Urban Maglev – Development Plans and Prospects

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ABSTRACT: This paper discusses the status of MagneMotion's Maglev *M3* project. MagneMotion has developed and tested a full scale test sled on a 48 meter long 1.8 meter gage track inside our facility in Massachusetts. In the next phase of the project, now underway, we will install 75 meters of track and test a single test sled on a pre-existing guideway at Old Dominion University in Norfolk, VA. Design objectives, system attributes, the status of our current project and the next steps to commercialization will be discussed.

1 INTRODUCTION

MagneMotion Maglev (*M3*) has been designed to address the transportation challenges of the urban environment. As part of the Federal Transit Administration's (FTA) Urban Maglev Project, MagneMotion (MMI) has developed a Linear Synchronous Motor (LSM) propelled Maglev system. By using small vehicles with short headway and rapid acceleration, it is possible to achieve outstanding performance at a lower cost than conventional urban transit systems. The details of the system performance and comparisons to alternative systems have been discussed in previous publications Thornton (2009), Thornton (2008).

This paper discusses the design objectives, our cost model, and how our design is optimally suited to address the transit market for urban travel and inter-city travel of less than 200 miles, with particular attention given to multi-stop and high passenger volume issues.

2 DESIGN OBJECTIVES

M3 has been designed as a system from the top down; achieving the multiple goals of minimizing cost, trip time, environmental impact, and technical risk. Consideration of the costs of various system components has driven some of the system design. Our cost model in this paper is based on actual costs of building the 48-meter test track and sled, and does not assume the potential and anticipated additional economies of scale that will be realized for longer installations. Significant cost reductions are also expected once we complete a design for manufacturing effort.

Our cost model shows that guideway beam, track structure, and propulsion electronics constitute 65% of the system cost.

Table 1. System Cost Model for a dual guideway System

Parameter	***Units/km***	***$k each***	***$M/km***	***%***
Guideway Infrastructure				**29**
Guideway beams	67	62	4.2	14
Guideway towers	33	20	0.7	2
Track structure	67	60	4.0	13
LSM /Position sensing				**26**
LSM Stators	67	110	7.4	25
Guideway installation /cables	67	6	0.4	1
Electrification				**10**
Inverter Station cabinets	16	40	0.6	2
DC power system	2	454	0.9	3
License and Maintenance	1	1,920	1.9	6
Vehicles	4	1,500	6.0	**20**
Subtotal			26.1	
Maintenance, 5%			1.3	**5**
Contingency, 10%			2.6	**10**
Total			**30.0**	**100**

Early in our design efforts, we identified the high cost components (e.g. guideway beams, track support, and LSM stators) and concentrated on reducing those costs. This was accomplished most effectively by using an LSM based system. The 'long-stator' LSM topology used in the *M3* system places all of the motor coils, inverter drives, and control electronics on the guideway. This configuration is beneficial in terms of reducing the weight of the vehicle and, more importantly, it eliminates the need to transfer the large propulsion power demand to the vehicle. In addition, the design enables precise control of vehicles from the wayside and eliminates the complexity and safety concerns of moving vehicles needing to communicate with each other.

The resulting light-weight vehicle helps reduce the costs of the concrete structure and the quantity of steel in the track. Lighter vehicles require less power to accelerate, hence reducing the stator size and wayside power electronics. In order to achieve higher capacities, the system may use many vehicles, which leads to more efficient regenerative braking.

The combination of these beneficial attributes yields a cost-effective replacement for rotary motor and Linear Induction Motor (LIM) powered transit, including both light and heavy rail. We have demonstrated that the system can be built for lower cost than traditional transit while delivering 12,000 passengers per hour per direction (pphpd).

This achievement is possible due to the use of LSM technology in conjunction with high energy permanent magnets and a proven wayside-based control system. Small vehicles operating with short headway and organized in clusters can achieve high capacity without offline loading. Very precise position sensing and guideway-based propulsion and control make short headways safe and affordable.

To address the needs of very high capacity transit applications that require larger vehicles, MMI has used a modular approach to vehicle design that enables us to increase the size of the vehicles. The larger vehicles increase the cost of the system, but the modular approach allows capacities up to 40,000 pphpd.

3 SYSTEM DESCRIPTION

The *M3* design uses an ElectroMagnetic Suspension (EMS) system consisting of permanent magnets surrounded by control coils. The design is unique to MMI systems; each levitation pod consists of one magnet array on each side that is used simultaneously for levitation, lateral guidance, and propulsion. Figure 1 shows the levitation array in a cut-out model of the sled.

