longitudinal inclination angle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Outside of stopping areas</td>
<td>≤ 10% or 5.71°</td>
<td>Required for alignment</td>
</tr>
<tr>
<td>• Within stopping areas in which standing vehicles are to be protected against unintended movements</td>
<td>≤ 10% or 5.71°</td>
<td>Required for alignment</td>
</tr>
<tr>
<td>• At station platforms, as well as in parking areas and at stopping areas, if dealing with ice</td>
<td>≤ 0.5% or 0.29°</td>
<td>Reliable holding brake function</td>
</tr>
<tr>
<td>• Horizontal radii (curves)**</td>
<td>≥ 350 m</td>
<td>Kinematics of the vehicle</td>
</tr>
<tr>
<td>• Vertical radii (crest, sag)**</td>
<td>≥ 530 m</td>
<td>Kinematics of the vehicle</td>
</tr>
<tr>
<td><strong>Transverse and vertical jerk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• In the area of entry routes to cities</td>
<td>≤ 1 m/s³</td>
<td>Rider Comfort</td>
</tr>
<tr>
<td>• Outside of entry routes to cities</td>
<td>≤ 0.5 m/s³</td>
<td>Rider Comfort</td>
</tr>
<tr>
<td>• On switches during turn-out</td>
<td>≤ 2 m/s³</td>
<td>Rider Comfort</td>
</tr>
<tr>
<td>• Superposition of horizontal radii and vertical radii***</td>
<td>$\frac{1}{R_{xz}} = \frac{\cos \alpha}{R_v} - \frac{\sin \alpha \cdot \cos^2 \beta}{R_h}$</td>
<td>Rxz criterion:</td>
</tr>
</tbody>
</table>

Additional guideway beam criteria are driven by the deflection criteria for the system and include:
- Loads
- Application of loads and load conditions
- Application of code rules for allowable stresses
- Analysis of finite areas of concern
- Code or regulatory check and verification
- Standards for US design

The guideway boundary requirements or dynamics are defined as:
- Longitudinal Jerk: <= 1.0 m/s³
- Lateral Jerk (outside Urban Areas): ≤0.5 m/s³
- Longitudinal Acceleration: $\leq 1.5m/s^2$
- Free Lateral Acceleration: $\leq 1.5m/s^2$
- Free Dynamic Vertical Acceleration
  - Crest: $0.6m/s^2$
  - Sag: $1.2m/s^2$

Permissible beam deformation values are defined as follows:
- Gaps between Beam Ends: 5mm min., 100mm max. (0.2 to 3.9 inches)
- Lateral Deflections (y direction) (for 31m span) (101.7 feet)
  - Vehicle Loads: $L/18000$ (1.72mm) (0.067 inches)
  - Thermal: $L/6960$ (4.45mm) (0.175 inches)
- Vertical Deflections (z direction)
  - Vehicle Loads: $L/4800$ (6.45 mm) (0.254 inches)
  - Thermal, (+, rise): $L/6500$ (4.77mm) (0.188 inches)
  - Thermal, (-, fall): $L/8000$ (3.87mm) (0.152 inches)

To maintain the safety and ride comfort criteria for the system, tolerances must be adhered to during manufacture of the beams. These are only a subset of the parameters that are being considered in the design and certification of the steel guideway beams that will be utilized. MAGLEV, Inc. continues to work to formalize the requirements and develop the necessary supporting software and equipment to integrate the manufacturing process for the fabrication of the beams.

### 4.2 Vehicle

The project has been designed for initial operation with a three-section vehicle capable of transporting 344 passengers during peak operating periods. Provisions for a five-section vehicle capable of transporting up to 600 passengers are included in the system design for the stations, maintenance facility and propulsion layout. Vehicle data are shown in Table 3.

