

IMPLEMENTATION OF THE PENNSYLVANIA HIGH SPEED MAGLEV PROJECT

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Implementation of the Pennsylvania High Speed Maglev Project

ABSTRACT

With the advent of the first commercial deployment of the Transrapid maglev in China, the technology has evolved from the demonstration stage to an emerging new and promising alternative. Multiple high-speed maglev projects are proposed that will represent the first commercial deployment in the U.S.

This paper discusses the implementation plans for the Pennsylvania High Speed Maglev Project. Pennsylvania's rolling terrain, rivers and geographic features provide multiple challenges to the technology supplier and for fabrication, construction and installation of the guideway system.

The Pennsylvania Project is developing an Environmental Impact Statement (EIS) with various alignment alternatives having been identified and studied. Alignments, EIS, planned construction techniques, project costs, operating plan, safety methodology, support facilities, and advanced manufacturing and fabrication required to meet the guideway and rider comfort requirements are discussed.

The paper concludes with a discussion on the implementation plans and overall benefits of the project.

1. INTRODUCTION

The Federal Railroad Administration (FRA) has proposed deployment of a high-speed transportation system using maglev technology. The purpose of this action is to promote development and construction of alternative transportation systems in the US, employing magnetic levitation technology capable of safe use by the public at speeds in excess of 386 kilometers per hour (240 miles per hour). Maglev 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). The legislation identifies federal funding of \$950 million for the deployment of the first US high-speed maglev system. This legislation is scheduled to expire in 2003 and will be replaced by new legislation as part of the transportation and infrastructure planning for the country.

Studies have been conducted for the deployment of maglev in the states of California, Florida, Georgia, New Orleans, Maryland, Nevada, and Pennsylvania with Project Descriptions submitted to the FRA in June 2000. Following review of the descriptions, the FRA currently is sponsoring studies in both Pennsylvania and Maryland with the objective of funding one or more projects.

The Pennsylvania Project includes the guideway, vehicles, passenger stations, maintenance and operation control facilities and related infrastructure to support the system.

Planning for the 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) in cooperation with the Pennsylvania Department of Transportation (PENNDOT).

The Project will utilize the maglev technology of Transrapid International that has been in development in Germany for more than 20 years and was recently deployed in Shanghai, China as a 31-kilometer (19 mile) system. During the December 31, 2002 inaugural run, speeds of 434 kilometers per hour (270 miles per hour) were achieved.

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. The east/west corridor the system will serve is highly congested with no light rail or other rail or transit services available. The Project provides an alternative to the region's most highly congested highway, I-376. Current travel times from the airport to downtown range from 25 minutes to more than 45 minutes. Travel times from Greensburg to the airport are 45 to 60 minutes non rush hour and 75 to 90 minutes during rush hours. Travel times are primarily impacted by 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 are at capacity and remain congested through the day.

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 and an average speed of approximately 160 kilometers per hour (100 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 2 miles from the air terminal. The downtown Pittsburgh station will be located within a 15 minute walking distance from major businesses and employers. Suburban and rural stations in Monroeville and Greensburg complete the system.

The basic operating features are summarized in Table 1.

3. CHALLENGES

The Project area is part of the Appalachian Plateaus Province consisting 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 slope exist 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 roadways and other forms of transportation in the area. The maglev represents an effective alternative solution to the congested east/west corridor. The Project will serve as an ideal example for the implementation of high-speed maglev in the US by demonstrating performance under varied terrain and climatic conditions as well as the advanced guideway fabrication and construction techniques described later.

4. TECHNOLOGY AND IMPLEMENTATION

Multiple technical challenges exist with the implementation of the system. One significant challenge 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 beams that can meet the rider comfort criteria for the system.

4.1 Guideway Beams

The various guideway beam types are shown in Figure 1. The Project's primary guideway structure will be the Type-I, 62-meter (203 feet) long beam. The Transrapid system design parameters set the limits on manufacturing processes and equipment that must be utilized to construct the beams.

There are two main factors that influence the geometry of the guideway:

- (1) The design variations in the alignment (horizontal plane) and profile (vertical plane), which consist of sections of tangents and curves, and
- (2) Deviations from the design that arise from manufacturing and installation imperfections, structural flexing as the guideway is subjected to load, structural expansion/ contraction from thermal effects, and degradation of 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 outside the design limits can reduce the ride quality of the system.

The guideway system design provides data directly to the manufacturing process as well as to 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 are able to be manufactured in a mass production environment.

The guideway/alignment parameters are identified in Table 2.

