General Atomics Urban Maglev Program Status

No. 99
Sam Gurol and Bob Baldi
General Atomics, Electromagnetic Systems Division, P.O. Box 85608, San Diego, CA 92186-5608, USA
sam.gurol@gat.com, bob.baldi@gat.com

Richard Post
Lawrence Livermore National Laboratory, P.O. Box 808, L-644, Livermore, CA 94551, USA
post3@llnl.gov

ABSTRACT: This paper discusses the status of the General Atomics Urban Maglev project. The status of the project was previously discussed at the Maglev 2004 conference in Shanghai, China. Since that time, the test track construction has been completed and significant testing accomplished. The next steps in the project in moving towards a demonstration system will be discussed.

1 INTRODUCTION

This paper discusses the status of the General Atomics Urban Maglev program and the next steps in moving the project towards a demonstration system. Since the last report, the test track construction has been completed and significant testing accomplished. The test track is full-scale, 120 meters in length, with a 50-meter radius curve. The track was completed in November 2004, and is shown with team members in Figure 1.

Figure 1. Completed test track in San Diego, CA.

The test vehicle consists of a single 5-meter chassis unit (a complete urban vehicle is comprised of two 5-meter chassis units). The full-scale test chassis and its relation to a complete vehicle are shown in Figure 2.

The levitation suspension system is of the ElectroDynamic type, consisting of permanent magnets arranged in a Halbach Array configuration. The basic magnetic system as well as the overall program status was discussed in a number of previous publications [1]-[9]. A passive secondary suspension system provides damping and passenger ride quality. Propulsion and guidance are achieved with a permanent magnet Linear Synchronous Motor (LSM). Testing with chassis weight up to 10,000 kg, to a speed of 10 m/s, air gaps up to ~30 mm, and acceleration up to 2.8 m/s^2 has been achieved (nominal acceleration is 1.6 m/s^2). The next steps in the program involve technology development needed to move the project towards a demonstration system.

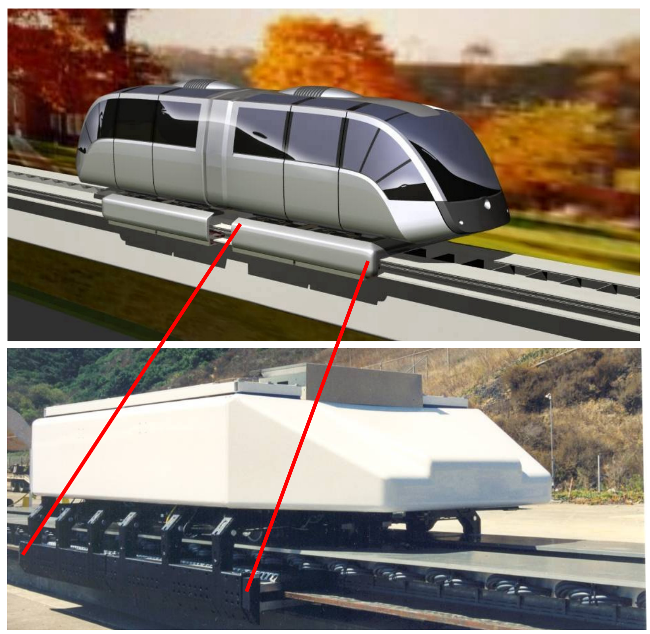

Figure 2. Full-scale chassis under-going dynamic testing, and its relation to a complete vehicle.

On-going and planned activities include: control system optimization, hybrid girder testing, levitation/track system optimization, block switch and power pick-up testing, and vehicle body fabrication. The planned demonstration system is located at California University of Pennsylvania (CUP) in California, Pennsylvania. The demonstration system will provide the needed operational and reliability data prior to revenue system deployment.

2 TECHNOLOGY DEVELOPMENT

2.1 Near-Term Planned Activities

Over the next several years, we plan to perform a number of tasks which will enable the project to transition from test track operations to construction of the demonstration system at CUP. First priorities involve the refinement of the propulsion control system and completion of a detailed vehicle dynamics test program.

The on-going work related to the control system and associated position sensing for control of the LSM are discussed by Jeter, et.al. (paper no. 95, this conference). We are replacing the current optical position sensing equipment with a non-optical system, which enables all-weather operation, is not speed-limited, and results in more reliable operation since it is hard-wired to the control system. The propulsion control system is being modified to incorporate this new position sensing, as well as being optimized to provide good ride quality, while following the programmed speed profile. A detailed test program will be undertaken once these changes are implemented to evaluate the vehicle dynamic behavior.

The control system works in tandem with the General Atomics built IGBT-based Variable Frequency Drive, shown in Figure 3, which is continuing to be tested for reliability, having undergone several modifications to improve thermal performance for urban maglev system operation. This system was developed for use on urban and high speed maglev, as well as for the Electromagnetic Aircraft Launch System (EMALS) for the U.S. Navy, and has been proven to be capable of reliable, high power operation over the last three years.

Figure 3. General Atomics IGBT-based urban maglev inverter system.