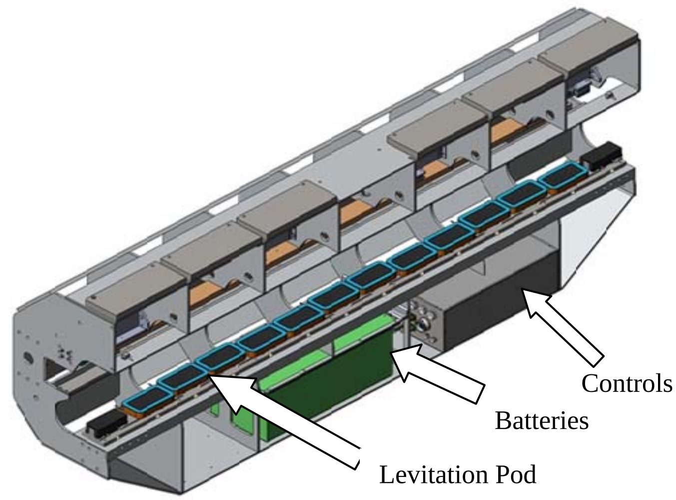

Figure 1. Levitation array and electronics locations

The *M3* uses a coordinated but separate control and drive system for the port and starboard LSMs, thus providing redundancy and enhancing the fault tolerance of the system.

The system utilizes off-the-shelf inverters controlled by MMI-designed electronics. The inverter controller and a number of the power electronic devices use the same design that has undergone full MIL qualification as part of the equipment provided by MMI to the U.S. Navy.

Figure 2 shows a view of the test sled with position sense transducers and simulated passenger payloads. Each of the plates on top of the sled weighs 85 kg. During testing these plates were moved to different positions on the vehicle to simulate uneven passenger loading.

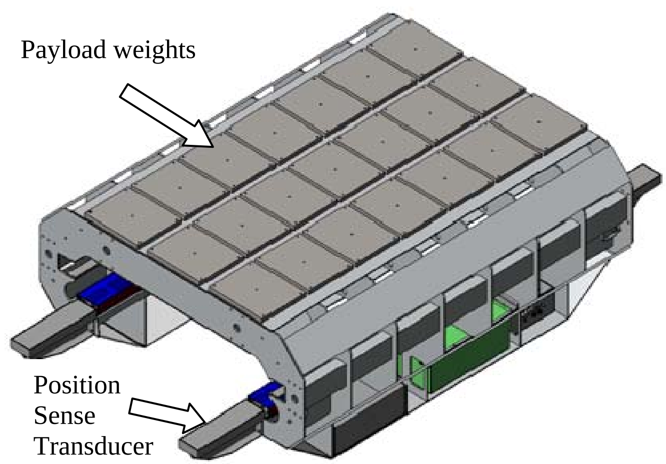

Figure 2. Isometric view of Test Sled

Figure 3 shows a picture of the test sled on the test track at MagneMotion's facility.

Figure 3. Test Sled mounted on indoor 48 meter Test Track at MagneMotion, Devens, MA

The test sled consists of an aluminum chassis that is suspended on each side by a 3.5 meter long levitation pod assembly. Each levitation pod assembly contains approximately 38 kg of Neodymium Iron Boron (NeFeB) magnets. In production, these levitation pods will be integrated into each side of the undercarriage to support the vehicle. Vehicle modules can be coupled together to construct longer vehicles; however as stated earlier, making the vehicle larger increases the weight and the cost of the support beam and electronics.

The baseline *M3* was designed to meet the FTA (2004) specifications listed in Table 2.

Table 2. FTA Urban Maglev Specifications

Parameter	**Metric**		**English**	
Speed, max	44.7	m/s	100	mph
System capacity, min	12,000	pphpd		
Acceleration, max	1.6	m/s^2	3.6	mph/s
Jerk, max	2.5	m/s^3	5.6	mph/s^2
Braking, emergency	3.6	m/s^2	8.1	mph/s
Horizontal turn radius, min	25	m	60	ft
Vertical turn radius, min	1000	m	3048	ft
Grade, max	10	%		
DC magnetic field in vehicle	0.5	mT	5	Gauss
AC magnetic field in vehicle	0.1	mT	1	Gauss
LSM efficiency, min	80	%		
Availability, min	99.99	%		
Wind limit for full operation	14	m/s	31	mph
Ride quality, min	ISO	1997		
Noise level inside, max	70	dBA		

The baseline vehicle consists of two modules that are coupled together. Each side of each module has a levitation pod and position sensing electronics. The vehicle depicted in Figure 4 is designed to carry 24 sitting and 16 standing passengers.