Additional guideway beam criteria include the beam design requirements that are driven by the deflection criteria for the system. Beam design includes definition of:

- 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
- Certification of design

The guideway boundary requirements are defined as:

- Longitudinal Jerk: $\leq 1.0\text{m/s}^3$
- Lateral Jerk: $\leq 0.5\text{m/s}^3$
- Longitudinal Acceleration: $\leq 1.5\text{m/s}^2$
- Free Lateral Acceleration: $\leq 1.5\text{m/s}^2$
- 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: 5 to 100mm (0.2 to 3.9 inches)
- Lateral deflections (y direction 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 for the system, tolerances must be adhered to during manufacture of the beams.

Many additional parameters are being considered in the design and certification of the steel guideway beams for the Project. MAGLEV, Inc. continues to formalize the requirements and develop the necessary software and equipment to integrate the manufacturing process for the fabrication of the beams.

4.2 Vehicle

Initial Project operation will utilize a three-section vehicle capable of transporting 422 passengers during peak operating periods (70% or 295 seated). Provisions for a five-section vehicle capable of transporting up to 722 passengers is included in the design of the stations, maintenance facility and propulsion layout.

The vehicles are based on the Transrapid TR08 that is currently at the Transrapid Test Facility in Germany. This vehicle is also the basis for the Shanghai project. The vehicle data are identified in Table 3.

4.3 Control System

The operations control center is located in the maintenance facility complex near 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 onboard operators. Vehicle attendants provide passenger assistance and monitor operating conditions. The dispatcher functions typical of train control systems are incorporated into the automatic software of the control system. The system ensures safe operation including vehicle movements, spacing, location, switch positions, guideway monitoring, etc.

The safety approval of this fully automated system will be the responsibility of the FRA and is discussed later.

4.4 Stations

The building complex known as a MAGport® Station houses the passenger station area, parking, amenities and services such as dry cleaning, restaurants and various business and shops. For convenience the stations are located for easy connection with bus and other transportation modes.

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

Continuing to downtown Pittsburgh, a station is located just a 15-minute walk from major business and employers in the city. The station is connected by moving sidewalks to the existing light rail and the east bus way.

Continuing on to the eastern suburbs of Monroeville and Greensburg, stations are located near Thompson Run and Greensburg 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 development. The Greensburg station area has similar developable land available.

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

4.5 Operating Plan

The system will initially operate as a high-speed regional connector. The guideway configuration and operating plan includes dual guideway from the airport to Monroeville and single guideway from Monroeville to Greensburg. The basic operation is for 18-hours/day with a reduced operating frequency for weekends and holidays. Vehicle headway during peak hours will be 7.5 minutes with off peak operation at either 10 or 15 minutes. With single guideway between Monroeville and Greensburg, every third vehicle serves Greensburg. Dwell times are planned for one-minute at the intermediate stations and longer at the airport and Greensburg.

5. MANUFACTURING AND FABRICATION

The goal is for the system to operate at speeds of 240 mph without seatbelts and the passenger should feel little or no motion during operation. Meeting this stringent requirement necessitates adherence to:

- Very strict design criteria for rider comfort that establishes the route curvature features of the guideway through space, and
- Very tight manufacturing tolerances.

Precision manufacturing techniques, combined with numerical and finite element analysis for each beam are driven by criteria for rider safety and comfort. The result means that each beam is unique in shape, curvature and camber.

The guideway for the Project requires over 300,000 tons of plate steel to be produced in the US. Production of the beams requires a new, one million square foot, temperature controlled facility with a highly skilled work force. The facility will be located near river with rail and highway access so that raw materials can be transported to facility by motor freight, rail and/or barge.

The Project will utilize the Type I, II and III beam designs, certified by the German Government.

The Type I is a two-span continuous steel guideway beam consisting of a trapezoidal box approximately 2m (6.56 feet) deep and 61.92m (203.14 feet) long with support span lengths of 30.96m (101.57 feet).

The Type II is a two-span continuous steel guideway beam consisting of a trapezoidal box approximately 1m (3.28 feet) deep and 24.768m (81.26 feet) long with support span lengths of 12.384m (40.63 feet).

A Type III is a continuous span steel guideway beam having a length of 6.192m (20.34 feet) consisting of three support lengths spaced at 2.752m (9.03 feet) and is approximately 1.4m (4.59 feet) in height.

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

The challenge is to select a guideway beam from the alignment and with various civil, structural, analysis and 3-D modeling programs, run a precision manufacturing plant by the use of an integrated software system. This

integrated system drives the cutting, fit-up, robotic welding, precision machining, painting and stator installation processes. All this must be done without the need for detail drawings on the shop floor.

