

# California University of Pennsylvania (CALU) – Maglev Sky Shuttle

No. 119

Thomas E. Riester, P.E.

*Mackin Engineering Company, RIDC Park West, 117 Industry Drive, Pittsburgh, PA 15275*

[riester@mackinengineering.com](mailto:riester@mackinengineering.com)

Dr. Allan Golden

*California University of Pennsylvania, 250 University Avenue, California, PA 15419*

[golden@cup.edu](mailto:golden@cup.edu)

**ABSTRACT:** This paper discusses the California University of Pennsylvania (CALU) – Maglev Sky Shuttle Project, the first Demonstration Project for Urban Maglev. The paper includes the history and background of the project, discussion of California University Projects 1, 2, and 3, project funding, discussion of Project 1 design, advancements in Guideway design and construction currently under consideration for the California University Project, and a summary of advantages of the Urban Maglev System.

## 1 INTRODUCTION

The CALU Sky Shuttle Project was initiated in 2001 by the Urban Maglev Team and California University of Pennsylvania and its President Angelo Armenti.

California University of Pennsylvania is situated on the banks of the Monongahela River in California Borough, Washington County, approximately 50 miles south of Pittsburgh. The University is divided into 2 Campuses – the lower, or Main Campus, which includes all class room and administration buildings and the upper campus (sometimes called “The Farm”) which includes James Adamson Stadium (football field), various other sports fields and recreation areas, and student housing constructed between 2000 and 2006.

The University plans to implement a new transportation system, in this instance – Urban Maglev, to transfer students between the campuses.

The University was, in 2001, and currently is, using a shuttle bus system to transfer students between the two campuses – the University desired to replace the shuttle bus system with a more environmentally friendly system with greater capacity. (Shuttle busses run every 20 minutes between 2 campuses)

The University currently has extensive parking on the lower campus – some located between train tracks and the Monongahela River. Parking in this

area constitutes a hazard for students – at least 1 fatality has occurred due to use of at-grade crossings.

The University has developed a new master plan. The plan eliminates a large portion of parking from the lower campus – currently, the majority of parking on the campus proper, excluding areas adjacent to the river, has been eliminated. The University envisions construction of a large capacity parking garage on the upper campus, with the urban maglev system utilized to transfer students from the parking garage on the upper campus to classrooms and the student center on the lower campus.

## 2 PROJECT DESCRIPTION

Following initial meetings, including enlistment of support from local political leaders, the Maglev Team developed a program plan, with estimated construction costs and design/construction schedules, and development of conceptual alignments. The Project was divided into 3 individual projects to spread required funding over a period of years, and to facilitate environmental clearance. The project will be constructed in 3 phases as follows: (Refer to Figure 1 which follows).

### 2.1 Project 1

Upper Campus – James Adamson Stadium to the Mid-Mon Valley Transit Authority (MMVTA)

Intermodal Center, including stations at Adamson Stadium, Student Housing, and the Intermodal Facility. Project 1 will be constructed as a Demonstration Project.

### 2.2 Project 2

Intermodal Facility to the future Convocation Center Station on the lower campus. This project includes a one-mile, 7% grade. Project 2 will also be constructed as a Demonstration Project.

### 2.3 Project 3

Main campus system including the extension to California Borough adjacent to the lower campus and the extension from James Adamson Stadium on the Upper Campus to the Center in the Woods, a senior citizen facility located in California Borough at the southern end of the upper campus. The future parking garage will be located on the west side of State Route 88, across from the Center in the Woods.

## 3 STATUS

Due to lack of funding, the majority of the project is still in the preliminary stages of design; however, some progress has been made.

### 3.1 Project 1

An Environmental Assessment (the required environmental document required by the Federal Transit Administration) was prepared in early 2006, and underwent several reviews by the FTA in 2007. At this point, all comments have been addressed, and Final Environmental Approval of the FTA is pending. The conclusion of the Assessment was that there are no permanent environmental impacts – the only impacts are temporary and largely consist of noise impacts due to construction equipment. It is important to note that noise impacts due to maglev operation, which passes in close distance to student housing, is less than 70 dB, or the level of soft music.