Other key technology development next steps involve the fabrication and testing of a second chassis (with articulation), vehicle car body, and a hybrid girder. The planned configuration for the first car body and its installation on the existing test chassis is seen in Figure 4. The body fabrication will enable verification of the modular construction approach, and development of a supplier base.

Significant work has been performed to date related to the use of a steel fiber-reinforced hybrid girder system. The results of this work are described in paper no. 97 of this conference (Venkatesh and Jeter). The basic girder system, with its attachments for the LSM and the levitation track is shown in Figure 5. This system provides high strength and low cost for the demonstration system at CUP.

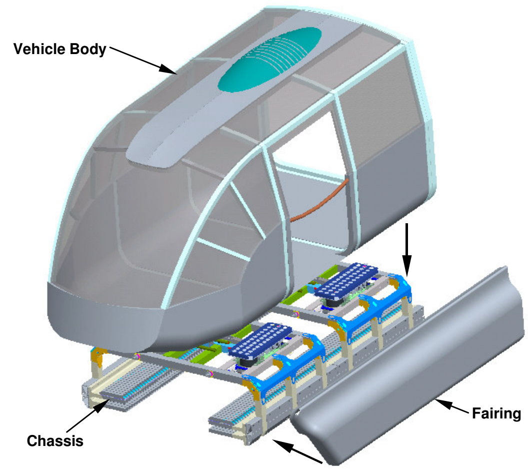

Figure 4. Installation of car body on test chassis.

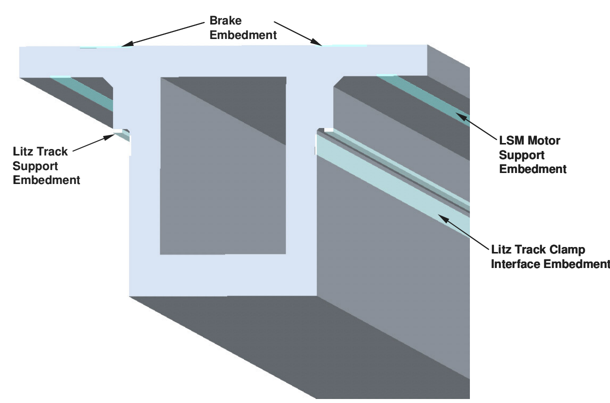

Figure 5. Steel fiber reinforced hybrid girder system.

2.2 Levitation System Optimization

We are also evaluating a number of optimizations to the levitation system to improve its performance and efficiency in future revenue service. These range from optimizing the Halbach array configuration for maximum suspension stiffness to reducing the track construction cost (by using a simpler laminated track).

A novel approach has been developed by Post [10] to improve both the suspension stiffness and the system efficiency (by reducing the drag power).

This approach involves the use of "generator magnets" on a small part of the track. The modification is to append, on one or both ends of the levitation track, dual Halbach arrays configured in a "generator" mode, as shown in Figure 6. The upper and lower arrays are phased with respect to each other so that their vertical field components add, while their horizontal field components cancel (or nearly cancel) in the gap between the two arrays.

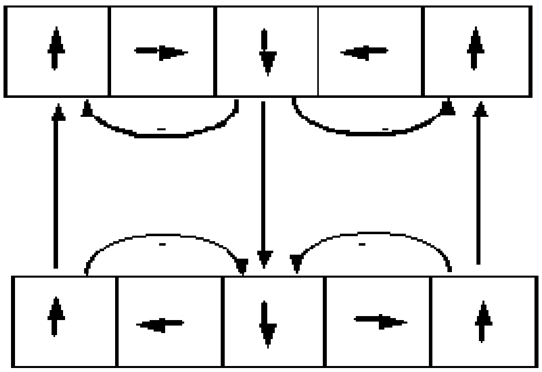

Figure 6. Dual Halbach Array in generator mode.

The effect of appending these generator arrays to the normal Inductrack II dual array (as used on the test track) is to modify the amount of flux threading the circuit without appreciably changing the levitation force per ampere induced in the track conductors. When two such arrays are appended, a new possibility exists, as follows: by shifting the phases of the vertical field component produced by the two arrays either flux enhancement (or cancellation) of the net inducing flux can be achieved. For example, if the phase of one generator array is advanced by ϕ radians, while that of the other is retarded by the same amount, then the net generator flux, Φ_g, will be varied in the manner given by equation 1.

$$\Phi_g[t] = \Phi_0 \mathrm{Cos}[\phi]\mathrm{Cos}[\omega t] \qquad (1)$$

Thus by varying the phase angle ϕ, it is possible to change the magnitude (and sign) of the flux through the track circuits in response to such perturbations as load changes. With rapid enough response, such a system could respond to gap changes associated with external perturbations, such as wind loads, etc. In the latter case it would be possible to correct for both pitch and roll motions of the train car.