<table>
<thead>
<tr>
<th>Comparison Parameter</th>
<th>Pennsylvania Project Transrapid TR08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (End, Mid)</td>
<td>27.0 m (88.6 feet) End section, 24.8 m (81.4 feet) Mid Section</td>
</tr>
<tr>
<td>Width</td>
<td>3.70 m (12.1 feet)</td>
</tr>
<tr>
<td>Height</td>
<td>4.20 m (13.8 feet)</td>
</tr>
<tr>
<td>Total length (3 section)</td>
<td>79.69 m (261.5 feet)</td>
</tr>
<tr>
<td>Vehicle weight (loaded):</td>
<td></td>
</tr>
<tr>
<td>Per section (approx.)</td>
<td></td>
</tr>
<tr>
<td>3 Section train (approx.)</td>
<td>67 t End, 70 t Middle (65.9 ton End, 68.9 ton Middle)</td>
</tr>
<tr>
<td></td>
<td>204 t (200.8 ton)</td>
</tr>
<tr>
<td>Passengers:</td>
<td>Up to 108 End, up to 128 Middle (Seated and standing)</td>
</tr>
<tr>
<td>Per section (End, Middle)</td>
<td>344 (148 seated and 196 standing)</td>
</tr>
<tr>
<td>3 Section train</td>
<td>600 (260 seated and 340 standing)</td>
</tr>
<tr>
<td>5 Section train</td>
<td></td>
</tr>
<tr>
<td>Levitation / Guidance Magnet Locations</td>
<td>Continuous along undercarriage (overlapping to next section)</td>
</tr>
<tr>
<td>Vehicle body configuration</td>
<td>Vehicle wraps around guideway – can not derail</td>
</tr>
<tr>
<td>Suspension</td>
<td>Primary, secondary suspensions</td>
</tr>
<tr>
<td>Guideway loads</td>
<td>Low at 0.7 kg/cm$^2$ (1.54 lb/ 0.39 inch$^2$ (approx. 10% of static loads)</td>
</tr>
</tbody>
</table>

The vehicle design is based on the Transrapid TR08 that is currently at the Transrapid Test Facility in Germany. This is also the basis for the Shanghai project vehicles.

### 4.3 Control System

The operations control center will be located in the maintenance facility complex in the vicinity of the airport. The control system is a communication based signaling system with all vehicle movements controlled and monitored from the operations center. There are no operators onboard the vehicles. Onboard vehicle attendants are however planned for passenger assistance and to monitor vehicle
conditions. The basic dispatcher function typical of train control systems is incorporated into the automatic dispatching software of the control system. The control system ensures safe operation including vehicle spacing, location, switch positions, guideway monitoring, etc. Illustration 11 provides an overview of the current guideway and propulsion layout for the Project.

Illustration 11: Propulsion and Guideway Layout

4.4 Stations

Stations for the Project will provide full functions with amenities. The building complex known as a MAGport® Station will house the maglev passenger station area, parking, passenger amenities and services such as dry cleaning, restaurants and various business and shops. For convenience the MAGport® Stations have been located for connection with bus and other modes allowing for easy transfer.

Starting at the airport terminal the station will be located adjacent to the current ticketing area on the landside of the airport prior to the security check in area. A second airport station will be located approximately two miles southeast of the airport terminal station to serve commuter passengers.

Continuing on to downtown Pittsburgh, a station is located above the Cross Town Boulevard just a short 15-minute walk from major business and employers in the city. This location in the heart of the city is served by moving sidewalks that connect the maglev to the existing light rail and east bus way. Illustration 12 is a conceptual rendering of this downtown station.

Illustration 12: Conceptual Rendering of the Downtown MAGport® Station

Continuing on to the eastern suburbs of Monroeville and Greensburg, stations are located near Thompson Run and in the Greensburg area near the intersection of Toll Road 66 and Route 136. The
Thompson Run area is a brown field development site with more than 500 acres available for future development. The Greensburg station area has similar developable land available.

Station locations have also been planned to accommodate future expansion of the initial system to the east and west.

### 4.5 Operating Plan

The Pennsylvania Project would initially operate with a service frequency of 8.5 minutes (headway) during peak (rush hours) hours and a service frequency of either 10, 15 or 20 minutes during non peak or non rush hours dependent on passenger demand. In the segment from the Monroeville/ Penn Hills area to the Greensburg area, only every third vehicle will travel to Greensburg. This would mean that the peak service at the Toll 66/ Route 136 MAGport® Station would be every 22.5 minutes (3 x 8.5 minutes) and the non peak service frequency would be either 30, 45 or 1 hour dependent on passenger demand.