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 to assure the completed component meets dimension without rework.

Each beam is slightly 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 guideway beams that weigh 135 tons each. To insure a safe, comfortable, high-speed ride, the fabrication process must provide for dimensional control for beams with a 2 to 6mm (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 or web plates is defined for the specific type of beam from the alignment data by using a special computer program. Using a Global Positioning System (GPS) the surveying team supplies the alignment data. The data is transferred to Numerical Control (NC) cutting machines to produce all parts. This 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 is 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 guidance rails 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 beam is welded tight to ensure a long-term stable environment inside the beam.

After welding is completed, the beams undergo 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 machining 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 adjacent to the welding and corrosion protection areas to allow ease of transfer between locations.

The stator flange areas are machined to allow a 3-D location tolerance (after welding) of +1 to -4mm (0.039-0.157 inch). The beams are set on a special table and placed in the same configuration they will experience on the final substructure. After machining, the tightest tolerances for the machined surfaces are +1.0 to -0.1mm.

Beams are then blasted and painted. The painting process is automated utilizing programmed robots to insure proper thickness of the coating and includes temperature/humidity control and a curing process.

After each major process, the beams must pass dimensional inspection and quality checks before shipment to the jobsite. Following assembly, the functional surfaces (lower surface of the stator packs, the outer surfaces of the guidance rails, and the gliding surfaces) are re-checked prior to shipping.

Precision built large curved steel structures is the key. The pencil thick magnetic gap between the vehicle and the guideway is the controlling tolerance. As the vehicle passes over the length of a football field every second, this gap cannot vary by more than the pencil's point. 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 tools and technology to meet these requirements. This includes cutting edge coherent laser radar, laser trackers and total stations in addition to planer lasers for accurate measurement and monitoring of manufacturing and construction. Field, installation of guideway structures requires the use of ultra-high accuracy GPS techniques. MAGLEV, Inc. has leading edge experience in this form of satellite measurement and we are continuing to explore and validate the latest applicable technologies in the industrial metrology field to ensure the success and efficiency of the system. The required precision raises the bar on steel plate fabrication in the US for large steel plate structures.

6. CONSTRUCTION/INSTALLATION

The maglev system demands a significantly difference approach to fabrication and construction of the guideway and supporting substructures. The Project requires building a 54-mile long linear motor, one on each side of each guideway. Tolerances required are extremely tight, and must be met to guarantee performance. Since fabrication and construction are inexplicably connected, this calls for a re-evaluation of the techniques from beginning to end. This connection is created by the design for the basic electric motor and control system along an alignment in the field, driven by ride comfort criteria.

Typical construction processes used in Germany and China for column and beam setting involved building a construction road along the alignment. This method is costly and has potentially environmental impacts. Project objectives include the development of column construction and beam installation methods that do not require permanent construction roads. This requires an evaluation of all disciplines and techniques for construction and transport in and outside of the traditional highway and bridge construction industry. The Type I beams will be the primary beams used. Other beams and lengths will be used, but are shorter and lighter. Transporting a 62m beam to the construction sites poses many challenges. The Project 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.

Truck/trailer transport is also required at various locations. Specialized multi axle flat bed trailers with trailing dollies and support cradles are available to transport the beams from the fabrication facility to the construction sites.

Railroads and rivers along much of the alignment make movement by rail or barge a preferred method. Transport of guideway beams will utilize special highway transport trailers, and rail cars where applicable. Standard double crane setting procedures will also be used.

Due to the varying terrain, existing structures, and remote access, most beams however will be erected with girder launching equipment. The concept involves a launcher that travels on the guideway. The launcher can place two beams at a time and advances by traveling on the previously placed beams. To feed the launcher, two beams are lifted by cranes and placed on a cart at a staging area. The self-propelled cart moves along the guideway to the launch position. Launching equipment will be designed and fabricated to meet the specific needs of the Project including curves and grades. Theoretically all girders could be placed with one launcher and the cart but schedule considerations necessitate multiple carts and launchers.

Another method for construction of columns and beams is the use of tow balloons to position column drilling platforms and equipment. This process is being developed for gas pipeline construction in Canada.

Maglev is not a highway construction project. Balancing of cuts and fills is not probable, since construction requires no significant fill. Removal of cut materials becomes paramount. The availability of open areas for trucks to move material will not exist. Material movement via conveyors and off road vehicles similar to rough terrain quarry vehicles will be employed. Movement of excess earth by rail cars to other construction projects will also be employed.

The elevated guideway substructures are made of reinforced concrete and are constructed on site using conventional 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.

