ZB8.2 - Appendix 1

MAGNOVATE

Efficient, Quiet & Sustainable Ground Transportation

A Collaborative Proposal for:

The Toronto Zoo

March 2016

www.magnovate.com

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1. Vendor Profile

1.1 Magnovate

Magnovate was founded to commercialize Magline, a proprietary magnetic levitation (maglev) powertrain platform that enables a whole new generation of advanced transit systems. Our portfolio is to expand the practical applications of maglev technology to power efficient, economical and sustainable high efficiency and performance transit networks. Magline technology comprises pivotal developments that overcome the technical and economic limitations that have prevented the widespread adoption of maglev drive systems. These advances include innovations in suspension, power train, track and switching. Magline is nearly silent and frictionless and runs on any source of electric power, including solar, wind and hydro.

Magnovate is the lynchpin of a consortium that includes several multi-billion dollar international industrial leaders who are all committed to creating a complete maglev transportation industry in Canada. The Magnovate consortium will provide end-to-end services, from planning and analysis, infrastructure and vehicle manufacturing and operations, to ticket, routing, and condition based maintenance.

1.2 The Consortium

Magnovate's engineering and science partners have worked on maglev satellite launch systems, and invented maglev heart valves… and now the first maglev automated transit system with passive switching capabilities. Our industrial consortium includes:

Lockheed Martin: This aerospace leader will be the systems integrator for the Maglev Ride at the Toronto Zoo.

PCL Construction: PCL's civil construction companies possess the ingenuity and the experience needed to undertake any civil structure imaginable, from bridges, overpasses, tunnels and interchanges, to water treatment facilities, pipelines, and light-rail transportation projects; with competitive pricing, financial strength, and integrity.

Stantec Engineering: Stantec's leadership and experience in transit infrastructure extends to some of the most innovative systems in North America, including management of complete light rail projects, track work, design of individual components, stations, bridges, and mechanical and electrical systems. Stantec will support the Condition Based Maintenance program of all Magline systems.

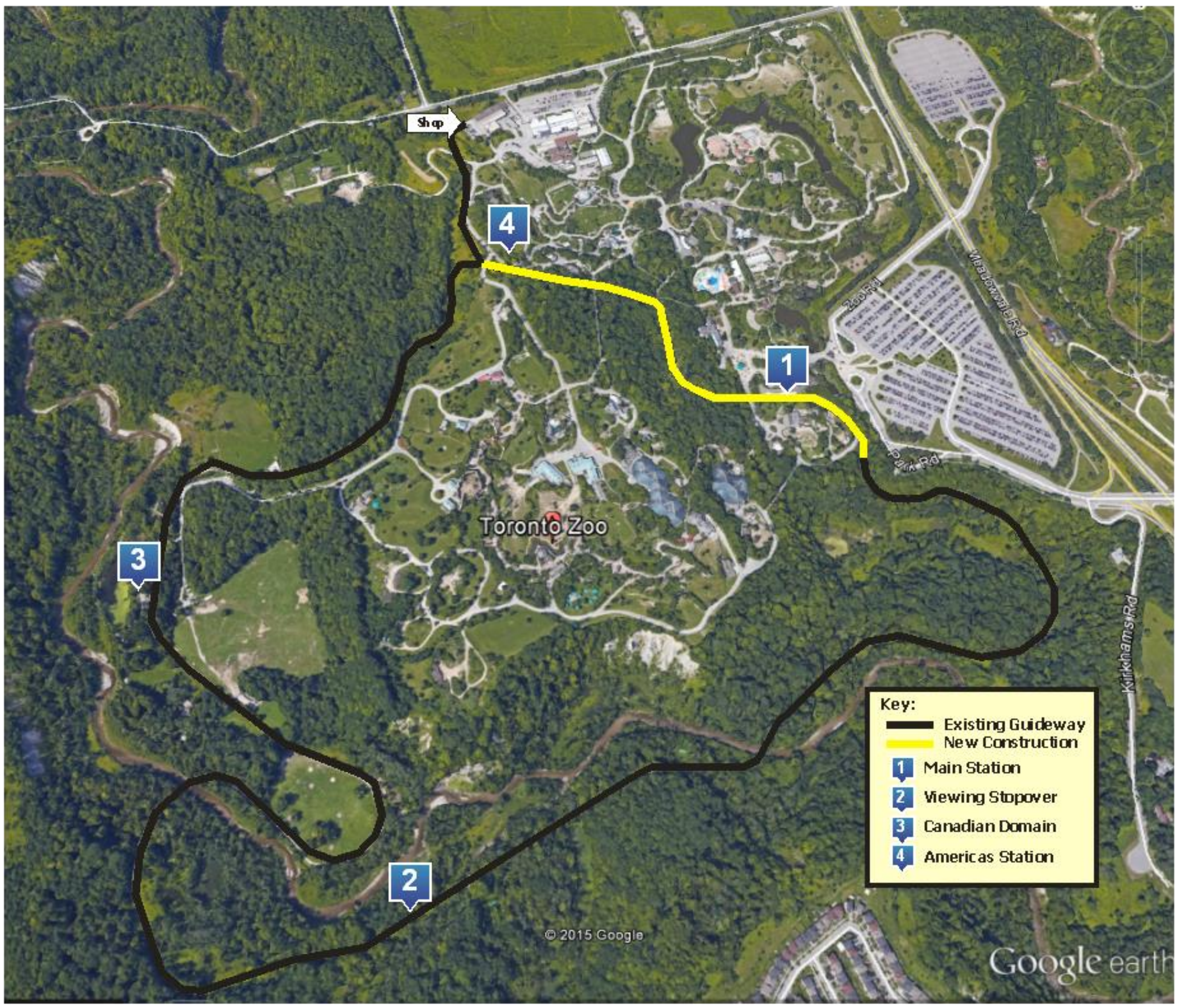
Magna International: Magna, the most diversified automotive supplier in the world, will build Magline vehicles. Magna has 305 manufacturing operations and 88 product development, engineering and sales centers in 27 countries on five continents.