The system and passenger stations are designed to handle vehicles up to 5-sections in length and peak headways can also be reduced to 7.5 minutes to accommodate future ridership growth. Table 4 provides an overview of the proposed operating plan for the Project while Illustration 13 shows the planned speed profile for environmentally preferred alignment.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Planned Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Hours</td>
<td>18 hours per day passenger service</td>
</tr>
<tr>
<td></td>
<td>(6 AM to 12 AM) week days</td>
</tr>
<tr>
<td></td>
<td>(7 AM to 1 AM) Weekends</td>
</tr>
<tr>
<td>Operating Frequency (Headway)</td>
<td>8.5 minutes (7 vehicles per hour)</td>
</tr>
<tr>
<td></td>
<td>10 minutes (6 vehicles per hour),</td>
</tr>
<tr>
<td></td>
<td>15 minutes (4 per hour) or</td>
</tr>
<tr>
<td></td>
<td>20 minutes (3 per hour)</td>
</tr>
<tr>
<td></td>
<td>Note: Service to Greensburg area only every third vehicle</td>
</tr>
<tr>
<td>Round Trips per Day</td>
<td></td>
</tr>
<tr>
<td>Weekday Airport to Monroeville</td>
<td>235</td>
</tr>
<tr>
<td>Weekend Airport to Monroeville</td>
<td>108</td>
</tr>
<tr>
<td>Weekday Airport to Greensburg</td>
<td>78</td>
</tr>
<tr>
<td>Weekend Airport to Greensburg</td>
<td>36</td>
</tr>
<tr>
<td>Vehicle Capacity – 3 Section Vehicles</td>
<td></td>
</tr>
<tr>
<td>Seated</td>
<td>148</td>
</tr>
<tr>
<td>Seated and Standing capacity</td>
<td>344</td>
</tr>
<tr>
<td>Daily capacity one direction</td>
<td>15,535</td>
</tr>
<tr>
<td>Peak Hour Seated Capacity one direction</td>
<td>1,036</td>
</tr>
<tr>
<td>Peak Hour Total Capacity one direction</td>
<td>2,408</td>
</tr>
<tr>
<td>Vehicle Fleet</td>
<td></td>
</tr>
<tr>
<td>Revenue Vehicles</td>
<td>Eight 3-section vehicles</td>
</tr>
<tr>
<td>Spares</td>
<td>One Spare 3-section vehicle</td>
</tr>
</tbody>
</table>

Table 4: Proposed Operating Plan
5 Manufacturing and Fabrication Requirements

The system must operate smoothly at speeds in excess of 240 mph. The goal is that the passengers, with no seatbelts required, should feel little or no motion during operation. Meeting this stringent requirement requires adherence to:

1) A very strict design criteria for rider comfort that establishes the route curvature feature of the guideway through space, and

2) Meeting very tight manufacturing tolerances.

Precision manufacturing techniques, along with numerical and finite element analyses for each beam are driven by criteria for rider safety and comfort. The resulting final alignment means that each beam will be unique in shape, curvature and camber.

The steel guideway for the project requires over 400,000 tons of plate steel to be produced exclusively in the US. Production of the guideway beams requires a one million square foot facility. The facility must be temperature controlled and will employ a highly skilled work force. The facility will be located in the Pittsburgh area near river with rail and highway access. The transport of raw materials to the facility will be accomplished by motor freight, rail or barge.

Steel guideway beams are fully welded with integrated functional components, lateral guidance rails, and gliding plane. The design of the steel beam largely takes into account automated fabricating processes.

The challenge is to be able to select a guideway beam from an alignment and with various civil, structural, analysis and 3-D modeling programs and run a precision manufacturing plant through the use of a fully integrated software system. This integrated system will drive the cutting, fit-up, robotic welding, precision machining, painting and stator pack installation processes. All is anticipated to be done without the need for normal detail drawings on the shop floor.