The study also concluded that there are no ill effects due to magnetic fields.

Under \$1,000,000 in funding provided by the Pennsylvania Department of Transportation in 2004, Mackin Engineering Company conducted final alignment design, preliminary guideway and station design, and final pier and foundation design. Additional funding is required to complete the

guideway design, as well as to complete vehicle, magnetics, and communication and signaling design.

### 3.2 Projects 2 & 3

Preliminary Planning, Conceptual Guideway Alignment Design, and right-of-way planning and pre-acquisition have been completed. It is important to note that right-of-way acquisition will be confined to 7 or 8 properties within Project 2. All other property in Projects 1, 2, and 3 is owned by either California University or the California University Student Association. Environmental studies and environmental clearance documents have not been initiated. No funds are currently available to advance either Project 2 or 3.

## 4 DESIGN/CONSTRUCTION COSTS AND FUNDING

The estimated program cost for Projects 1, 2, and 3 are as follows:

Project 1:	\$38,000,000
Project 2:	\$57,000,000
Project 3:	\$120,000,000
Total:	\$215,000,000

### 4.1 Funding to Date

The project has received no federal funds to date. The following funding has been provided by the Pennsylvania Department of Transportation (PennDOT) or the State of Pennsylvania.

Project 1: \$1,000,000 provided for the Alignment (PennDOT) and Guideway Design discussed above.

Federal Match: \$40,000,000 was appropriated in the Capital Budget to Match Federal Funds. Approximately \$3,000,000 of the total has been utilized as State Match for FTA funds utilized by the Maglev Team for research and development. The remainder will be utilized to match Federal Funds, if they are allocated for Projects 1, 2, and 3.

## 5 PROJECT 1 – PRELIMINARY DESIGN SUMMARY

Under funding provided by the Pennsylvania Department of Transportation, Mackin Engineering Company completed final alignment design, preliminary/pre-final guideway design, and final pier and foundation design for Project 1.

Project 1 begins at the Adamson Stadium Station, proceeds through Student Housing to Station 2 at the Housing Clubhouse, and terminates at Station 3 at the Intermodal Transit Facility, for a total length of 1,900 feet. The alignment utilizes a minimum horizontal radius of 50 M (164 feet) and spiral curvature to weave its way from Adamson Stadium through the Vulcan Housing Complex, culminating at the Intermodal Transfer Facility (Refer to Figure 2). The vertical alignment consists of a combination of vertical grades and curvature to accomplish changes of elevation between Adamson Stadium and the Intermodal Parking Facility (Refer to Figure 3). Maximum grades are 4.5% and 5.8%, in combination with vertical curvature (vertical curves are constructed with parabolic geometry, resulting in large equivalent radii which facilitates transition between vertical grades). The horizontal and vertical alignment clearly demonstrates the feasibility of Urban Maglev to operate at the minimum level of curvature (50 M, or 164 feet). The maximum 5.8% grade of Project 1 is very near the maximum 7% grade anticipated for the entire project, and demonstrates the vehicle's ability to handle steep grades. The only design requirement that the alignment does not demonstrate is speed – due to the short alignment, number of stations, and curvature, vehicle speed will be limited to a maximum of 20 mph.

### 5.1 Vehicles

The standard maglev vehicle will be utilized at CALU – the vehicle will be capable of carrying a maximum passenger load of 100. One vehicle will be used for Project 1 Demonstration (3 vehicles, ultimately) for Projects 1, 2, and 3). Vehicles are designated by Hall Industries of Pittsburgh (Refer to Figure 4).



Figure 4. CALU Maglev Vehicle

### 5.2 Pre-Final Guideway Design

Guideway structural design was essentially completed under the PennDOT, Project 1 Funding. In order to design piers and foundations, it was necessary to substantially complete the guideway design, and detailed geometry.