Geologic conditions along the alignments require a variety of suitable foundations. Maglev shares similar criteria that affect the design of highway and railroad structures, which can tolerate little settlement. However, highway and railroads 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. Depths to bedrock from the support base below the pylons will vary. The appropriate foundation type depends primarily on bedrock, and, to a lesser extent, groundwater depth. Typical foundation types include:

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

Close tolerance GPS will be used in setting the columns and guideway. The tolerance range is 3mm (0.12 inches). “Millwright GPS” techniques have been used on other projects and are proven in setting items within one millimeter horizontally and three millimeters vertically over four kilometers.

The pier height for the guideway system is driven by safety guidelines and has been set at a minimum height to the underside of the beam of 5m (16.4 feet). In isolated locations piers could be up to 25m (82 feet). Typical maximum column height for Type I beams is 20m (65 feet). Secondary bridge structures may also be required to support Type III guideway for heights over 25m. Secondary bridge structures are also utilized for crossings, pier heights over 25m and applications where it’s impractical to achieve Type I or Type II beam pier placements in within the system requirements of 6.2m increments. Deflection designs for these structures must limit the supported guideway deflection to $L/4800$.

7. SYSTEM COST

Costs for the Project have been developed based on Transrapid costing for the Hamburg to Berlin project and modified per the Shanghai project and MAGLEV, Inc.’s multiyear background and experience with the supplier and system requirements.

Table 4 provides an overview of the cost. In addition to the maglev system, the Project includes various roadway/local infrastructure improvements.

Capital costs including infrastructure improvements on a per mile basis are approximately \$64 million per mile or approximately \$54 million per mile for infrastructure cost alone. Final cost estimates will include an independent cost and risk analysis under development.

8. SYSTEM SAFETY

MAGLEV, Inc. continues to work with the FRA, and Volpe to support development of rules that will be used to access the safety of US maglev systems. Emphasis has been on the advancement of supporting documentation that is compliant with the proposed Processor-based Regulatory Rule that is scheduled to be forwarded to the Administrator in 2003.

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 developed a 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, 49 CFR 236 Subpart H, addresses the risk assessment process for the next generation of train control including maglev. The rule is a performance based standard with the following characteristics.

- Details of safety implementation are not specified,
- Flexibility is provided to the vendors for the safety implementation
- Utilizes both qualitative and quantitative risk assessment

- Requires new systems must be proven to be as safe as the systems they replace
- Establishes a “Safety Baseline” for comparison

No baseline exists for maglev. The safety baseline for US maglev installations will likely be established from high-speed rail, the air transport industry or some combination thereof.

Reasons for a performance-based standard include:

- Technology changes rapidly
- Specification or prescriptive standards would be required for each new technology
- The FRA (nor any agency for that matter) is not in the position to write specific 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 likely continue to supply approved systems. Therefore, safety ultimately would not improve over time.

The Processor-based rule states that new systems must be proven to be as safe as the systems they replace. That is:

$$\text{RISK}_{\text{System Being Deployed}} \leq \text{RISK}_{\text{System Being Replaced}}$$

Prior to deploying any new safety-critical train control product the operator and the technology supplier communities must demonstrate the new products safety. This is accomplished prior to placing the system in service through the development and FRA approval, of a “Safety Case” document. A Safety Program Plan (SPP, or for maglev, a Maglev Safety Program Plan, MSPP) and a Product Safety Plan (PSP) are to be developed.

The MSPP is top-level formal document describing what the operator’s strategic safety processes are for addressing potential hazards and their mitigation to ensure product safety.

The MSPP includes the:

- Description of the methods to evaluate a systems behavioral characteristics
- Description of the risk assessment procedures
- Identification of the safety assessment processes
- 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 a qualitative and a quantitative basis and the MSPP strategy will be implemented through the use of a PSP prepared for each safety critical product as described in § 236.905 of the Processor-based Rule.

The PSP is more detailed and 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
- The specific application
- Addresses the operation, testing and maintenance standards, as well as the risk assessment requirements

The operator in conjunction with the technology supplier must develop 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)

In developing the quantitative portion of the maglev risk assessment, the Project intends to utilize a tool set developed to be 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. 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:

- Route/alignment
- Operating rules
- Dispatcher safety critical behavior
- Vehicle/ maintenance crew safety critical behavior
- Guideway
- Vehicles
- Switches
- Control system

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

9. ENVIRONMENTAL

The FRA announced the preparation of an Environmental Impact Statement (EIS) on July 19, 2001. The Project's public partner, the PAAC with the assistance of PENNDOT, is preparing the EIS for the FRA. Technical support and design services are provided by MAGLEV, Inc. Cooperating agencies include the Federal Highway Administration (FHWA), Federal Aviation Administration (FAA), U.S. Army Corps of Engineers (USCOE), and U.S. Coast Guard (USCG).