To achieve this MAGLEV, Inc. has developed a software integration system called “BEAMSS” (Beams Engineering Analysis Manufacturing Software System)”. This software is knowledge-based
with rules for the manufacturing equipment and material/welding properties. The process includes robotic systems and metrological systems integrated into software control systems and intelligent fabrication systems where sensors are utilized to detect deviation from desired dimensional control. This allows immediate real-time corrections of fabrication processing parameters and thereby assures the completed component meets dimensional design criteria first time without necessitating rework.

Each guideway beam is distinctly different as it follows the ever-changing alignment. This requires using modified mass production processes to produce over 400 tons per day of finished product to meet a 20 beam per week production and construction schedule for the guideway beams that weigh up to 135 tons each. To insure a safe, comfortable, high-speed ride, the fabrication process must provide for dimensional control and produce beams within a 2.0-6.0 mm (0.08-0.24 inch) tolerance range over the control surfaces of the 62-meter beam. Each beam has unique dimensional requirements that entail “built-in” compound horizontal and vertical curves including sinusoidal and clothoidal curves as well as super-elevation and load cambers that must be included in the beam shape.

The geometry of the deck (glide or cover plate) or web plates has been defined for the specific type of beam from the alignment data by using a special computer program. Using a Global Positioning System (GPS) for the master layout, the surveying team supplies the alignment data. The data are transferred to automated Numerical Control (NC) cutting machines to produce all parts. This concept minimizes the need for individual beam drawings; only general beam type drawings are required. The beam is then assembled upside down on an automatic tack and welding table for manual and automated robotic welding. Automated fitting, welding and painting equipment are preprogrammed using the same beam data.

Fixtures hold and control the components of the guidance rails to ensure the overall dimensions and tolerances are maintained. Tolerances are managed by automatically welding the left and right components simultaneously. The lower flange plate of the beam is attached last to allow manual and automated welding access to the inside of the beam. After completion of the underside and inside welding, the beams are turned upright to provide access to the upper surfaces and joints. The completed beam is seal welded to ensure a long-term stable environment inside the beam eliminating the need for internal corrosion protection.

After welding has been completed, the beams undergo a dimensional and quality inspection where the functional surfaces (stator pack areas, guidance rails, gliding surfaces) as well as other important surfaces and dimensions (bearing surfaces, overall dimensions, etc.) are checked and archived for the later machining steps and data storage.

The machining of the beams is completed in the upright position (final installation position) using multi-head, multi-spindle, multi-pass, high speed machining equipment. This work is performed in a temperature-controlled area contiguous to the welding and corrosion protection areas to allow ease of transfer between locations.

The stator pack flange areas are machined to allow a 3-D location tolerance (after welding) of +1.0-4.0 mm (0.039-0.157 inch). The beams are set on a special table and placed in the same shape configuration they will experience on the final substructure. After machining, the tightest tolerances for the machined surfaces are +1 to – 0.1mm. The semi automatic machining equipment has an absolute tolerance of ± 0.1mm.

The beams are then grit blasted clean and painted. The painting process is automated, utilizing programmed robots to insure proper thickness of the coating materials. Temperature and humidity control are required with a curing processes.

Following assembly, the functional surfaces (lower surface of the stator packs, the outer surfaces of the guidance rails, and the gliding surfaces) are checked. Also after each major process step, the completed beams must pass dimensional inspection and quality assurance checks before being shipped to the jobsite.
Production of precision built large curved steel structures is the key to the maglev system. The “pencil thick” magnetic gap (10 mm, 0.375 inches) between the vehicle and the guideway is the controlling tolerance and as the train passes over the length of a football field every second this gap cannot vary by more than the thickness of the pencil’s point (3-4 mm, 0.12-0.16 inches). This high precision system requires an equally precise metrology plan for all aspects of the manufacturing, construction and maintenance.

MAGLEV, Inc. understands this challenge and has developed the tools and technology to meet these requirements. Technologies that will be used include cutting edge coherent laser radar, laser trackers and total stations in addition to planer laser equipment for accurate measurement and monitoring of manufacturing and construction efforts. Field, installation of guideway structures requires the use of ultra-high accuracy Global Positioning System (GPS) techniques. MAGLEV, Inc. has leading edge experience in this unique form of satellite measurement and it is continuing to explore and validate the latest applicable technologies in the industrial metrology field to ensure success and efficiency as the system is built. The required precision raises the bar on steel plate fabrication in the US for large steel plate structures.