The guideway consists of 19 spans of varying lengths and curvature: minimum length 18.4 M (60.3 ft.): Maximum length 36.3 M (119.2 ft.). Geometry varies between straight to a minimum radii of 50 M (164 ft.). Total length of the guideway for Project 1 is 584.3 M (1,916.9 ft.).

### 5.3 Guideway Section

The Typical Guideway Section (Refer to Figure 5) is composed of precast pre- or post-tensioned box beams, a concrete leveling slab, and the Steel Guideway Module. The Post-Tensioned Sections are utilized on curved sections of the alignment and consist of three prestressed box girder sections which are delivered to the site, then post tensioned and erected in place. The concrete leveling slab, which is constructed after the beams are erected, is utilized to provide a flat surface on which to mount the Guideway Module and accommodate upward camber in the beam which cannot be completely predicted.

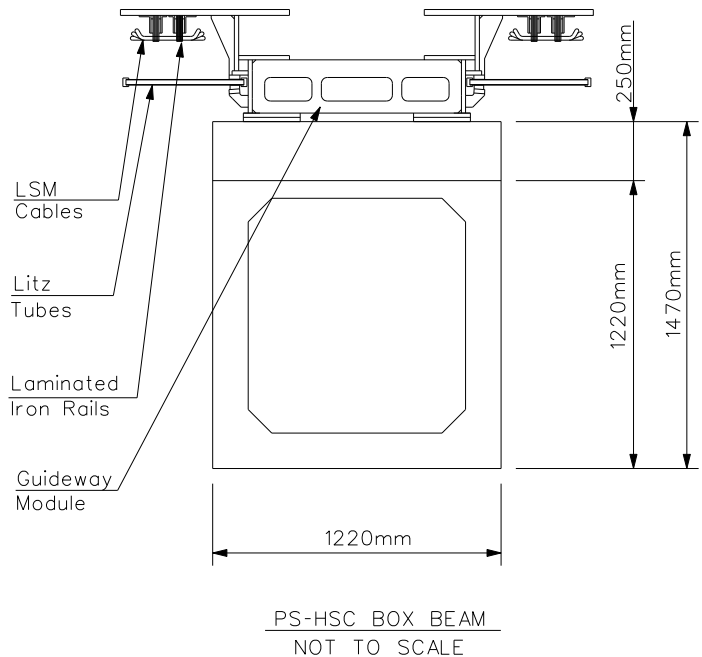


Figure 5. Baseline Box Beam/Guideway Module Cross Section

The Guideway Module is composed of stainless and carbon steel (top plate only) and carries the vehicle, LSM Cables, and Litz Tubes. The permanent magnets on the vehicle react with the Litz

Tubes to achieve levitation and with the LSM Motor to propel the vehicle. The Guideway Module is attached to the concrete leveling slab with anchor bolts cast in the concrete. Final adjustments to achieve the exact alignment are made with the leveling nuts.

The guideway has several advantages. The beams are fabricated offsite, delivered, then quickly erected in place. This is particularly advantageous in congested urban areas – impacts to pedestrians, traffic are minimized, and construction can proceed quickly. The concrete leveling pad corrects for all variations in beam camber and geometry, and allows the guideway and guideway module to be constructed to less stringent tolerances, reducing project costs. The Guideway Module does not require special fabrication techniques, and can be fabricated and erected quickly. However, it is important to note that Guideway Modules were utilized for General Atomics Test Track. Costs were significantly more than estimated, and distortion due to welding was a problem on some modules – we anticipate that higher volume production would reduce cost, and that automated fabrication and fabrication software/processes currently under development would reduce or eliminate the distortion.