Another use of the above configuration would be to allow the stable use of "biasing" permanent magnets, attracted upward to iron plates on the track, to take up part of the levitation load. If such magnets can be used they can reduce the drag power losses by a large factor. The concept here is to use the high stiffness of the Inductrack II Halbach array to maintain stability, and use the phase-shifted generator arrays to control the operating point in an optimum way. In a recent conceptual design study the drag power was shown to be reduced by more than a factor of two by this method.

3 CUP DEMONSTRATION SYSTEM

Our test track design and testing are driven by ongoing planning to construct a demonstration system. The test track will validate integrated levitation, propulsion, and guidance. Upon successful completion of trials, the test track will continue being used for system optimization, while a demonstration system is constructed at California University of Pennsylvania (CUP) in California, Pennsylvania, located about 60 miles southwest of Pittsburgh. When completed, this system will be 7.4 km in length with four stations, and 3 vehicles, connecting the upper and lower campus via a 7% grade. The system will serve the main campus, the city, and student housing/sports facilities on the upper campus. Initially, it will be used to demonstrate the all weather, grade climbing, and ride quality capabilities of a maglev system. An artist's rendition of the maglev system connecting the upper and lower campuses is shown in Figure 7.

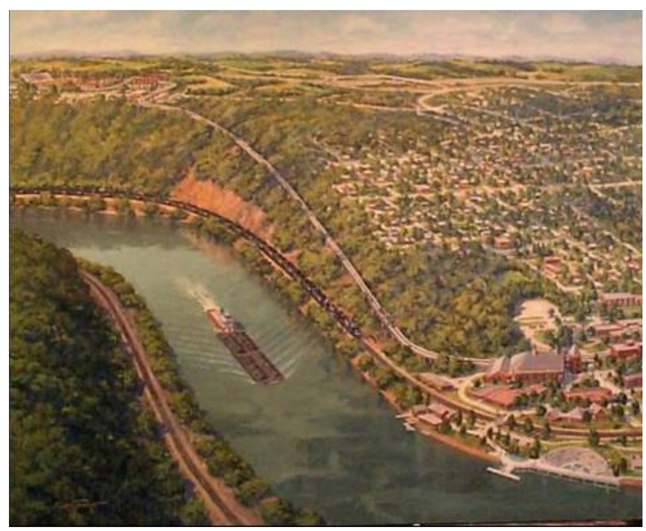

Figure 7. The CUP demonstration system will demonstrate maglev capabilities and serve a transportation need.

The demonstration system construction is divided into three different phases, referred to as Projects 1, 2, and 3 respectively. Each project would by itself serve a transportation need on the campus. Project 1 consists of ~700 m of elevated track, with a maximum grade of 5 %, and two stations. To date, we have completed for Project 1, the design of the alignment, utility coordination, geotechnical sampling and testing, pier/caisson design, conceptual station design, and an environmental assessment (since Project 1 is constructed entirely on university land, it benefits from a categorical exclusion, and does not require a full environmental impact assessment).

Project 1 will be constructed first, and be used to perform testing of the complete system, prior to full construction of Project 2. Project 2 connects the upper campus with the lower campus with a 1.6 km, 7% grade, double-track guideway. This phase would be used to fully test the grade-climbing and all-weather operating capabilities of the system (Pennsylvania can have severe winters). Project 3 will be extended to serve the main campus as well as the city. The ends will have end-of-track switches to allow the system to operate as a circulator system. Current funding allows continued engineering of the alignment, and environmental permitting. Full construction funding for the project would be provided by the next transportation bill in 2009.

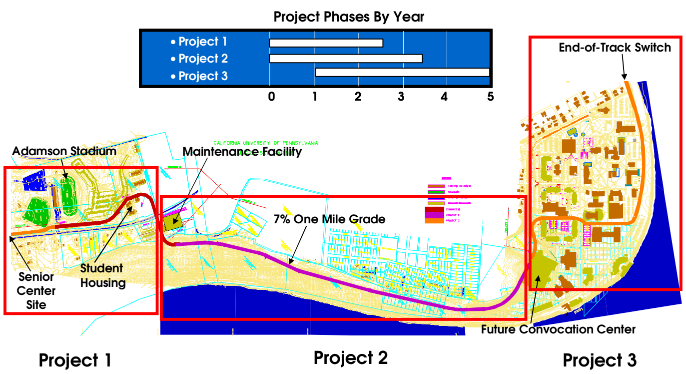

Figure 8. The CUP demonstration system consists of three projects, serving a university transportation need, and demonstrating the GA urban maglev system capabilities.

4 CONCLUSIONS

We have successfully completed the construction, and integration of the test track, and demonstrated basic levitation, propulsion, and guidance. We plan to continue refining the basic technology components using the test track to get prepared for construction of the demonstration system at CUP. Initial activities during 2006 include refining the propulsion control system, and starting construction of a second chassis for a complete vehicle dynamics evaluation. We also have put together plans to test block switches, inductive pick-up system for housekeeping power, automatic train protection (ATP), hybrid girder, and car body. Preliminary engineering is currently being performed for the demonstration system at CUP; it is expected that construction of Project 1 can start in about two years.

5 REFERENCES

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