6 ENVIRONMENTAL CONSIDERATIONS

The Federal Railroad Administration (FRA) formally announced the preparation of an Environmental Impact Statement (EIS) on July 19, 2001. The Project’s public partner, the Port Authority of Allegheny County with the assistance of PENNDOT, is preparing the EIS for the FRA. Technical support and design services are being provided by MAGLEV, Inc. Cooperating agencies include the FHWA, FAA, USCOE, and the USCG.

For planning and study purposes the project has identified three project sections:
- Section A – Pittsburgh International Airport to downtown Pittsburgh,
- Section B - Downtown Pittsburgh to Monroeville, and
- Section C – Monroeville to Greensburg.

The project has considered twenty-four alternative alignment segments and variations identified as: A1, A2, A3, A4, A5north, A5south, A6option1, A6option2, A6option3, A7, B1, B2, B3, B4east, B4west, C1, C1modified, C2, C2modified, C3, C4north, C4south, C5 and C6. Illustration 1 provides an overview of these alternative alignments.

The project also considered multiple station locations along the alignments including: Airport Landside, Airport Commuter East and West, Airport Radar site, Station Square, Steel Plaza, North Side, Thompson Run, Turnpike Interchange, Monroeville Mall, Greengate Mall and the SR136/66 site plus several other alternatives in the Monroeville area.

Public scoping meetings were held at four locations on October 23, 24, and 30, 2001, and November 1, 2001. In a continuation of the previous consultation and coordination activities with transportation and environmental resources agencies, a special group identified as the Agency Coordination Meeting (ACM) was formed to provide guidance and assistance to the Project through the EIS process. The ACM consists of representatives from the Federal Highway Administration (FHWA), Port Authority of Allegheny County (PAAC), Pennsylvania Department of Transportation (PENNDOT), Federal Aviation Administration (FAA), U.S. Coast Guard (USCG), U.S. Environmental Protection Agency (USEPA), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (USCOE), Pennsylvania Department of Environmental Protection (PADEP), Pennsylvania Game Commission (PGC), Pennsylvania Fish and Boat Commission (PFBC), Pennsylvania Historical and Museum Commission (PHMC), and the Pennsylvania Department of Agriculture. Starting in November 2001 a series of meetings were held with the ACM to provide updates on Project activities, involve them in the environmental process, and to resolve and reach consensus on issues.
The project has also held more than 60 meetings with the public, municipal and public officials, and special interest groups to date. This ongoing public involvement includes a series of five Public Meetings with the first held November 15, 2001 and the most recent April 21, 2003.

The project is currently in the detailed alternatives analysis/pre-Draft EIS phase. Following publication of the Draft EIS a series of Public Hearings is planned. The current schedule is for the Draft EIS released in the fall of 2004 with Public Hearings completed in 2004, the Final EIS will be published in 2005 followed by the Record of Decision (ROD).

7 System Safety

MAGLEV, Inc. continues to work with the FRA, and Volpe Center to support the development of the rules that will be used to access the safety of any US maglev system. Emphasis has been on the advancement of supporting documentation that is in compliance with the proposed new Processor-based Regulatory Rule that was forwarded to the Administrator in 2003 and is scheduled to become law in 2004. In anticipation of new and innovative risk oriented safety assessment methods, the FRA founded the Rail Safety Advisory Committee (RSAC) in 1996. The Positive Train Control (PTC) Working Group of RSAC has developed the draft rule that was submitted for industry and public comment in August 2001 (Notice of Proposed Rule Making, NPRM, Federal Register: August 10, 2001, Volume 66, Number 155, Proposed Rules Page 42351 – 42396).

The Standards for Processor Based Signal and Train Control Systems rule 49 CFR 236 Subpart H is intended to address the risk assessment process for the next generation of train control systems including systems such as maglev. The rule is a performance based standard with the following characteristics.