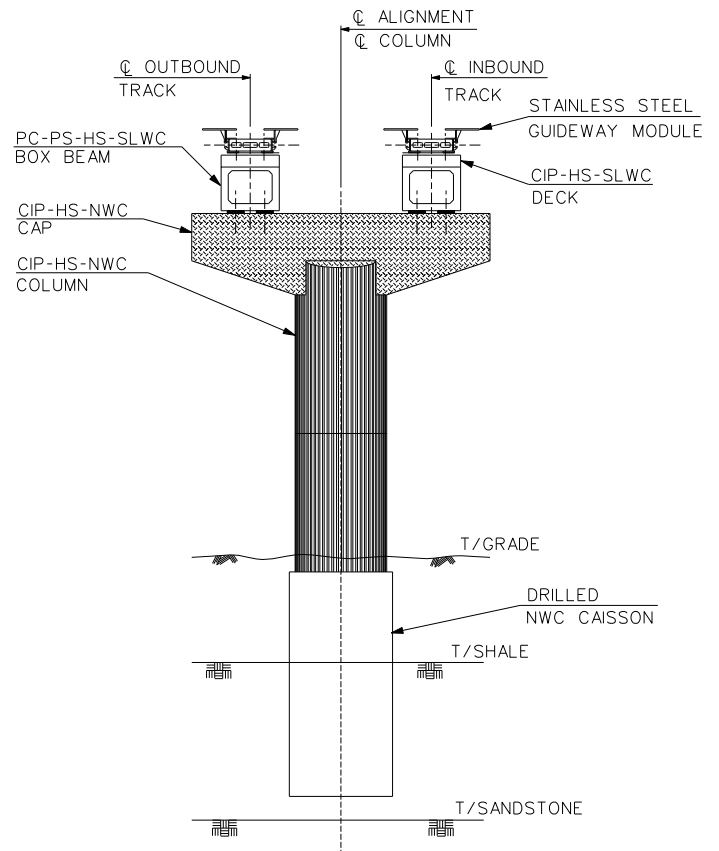


Figure 6. T-Shaped Pier with Hammerhead Cap

#### 5.4 Piers and Substructure

Geotechnical Engineering, and Pier and Foundation Design were completed for Project 1 of California University, along with the Pre-Final Guideway Design. The construction of the piers and foundations can begin almost immediately, following appropriation of construction funds.

The piers are composed of reinforced concrete, and are either T-shaped or L-shaped (Refer to Figures 6 & 7). T-shaped piers are generally used; L-shaped piers are utilized when space is not available for T-shaped piers – minimizing impacts to buildings, right-of-way, city streets, etc. At CALU, the piers (and foundations) are designed to carry Project 1 loads (1 vehicle/guideway only) and Project 3 loads (dual guideway system). The Project 1 loads control stability and bending stress in the pier column and foundation. Piers at CALU are designed to be cast-in place, as preferred by Trumbull/P.J. Dick, the construction partner of the Urban Maglev Team. However, precast piers can also be utilized, and may be preferable in true urban areas. The piers vary in height from 3.0 M (9.9 ft.) to 14.7 M (48.2 ft.).