2. Proposal Overview

2.1 Zoo Transit System

Magnovate proposes to build a Maglev Ride on the guideway and other existing ride infrastructure at the Toronto Zoo. A map of the ride is depicted below.

Maglev Ride Map



2.2 Synergies

The proposed project will accomplish several goals important to the mission of the Toronto Zoo and to Magnovate.

Toronto Zoo: As one of the top Zoo's in the world the Toronto Zoo has taken a leadership role in green initiatives and in reducing its ecological footprint. To fulfill its mission and progress towards realizing its vision the Toronto Zoo has set out a strategy that includes investing in the Zoo's infrastructure and support systems with a commitment to state-of-the-art facilities, equipment and environmental best practices.

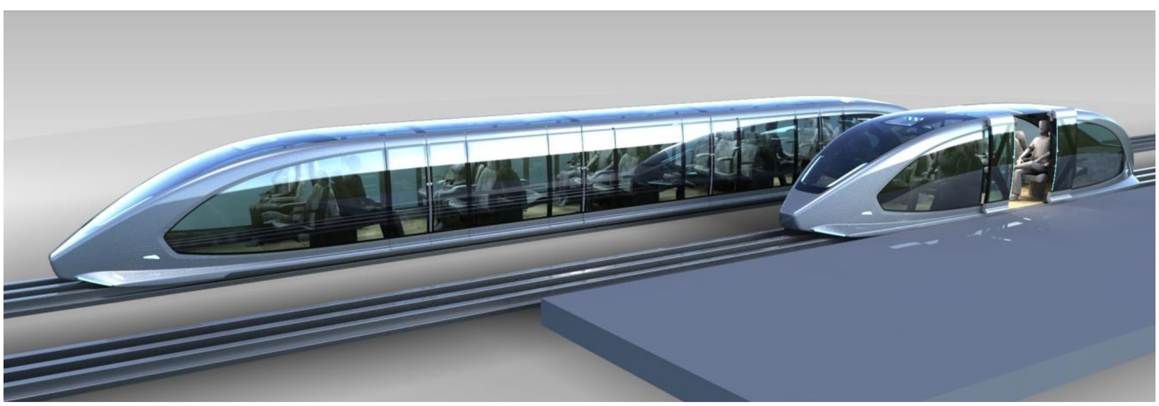
Magnovate: Magnovate has developed and tested prototypes of Magline, a breakthrough green and sustainable transit system. The existing infrastructure at the Zoo would be an ideal place to begin building the world's first commercial Magline system. It is well matched to Magline technology from a structural perspective, and obviates the substantial cost of building infrastructure from scratch for our development program.