For planning and study purposes the Project identified three sections:

- Section A – Pittsburgh International Airport to downtown Pittsburgh,
- Section B - Pittsburgh to Monroeville, and
- Section C – Monroeville to Greensburg.

Twenty-four alternative alignment segments and variations were considered and are identified in Figures 2,3, and 4 that provide an overview of the alternative alignments. More than twelve alternative station locations were also considered.

Four public scoping meetings were held in October/November 2001. Continuing 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 for the EIS process. The ACM consists of representatives from FHWA, PAAC, PENNDOT, FAA, USCG, U.S. Environmental Protection Agency (USEPA), U.S. Fish and Wildlife Service (USFWS), (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. Meetings are held with the ACM to provide updates, involve them in the environmental process, and to resolve/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 five Public Meetings.

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 release late 2003/2004 with Public Hearings 1st quarter 2004, the Final EIS late 2nd quarter/early 3rd quarter 2004 followed by the Record of Decision 3rd quarter 2004.

10. 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, maintenance and 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 of the facility will provide operational verification and an initial evaluation platform for early assessment of the overall system.

11. 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. The project has independent utility with the long-term vision to expand the system so it becomes part of a larger intrastate and interstate transportation system. The Pennsylvania Project will serve as the basis for future maglev installations throughout the US and provides an excellent example of the capabilities of the technology and the advanced construction and fabrication techniques that will be used during deployment.

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TABLE 1 Pennsylvania Project Operating And Implementation Features

<u>ITEM</u>	<u>IMPLEMENTATION OR FEATURE</u>
Distance	~ 54.4 Miles (87.6 km) - Mainline
Airport to Downtown	~ 17.6 miles dual guideway (~10 minutes)
Downtown to Monroeville	~ 17.5 miles dual guideway (~11minutes)
Monroeville to Greensburg	~ 19.3 miles single guideway (~10 minutes)
Trip Time	~ 35 Minutes (including stops)
Peak Headway	7.5 - 8.0 minutes (5 minutes with propulsion upgrade)
Non-Peak Headway	10 - 15 minutes based on demand
Dwell Time	1- 2 minutes
MAGPort® Stations	Five (Split station at Airport)
Fare	\$15 for 54 Miles (\$5 / segment)
One-way passenger trips	66,000 one way trips per day (Under refinement)
Vehicle Sets	8x3 Sections initial (Designed for 5 section)
Passengers/ Vehicle	422 (3 section), 722 (5 section), (70% seated)
Maximum Grade	6 - 8 Percent (Dependent on alignment)
Hours of Operation	18 hrs/ day
Max. Speed, Average. Speed	244 mph, 100 mph (393 km/h, 161 km/h)
Guideway Configuration	Dual Dedicated-35.1 miles, Single-19.3 miles
Number of Substations	4
Operations & Maintenance Facility	1
Major River Crossings	1
Million Vehicle Miles/ yr.	3.45
Guideway	Primarily 62 meter, Steel, 96% Elevated
Operational Start	2008 (Airport to Downtown segment)

TABLE 2 Transrapid Guideway/ Alignment Parameters

Characteristic	Range	Criterion for Maximum Value
Cant (Super elevation)		
▪ Outside of stopping areas	≤ 12°, In special cases up to 16° *	Required for alignment
▪ At stopping areas	≤ 12°	Evacuation possibility
▪ At station platforms	≤ 3.0°	Wheelchair and Passenger access/ egress
▪ Torsion	≤ 0.10°/m, In special cases up to 0.15°/m *	Kinematics of the vehicle
Longitudinal inclination or longitudinal inclination angle		
▪ Outside of stopping areas	≤ 10% or 5.71°	Required for alignment
▪ Within stopping areas in areas in which standing vehicles are to be protected against unintended movements		
▪ At station platforms, as well as in parking areas and at stopping areas, if dealing with ice	▪ ≤ 0.5% or 0.29°	▪ Reliable holding brake function
▪ Horizontal radii (curves)**	≥ 350 m	Kinematics of the vehicle
▪ Vertical radii (crest, sag)**	≥ 530 m	Kinematics of the vehicle
Transverse and vertical jerk		
▪ In the area of entry routes to cities	≤ 1 m/s ³	Rider Comfort
▪ Outside of entry routes to cities	≤ 0.5 m/s ³	Rider Comfort
▪ On switches during turn-out	≤ 2 m/s ³	Rider Comfort
▪ Superposition of horizontal radii and vertical radii***	$\text{R}_{xz} \text{ criterion: } \frac{1}{R_{xz}} = \frac{\cos\alpha}{R_v} - \frac{\sin\alpha \cdot \cos^2\beta}{R_H}$	

β Longitudinal inclination angle

α Amount of transverse slope

R_H Amount of the horizontal radius

R_V Vertical radius (positive for a crest / negative for a sag)

* Transverse slope > 12 ° and torsion > 0.10 °/m only at compulsory points of the alignment, after checking and authorization in every individual case.