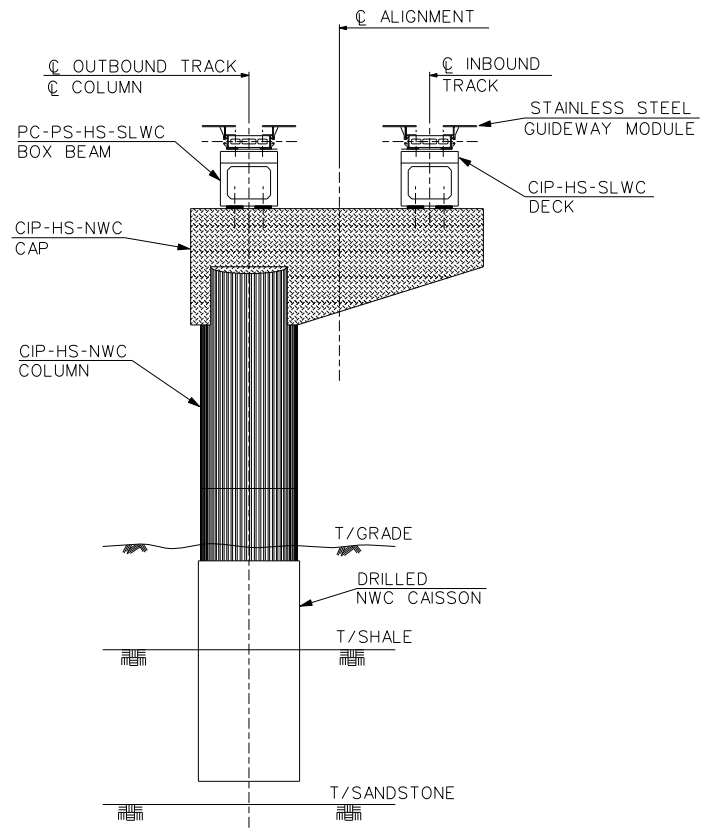


Figure 7. L-Shaped Pier with Cantilever Cap

## 5.5 Foundations

Urban Maglev systems generally use concrete caissons to support the pier and guideway – concrete caissons can be constructed without the noise and vibration of steel pile foundations, and with a lesser footprint. At CALU, a single concrete caisson is utilized to support the pier. This is possible due to the presence of a rock layer (shale) located between 0.9 M (3.0 ft.) and 5.3 M (188 ft.) below the ground surface. Use of the single caisson results in several advantages over multiple caissons, which may be necessary depending on the location of the soil/sand/rock layers below the piers.

Faster and more economical construction.

Minimal footprint and effect on existing streets, utilities, etc.

Plans for all substructure units were completed in 2004 – construction, as indicated earlier, is dependent on funding.

## 6 ADVANCES IN GUIDEWAY TECHNOLOGY

Mackin Engineering Company and General Atomics, over the past 2 years have been evaluating an improved Guideway Concept – the Hybrid Girder. While the Pre-Cast Girder with Guideway Module has all of the advantages identified, there is a desire to 1) Improve Aesthetics, and 2) Combine the prestressed beam and Guideway Module into 1 unit, the Hybrid Girder (Refer to Figure 8). The hybrid girder consists of a pre-or post-tensioned high-strength concrete box beam, with stainless steel fiber reinforcement instead of standard steel reinforcement. The hybrid girder will be fabricated to include all components present on the current prestressed girder, Guideway Module combination, but in a much more aesthetic manner. The hybrid girder includes carbon steel top plates (to accommodate vehicle landing wheels), Litz Tubes, and LSM cables all attached to embedments cast into the concrete girder.

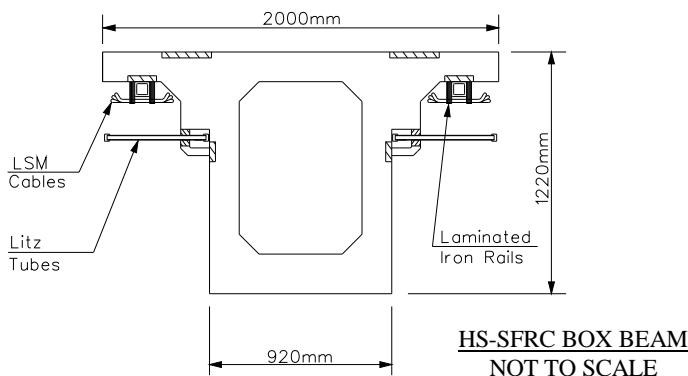


Figure 8. Alternative Hybrid Girder Cross Section

## 6.1 Original Concept

The original concept considered use of high strength steel fiber reinforcement only, without pre- or post-tensioning. Initial and follow-up testing was conducted by Mackin Engineering Company and General Atomics. The results of the testing indicated a brittle failure of the girders (a sudden failure due to a loss of bonding between the fiber reinforcement and the concrete (Refer to Figure 9)) at strengths well below those required. As a result, it was determined that pre- or post-tensioning would be necessary.