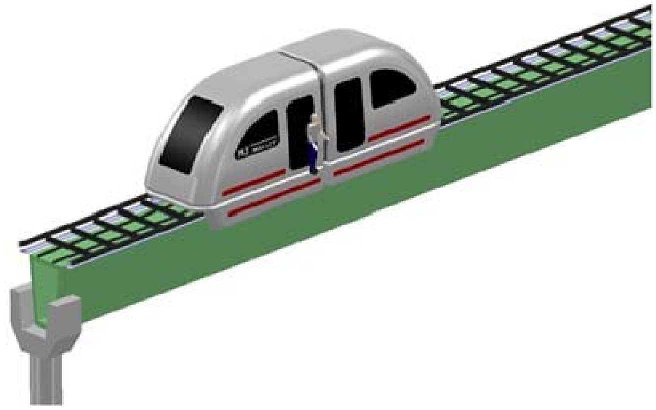

Figure 4. Model of a 40 passenger vehicle (Illustration compliments of Magplane, Inc.)

An example of an extended vehicle capable of carrying 36 sitting and 24 standing passengers is shown in Figure 5.

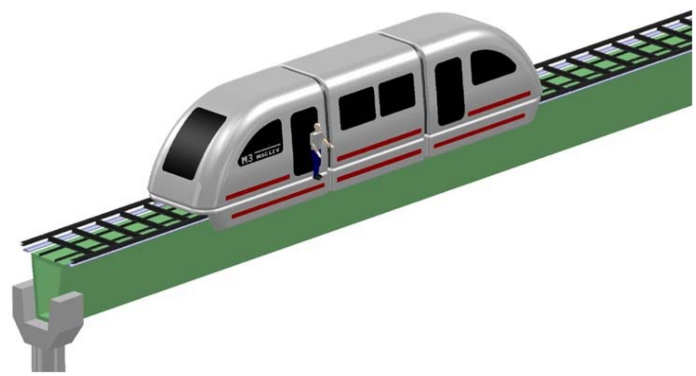

Figure 5. Model of a 60 passenger vehicle (Illustration compliments of Magplane, Inc.)

4 SYSTEM BENEFITS

The FTA sponsored Urban Maglev Program has allowed MagneMotion to develop a system that directly addresses the Urban Transit problem. The system:

- Minimizes Capital Costs – The low cost guideway and track and the simple design utilize standard commercial components which require little special tooling for fabrication.
- Minimizes Operational Costs –The control of propulsion using automated wayside controls increases safety and the ability to take vehicles out of service allows the transit operator to tailor the system to passenger demand. There

is no third rail or catenaries, and no wheels or mechanical brakes used in normal operation that need maintenance.

- Minimizes Trip Time – The use of many closely spaced vehicles results in short station wait times. The vehicle's high accelerations and cruise speed results in quicker trip times than conventional transit.
- Minimizes Environmental Impact – The energy efficient LSM design and regenerative braking present a green solution while quiet operation and a small unobtrusive guideway make the system ideal for the urban environment.
- Minimizes Technical Risk – By utilizing proven LSM technology and the latest in industrial control technology the system provides a simple "state-of-the-art" control design.

More details of the benefits of the M3 system are detailed in Thornton (2011).

5 PROJECT STATUS

MagneMotion completed Phase 1 of the FTA project in December 2010. We have designed and built a 48 meter long, 1.8 meter gage indoor test track and a test sled with the following features; the ability to levitate 4500kg when fully loaded, a nominal air gap of 20 mm, a sled with verified thrust and lateral stability, and an operating speed of 9 m/s. Our demonstration speed is limited only by the length of track. The system is designed for speeds up to 45 m/s.

Phase 2 of the project, initiated in January 2011, consists of installing 75 meters of track on an existing concrete guideway beam at Old Dominion University (ODU) in Norfolk, Virginia. Once installation is complete at ODU, the MagneMotion and ODU teams will test the movement of a single sled along beams of varying lengths in an outdoor environment.

The existing ODU guideway (Figure 6) offers a way to achieve this next step by minimizing up-front expenses and proving the potential to convert an unused guideway into an operational transportation system in the future.

Current funding allows continued engineering and environmental sealing of the vehicle components and installation at ODU. Full construction of a transportation system and population of the 1 km guideway at ODU will require funding beyond the scope of the current project.

Figure 6. A portion of the ODU guideway will be used as a demonstration system

6 PLANNED DEVELOPMENT ACTIVITIES

Beyond our current Phase 2 project, we plan to perform a number of tasks which will enable the project to transition from test track operations to full commercialization. Tasks include the development of a passenger vehicle, integration with a dispatch and automated train control system, development of simple and complex curves, development of a switch, development of a safety program, and an extensive test program.

7 CONCLUSIONS

We have successfully completed the construction and integration of the test track and have demonstrated basic levitation, propulsion, and guidance. With our proven state-of-the-art control system we can deliver an energy efficient, high passenger capacity system, at a lower cost per kilometer than existing mass-transit systems. MagneMotion is currently investigating options for the commercial development of the *M3* system.

8 ACKNOWLEDGEMENTS

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