** Within, and outside of, stopping areas

*** The R_{xz} criterion is to be observed when there is a superposition of vertical curvature with horizontal curvature; according to this criterion, the three-dimensional radius resulting from R, H, α and β may not drop below a minimum value in the xz plane due to vehicle-design circumstances. In areas with torsion, the freedom of z-movement of the vehicle, based on the limits of the free ranges of the springs of the secondary spring system of the superstructure, is to be taken into consideration.

TABLE 3 Vehicle Data

Comparison Parameter	Pennsylvania Project Transrapid TR08
Vehicle:	
Length (End, Mid)	27.0 m (88.6 feet) End section, 24.8 m (81.4 feet) Mid Section
Width	3.70 m (12.1 feet)
Height	4.20 m (13.8 feet)
Number of sections	3
Total length	79.69 m (261.5 feet)
Vehicle weight (loaded):	
Per section (approx.)	67 t End, 70 t Middle (65.9 ton End, 68.9 ton Middle)
3 Section train (approx.)	204 t (200.8 ton)
Passengers:	
Per section (End, Middle)	Up to 136 End, up to 150 Middle (70% seated)
3 Section train	422 (70% seated)
5 Section train	722 (70% seated)
Levitation / Guidance Magnet Locations	Continuous along undercarriage (overlapping to next section)
Vehicle body configuration	Vehicle wraps around guideway – can not derail
Suspension	Primary, secondary suspensions
Guideway loads	Low at 0.7 kg/cm ² (1.54 lb/ 0.39 inch ²) (approx. 10% of static loads)

TABLE 4 Estimated Capital Cost

Component	Total Cost (Millions)
Stations Maintenance Facility and Infrastructure	\$ 595.76
Substructure, Superstructure, special Structures (Foundations, piers, mine subsidence, guideway, switches, etc.)	\$ 1,727.88
Guideway Equipment (Propulsion, energy supply and communications/ control)	\$ 330.94
Earthwork and Utility Relocations	\$ 150.83
TOTAL INFRASTRUCTURE COST	\$ 2,805.41*
Engineering	\$ 280.54
Environmental Mitigation and Commitments	\$ 62.50
Vehicles	\$ 208.80
Right of Way	\$ 201.31
Project Management, Construction Management and other Costs	\$ 106.76
TOTAL COST	\$ 3,665.32*