Figure 9. Failed Hybrid Test Beam Due to Brittle Fracture

There are several challenges associated with the hybrid girder which need to be addressed – solution of those challenges will affect both the cost and feasibility of use, and include:

The Litz Tubes and LSM Cables must be constructed at a constant distance from the alignment profile grade – adjustability must be provided to account for beam camber, beam superelevation, and vertical curvature.

Girder camber, due to pre- or post-tensioning cannot be completely predicted. Different methods of design/fabrication of the girders must be evaluated.

Fabrication of the girders to meet the vertical geometry must also be evaluated. The current beam/guideway module combination utilizes the concrete leveling slab to account for the variations in the camber. The guideway module accounts for the superelevation and vertical curvature.

The hybrid girder is a very promising concept. Additional design and fabrication development, and associated funds, are needed to finalize the concept, including evaluation of cost effectiveness.

## 7 ADVANTAGES OF THE CALU URBAN MAGLEV SYSTEM

The California University of Pennsylvania Project clearly illustrates the numerous environmental and operational advantages of an Urban Maglev System.

### 7.1 *Environmental Advantages*

The Urban Maglev System has significant environmental advantages, and is a truly “Green” system.

- Urban maglev is an all electrical system (in the case of California University, it will replace gas/diesel engine shuttle busses), with no emissions.
- The elevated system and tight turning radii minimize or avoid environmental impacts, as well as construction impacts.
- The system is very quiet – measurements taken at General Atomics’ test track in San Diego show noise levels equal to 70 dB (equivalent to soft music).
- There are no ill effects due to the magnets – magnetic field levels are less than the natural magnetic field levels of the earth.
- The vehicle and guideway are aesthetically pleasing and will blend with the surrounding environment.
- Safe and secure – on-board close circuit cameras will be placed in all vehicles and stations. The elevated guideway avoids any interference with vehicular traffic.
- The system will eliminate bus traffic and most vehicular traffic between the campuses at California University.

Urban Maglev is truly a “Green” Technology.

### 7.2 *Operational Advantages*

Urban Maglev Systems, due to the large air gap between the guideway and vehicles, elevated guideway, and permanent maglev technology provide many advantages which minimize cost, impacts, and maintenance.

- There are no moving parts, with the exception of the doors and air conditioning system.
- The one-inch air gap permits the vehicle to make horizontal turns on radii as little as 18.3 M (60.0

ft.), permitting guideways to be placed in urban areas (i.e., city streets) with minimal building and right-of-way impacts and displacements, and avoiding impacts to park and recreation areas.

- The system can be placed on alignments with vertical grades as high as 10%, providing additional operational flexibility.
- The system can be operated under all weather conditions.
- The elevated guideway is significantly less expensive than underground systems, and absolutely minimizes impacts to streets, utilities, etc.
- The elevated guideway is significantly safer than an at-grade system, and can be placed in areas where at-grade systems are not feasible.
- There is no friction between the vehicle and guideway, and no moving parts – as a result, maintenance costs will be minimized.
- The vehicle is automated – no driver – and is controlled at the system control center.