- Details of system safety implementation are not specified,
- Flexibility is provided to the vendors for the safety implementation
- Utilizes both qualitative and quantitative risk assessment
- Requires that new systems must be proven to be as safe as the system they replace
- Establishes a “Safety Baseline” for comparison

Since there are no maglev systems in the US there are no existing safety baselines for maglev. It is likely the safety baseline for US maglev installations will be established utilizing background from existing high-speed rail systems, the air transport industry or some combination thereof.

Some reasons for developing a performance-based standard include:

- Technology continues to change rapidly
- Specification or prescriptive standards would be required for each new technology implemented
- The FRA (nor any agency for that matter) is not in the position to write specification standards for each new technology (staffing and knowledge base limitations, etc.)
- Specification based standards would become obsolete as technology changes
- Specification based standards could hold back new technology since suppliers would be satisfied to continue to produce the same approved systems. Therefore, safety ultimately would not improve over time.

The rule simply states that new systems must be as safe as the systems they replace. That is:

\[
\text{RISK System Being Deployed} \leq \text{RISK System Being Replaced}
\]
Prior to deploying any new safety critical train control product the system operator and the technology supplier communities must demonstrate the new products safety. This is accomplished through the development and FRA approval of a “Safety Case” document prior to placing the system in service. A Safety Program Plan (SPP, or in the case of maglev, a Maglev Safety Program Plan or MSPP) and a Product Safety Plan (PSP) are to be developed.

The MSPP is a top-level formal document that describes what the maglev operator’s strategic safety processes are for addressing potential hazards and their mitigation and ensuring the products safety.

The MSPP includes:
- Complete description of the methods to evaluate a systems behavioral characteristics
- Complete description of the risk assessment procedures
- Identification of the safety assessment processes
- The system safety precedence to be followed (i.e. design in, reduce, warn or educate/ train)

The Pennsylvania Project intends to be Processor-based Rule compliant. Risk will be assessed from both a qualitative and a quantitative risk basis and the MSPP strategy will be implemented through the use of a PSP that must be prepared for each safety critical product as described in § 236.905 of the Processor-based Rule.

The Product Safety Plan is more detailed and must be approved by the FRA prior to any new product deployment (180 days in advance). It documents:
- How the product is (intended) to be used
- How the product meets the safety requirements
- A hazard log
- A risk assessment (both qualitative and quantitative)
- In-service requirements
- A single or specific application
- The operation, testing and maintenance standards, as well as the risk assessment requirements

The operator in conjunction with the technology supplier develops the PSP to include:
1. Maglev product description (general and physical description)
2. Operational concepts documentation (current and planned)
3. Maglev product operational concepts (functionality, information flow, etc.)
4. Safety requirements documentation (requirements for safe operation)
5. Maglev product system architecture (how the architecture satisfies safety)
6. Hazard Log (hazards identification and risk level)
7. Risk assessment requirements (quantitative analysis, hardware, software, human-machine interface)
8. Hazard mitigation analysis (eliminate, mitigate or control measures)
9. Validation and verification process (testing)
10. Safety assurance concepts (safety implementation)
11. Human factors analysis (human-machine interface)
12. Training requirements
13. Test procedures and equipment
14. Part 236 rules and regulations (what applies and what does not apply)
15. Security of safety critical systems/subsystems/components
16. Warnings and warning labels
17. Implementation testing (factory and field testing)
18. Post implementation validation testing and monitoring
19. Safety critical assumptions
20. Incremental and predefined changes (planned and future)

Illustration 14 provides a block diagram showing the basic FRA submission and approval process that will be required for a US maglev project to be processor-based rule compliant.

In developing the quantitative portion of the maglev risk assessment, the project intends to utilize a tool set that has been developed to be processor-based rule compliant. The Axiomatic Safety Critical Assessment Process (ASCAP) is a Monte Carlo risk assessment methodology. ASCAP determines the Mean-Time-to-Hazardous Event (MTTHE) of the system, subsystems and components through a dynamic simulation process. The simulation is based on millions of vehicle miles traveled and defines the risk in terms of a quantified accident risk exposure and translates it into societal cost.