* Includes maintenance alignment of approximately 3 miles

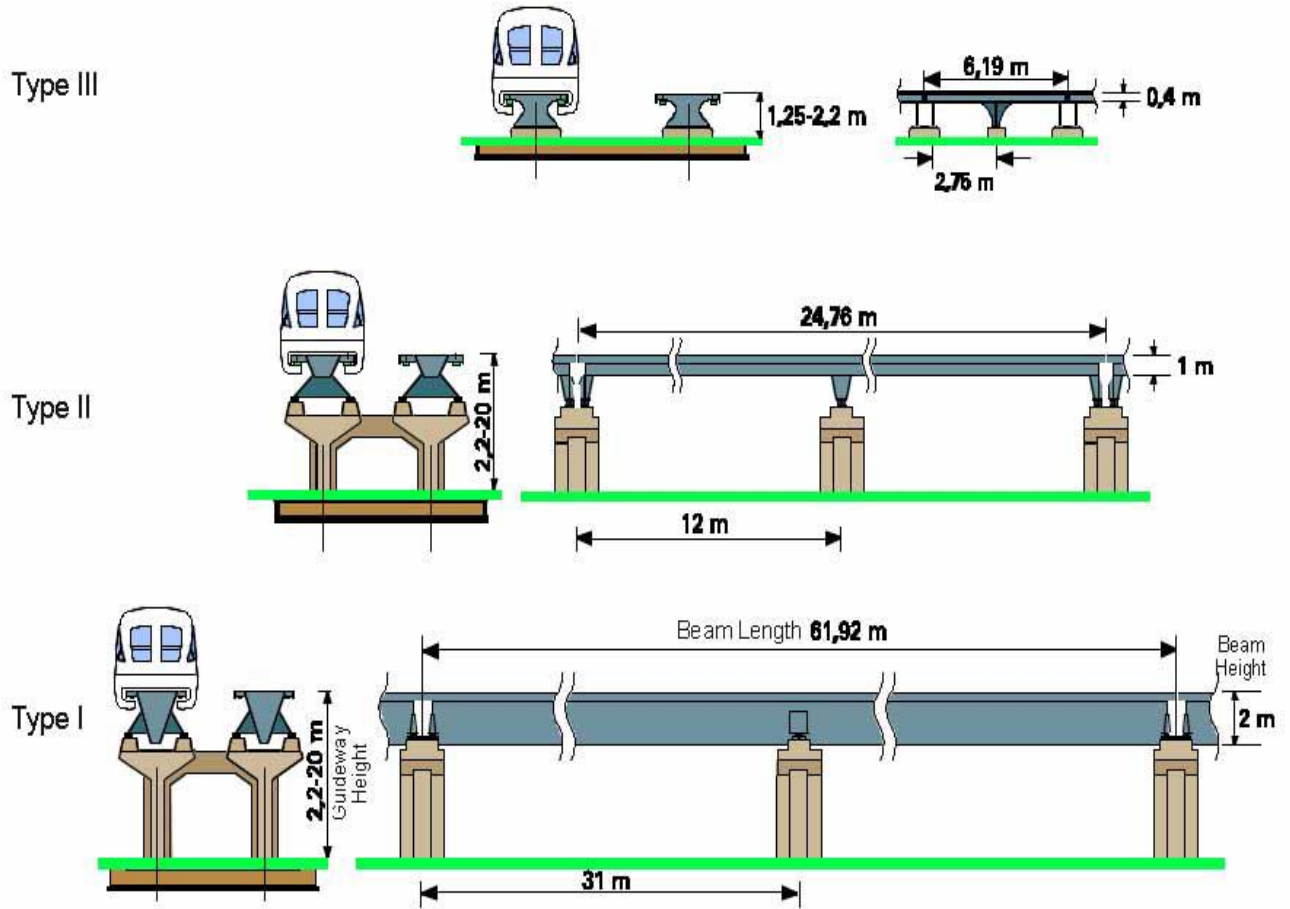


FIGURE 1 Guideway Beam Types



FIGURE 2 “A” Segment Alignment Alternatives (Airport to Downtown)