# CALIFORNIA UNIVERSITY OF PENNSYLVANIA MAGLEV SKY SHUTTLE

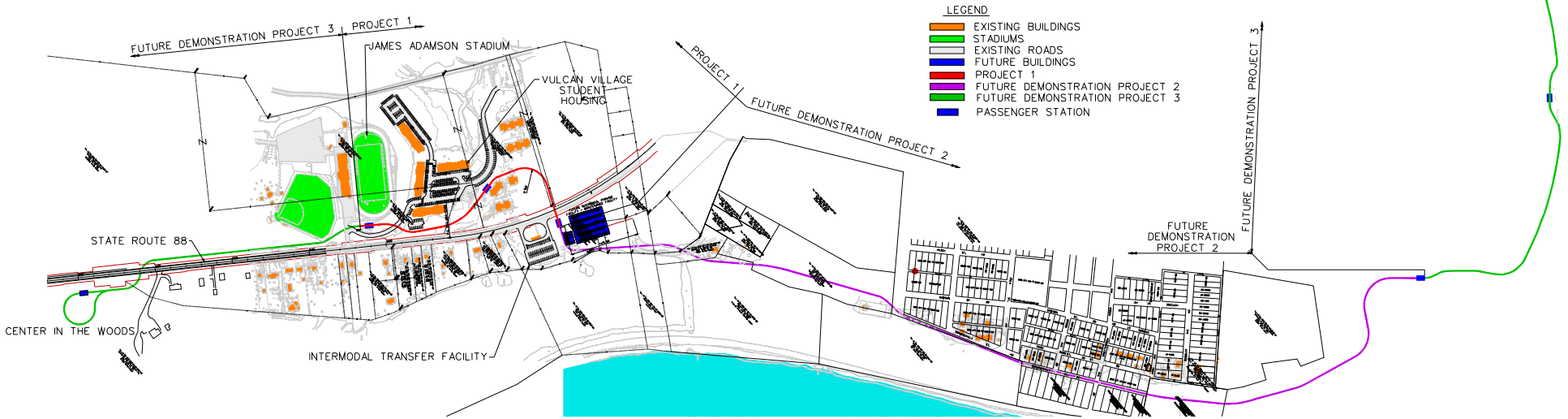


Figure 1. Plan of Projects 1, 2 and 3

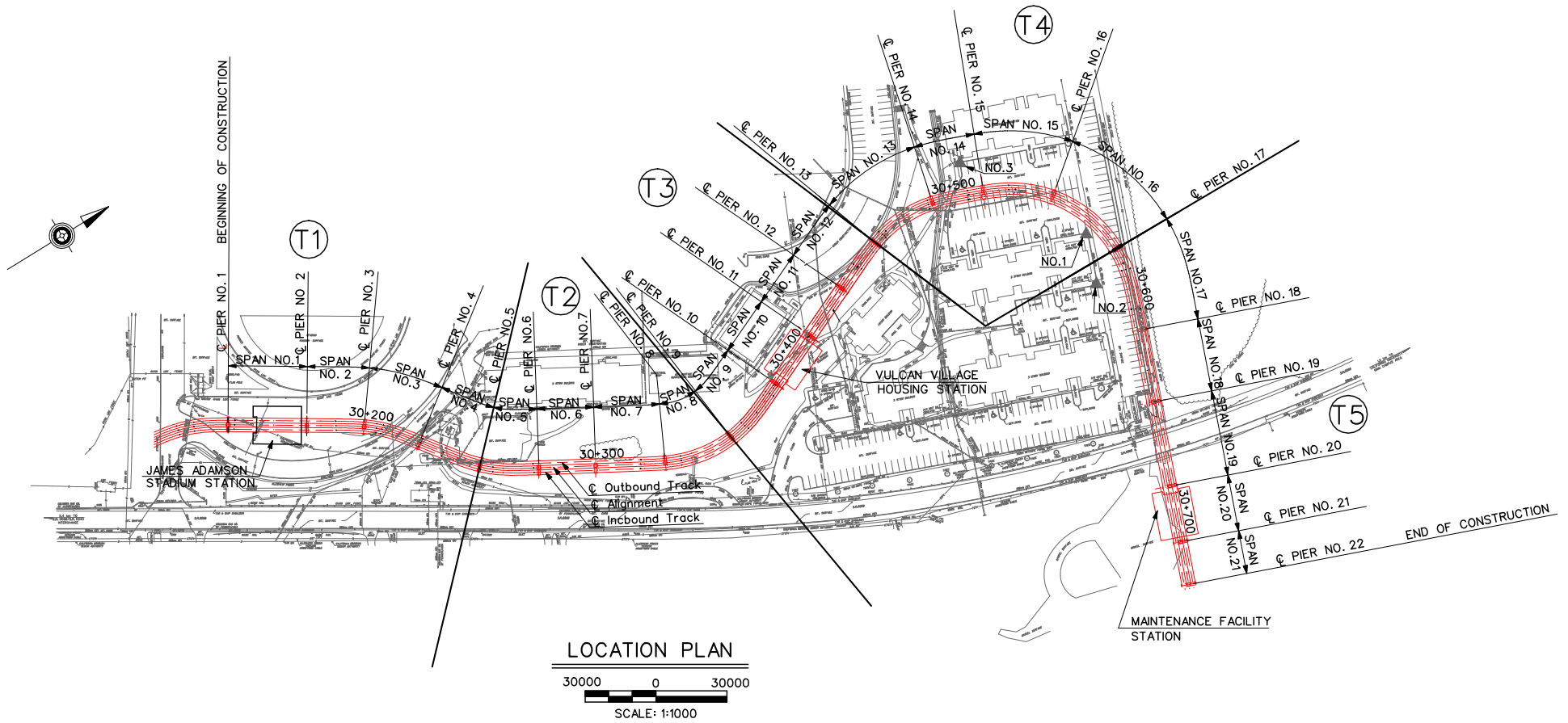


Figure 2. Plan of Project 1



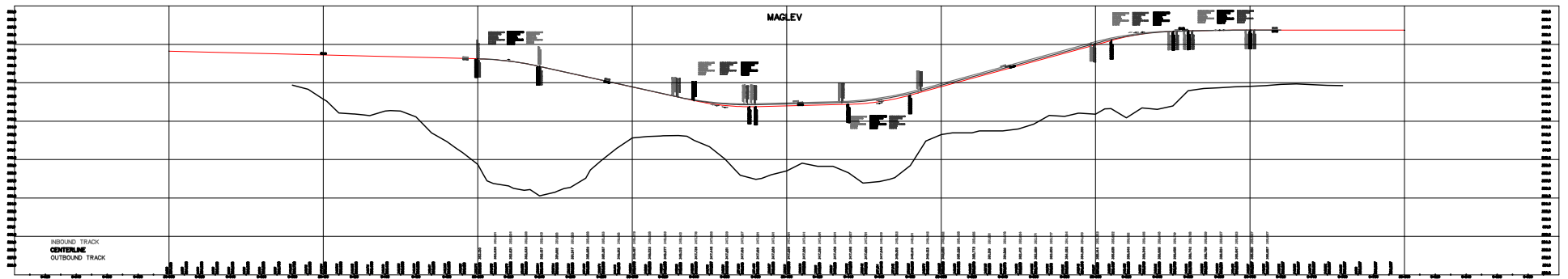


Figure 3. Profile of Project 1

## REFERENCES

- Gurol H. & Baldi R. & Bever D., Post R.F. 2004, October  
“Status of the General Atomics Low Speed Urban Maglev  
Technology Program”, 18th International Conference on  
Magnetically Levitated Systems and Linear Drives,  
Shanghai, China.
- Gurol H. & Baldi R. 2003, September “General Atomics Urban  
Maglev Program Status”, 4th International Symposium on  
Linear Drives for Industrial Applications, Birmingham, UK.
- Gurol H., & Baldi R., & Post R.F. 2002, September 4-8  
“Overview of the General Atomics Low Speed Urban  
Maglev Technology Development Program”, 17th  
International Conference on Magnetically Levitated Systems  
and Linear Drives, Lausanne, Switzerland.
- Gurol H, Baldi R. 2001, November 1 “Maglev Sky Shuttle Plan  
for California University of Pennsylvania”.
- Gurol H. & Baldi R. 2005, November 17 “Overview of the  
California University of Pennsylvania Urban Maglev  
Demonstration System”.
- Jeter P. & Venkatesh M. & Schardt J. 2008, December “Urban  
Maglev Fiber Reinforced Concrete Girder Design,  
Development and Testing”, 20<sup>th</sup> International Conference on  
Magnetically Levitated Systems and Linear Drives, San  
Diego, California.