ASCAP takes into consideration:
- The route layout
- The operating rules
- The dispatcher safety critical behavior
- The vehicle/maintenance crew safety critical behavior
- The guideway
- The vehicles
- The switches
- The control system

Being Processor-based Rule compliant on a systems basis should permit the FRA to utilize the maglev safety documents (MSPP and PSP) to provide clear and convincing evidence that the Pennsylvania Project is as safe relative to the existing product baseline. (high speed rail and/or air transport).

8 Operations and Maintenance

The system maintenance facility includes a multi-story operations and maintenance building with employee parking, maintenance vehicle parking/storage, open-air vehicle storage, guideway, switches, and transfer table required to maintain the system and deploy the vehicles and maintenance equipment.
The facility will also house a visitor’s center, the operations control center and the maintenance as well as various administrative offices. The maintenance center will initially provide for three all weather coverage bays for servicing up to a five-section vehicle with expansion capability to five bays.

The maintenance / operations control facility is anticipated to be one of the first structures to be constructed. It would serve as the main facility for the operations control center and will be utilized to initiate the certification of the entire system. Construction and outfitting, and operational verification of the facility would provide an initial evaluation platform for early assessment of the overall system performance of the system.

9 Ridership

The ridership demand estimate for the Pennsylvania Project was developed over multiple years and has included the use of two extensive and independent stated preference surveys that were administered in the corridor that the maglev system will serve. Two separate models and two studies were developed with the methodology and results of second ridership study serving as the basis for the project ridership

The total estimated average weekday ridership demand is 47,449 in year 2008 and 54,935 (in year 2026). Annual ridership demand is projected to be approximately 14,234,700 one-way trips in 2008 and 16,480,500 one-way trips in 2026. Assuming most riders would take round trips, this equates to approximately 23,725 people in 2008 and 27,468 people in 2026 using the system on a daily basis.

Indications are that many trips would be taken on the maglev system. Maglev would provide significant timesavings in the congested east-west corridor through the Pittsburgh region. The forecast also confirms that transit access to the Steel Plaza station and infrastructure improvements for improved automobile access to all other stations would be needed to support this ridership. The infrastructure improvements associated with park and ride lots have been included in the overall project costs and environmental impacts for the system.

The maglev corridor trips represent the auto and transit trips in the corridor that the maglev system would serve. The total maglev eligible corridor trips represent approximately 2.5 percent of all the trips occurring within the region. Illustration 15 and Illustration 16 show that maglev would serve 0.63 percent of all trips in the region and 25.0 percent of the trips within the maglev corridor.

Illustration 15: Trip Distribution within the Region
With implementation of the maglev system, there would be a shift of persons who previously traveled via auto or transit, shifting their travel to the maglev mode. The ridership demand estimates indicate that maglev will attract many people out of their cars to make their trip via maglev.

Illustration 17 shows the majority of the diversion to maglev (80.6%) is projected to be from the auto market, with 16.7% diverted from existing transit and 2.7% induced trips.

The characteristics of the year 2008 ridership estimate by trip purpose is also shown in Illustration 18 that identifies that 58.6% of the maglev trips are associated with work related trips, 32.1% are associated with non-work (social, leisure/recreational) trips, 4.6% are air business trips and 4.7% are air non-business trips.
10 Conclusions

The Pennsylvania Project is positioned to deploy the first high speed maglev system in the US. The challenges of the project in the areas of construction, design, fabrication, installation, safety and system certification are being addressed. Project benefits in the form of improved quality of life, reduced travel times, development opportunities and jobs in the areas of guideway fabrication, system operation and maintenance, construction and engineering will place Pennsylvania in the forefront.

Pittsburgh is the ideal location to demonstrate the feasibility of deployment of maglev in the USA. It is the ideal hub that connects a new high-speed maglev network with the most populous region of the country.

Pittsburgh offers a central location from which to expand by reaching across the state and into neighboring states. Pittsburgh's international airport is only a one-hour flight from fifty one percent of the total population of the U.S.A. and occupies a central location between the populous Northeast and Midwest, which comprises 70 percent of the potential high-speed maglev market. It is strategically located about halfway between New York and Chicago.

As shown in Illustration 19 future expansion of a Pittsburgh to Philadelphia maglev corridor will create an important high-speed transportation link from the Northeast to the Midwest.

Illustration 19: Maglev Vision