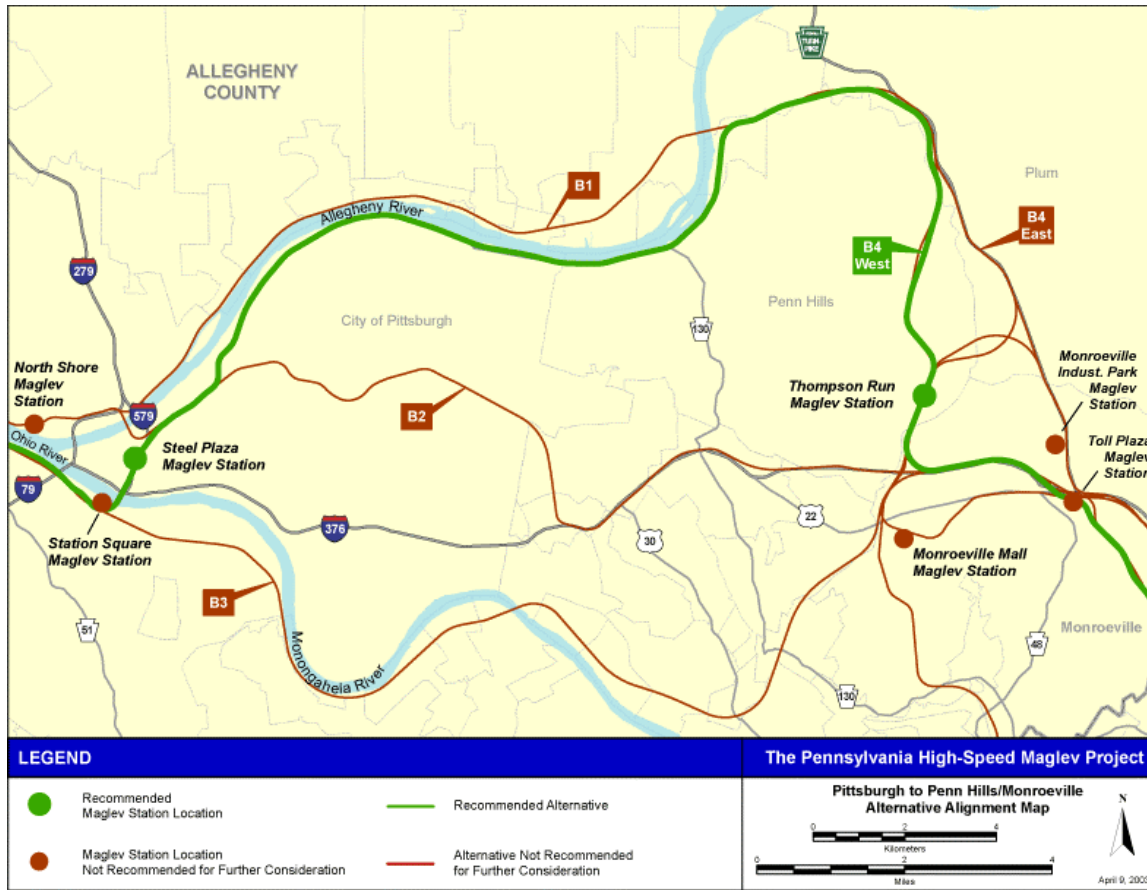


FIGURE 3 “B” Segment Alignment Alternatives (Downtown to Monroeville)

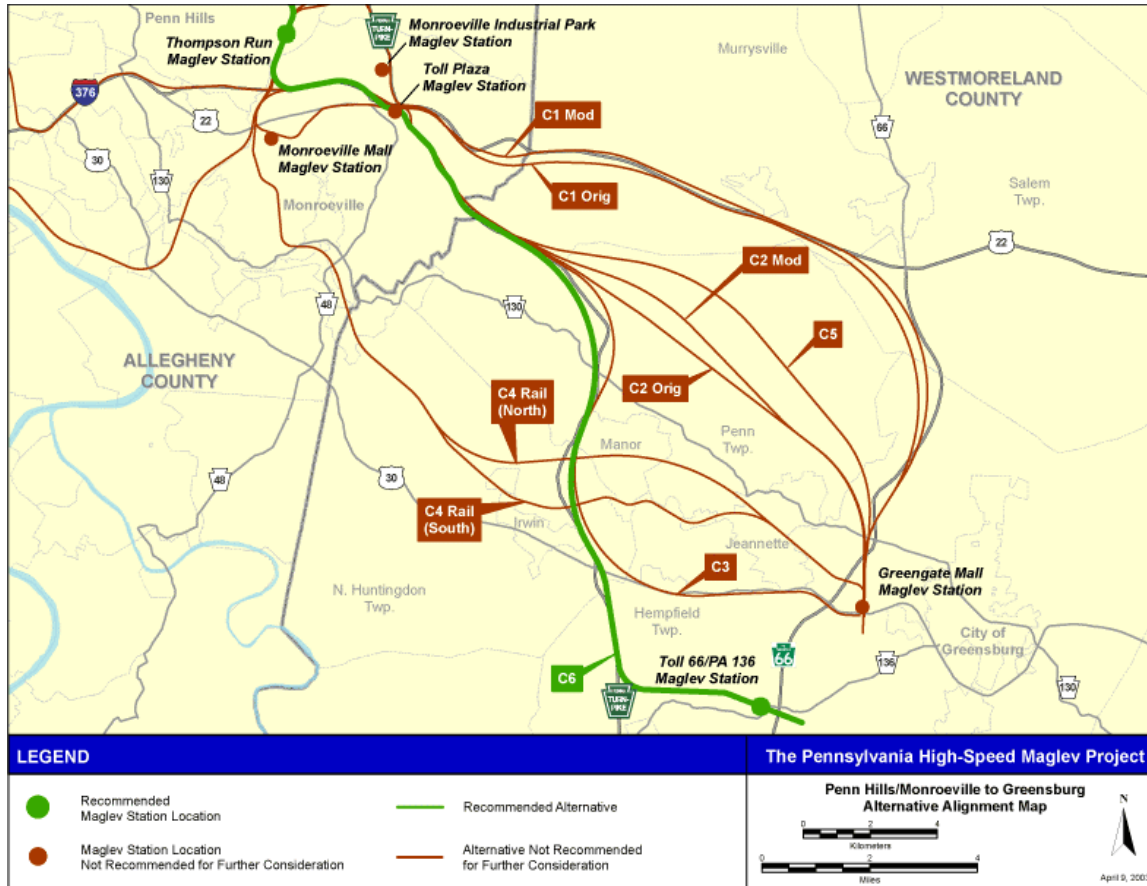


FIGURE 4 “C” Segment Alternative Alignments (Monroeville to Greensburg)