2.3 Proposal

Magnovate proposes collaboration with the Toronto Zoo to build a Maglev Ride on the zoo campus that will not only serve the practical transportation needs of visitors, but also create a new attraction to bring visitors desirous of riding on the first commercial maglev transit system on our continent.

2.4 Technology

Magnovate's technology is a breakthrough development of maglev (magnetic levitation) propulsion. It is a silent, frictionless and highly energy efficient powertrain that can run without recourse to carbon-based fuels. Solar panels mounted on stations and on other elements of the infrastructure can supply much of the system's day-to-day power requirements.[1]



[1] A more complete discussion of Magline Technology is included in Appendix A.

3. Objectives

3.1 Toronto Zoo Objectives

- **Maglev Ride**: Provide visitor transit so that it is easier for small children, mobility impaired and seniors to enjoy the Canadian Domain and other distant exhibits.
- **Environmental Leadership:** Express in a tangible, powerful way the zoo's commitment to energy efficiency, green and sustainable business practices. Tangibly exhibit Toronto Zoo's leadership in fighting global climate change.
- **Public Relations/Marketing**: Installation of the Maglev Ride at the Zoo is a genuinely newsworthy event. Local and national press will cover the story and that will create a substantial wave of interest and positive coverage. It will enhance the stature of the Zoo and bring visitors.
- **Added Attraction**: Building a modern and truly unique transit system creates a new attraction to the Zoo. Some people who may not have otherwise visited may come to see and experience the Maglev Ride. Word of mouth about the attraction will result in repeat visitors to the Zoo.
- **Revenue**: Ticket sales for the new ride will grow Zoo revenue by attracting new guests and more revenue per visitor.
- **Low Capital Outlay**: The new Maglev Ride will be designed to make maximum use of the existing infrastructure including rights of way, stations, and towers which will minimize capital expenditures. Further, the Magnovate Consortium and Sustainable Technology Development Canada will contribute considerable resources.

3.2 Magnovate Objectives

- **Commercial Installation**: The Toronto Zoo represents a unique opportunity because so much of the Domain Ride infrastructure remains in place.
- **Showcase**: This project represents a breakthrough opportunity to introduce this cutting edge technology to the market place, to the press, to the general public, to government agencies, to investors and to both public and private prospects from all over the world.
- **Sustainable Development Technology Canada**: This project is a keystone to completion of our quest to qualify for coordinating funding and business development support from SDTC.

4. Work Plan & Deliverables

4.1 Three-Phase Project

The project is designed with three major phases. For Phase 1, we will analyze, design, construct and test a full scale Maglev vehicle specific to the Maglev Ride. In Phase 2, we will construct the full scale track and integrate the control system. In Phase 3 we will test the system on site at the Zoo. Note that some of the development activities of the three phases will overlap with each other. A detailed Gantt chart is included in Appendix C.

- **Phase 1:Full-scale Maglev Lab Test System**

  Timeline: 15 months

A full-scale laboratory test vehicle will be designed, constructed, tested and refined until it meets Phase 2 operational requirements. The vehicle will include a fully functional maglev suspension, low-power linear motor, digital control system, and off-board power supply. A test track will be designed and constructed, including one second-generation maglev switch and 20 meters of track. Operational requirements will include stable levitation during acceleration, deceleration, and transition through the switch before advancing to Phase 2.

- **Phase 2: Production Maglev Demonstration System**

  Timeline: 24 months

Production-quality vehicles will be designed, constructed, and tested on the Phase 2 track. The vehicles will include the same operational features as the Phase 1 vehicle but will use production quality materials and components. The passenger cabins will include full amenities, including HVAC and an entertainment system. Production quality track elements and segments will be designed, fabricated and tested on the Phase 2 track. Production drawings for the vehicles and track elements will be produced. A traffic control system will be deployed and tested on the Stage 2 track.

- **Phase 3: Commisioning/Safety Certification**

  Timeline: 7 months

Work with the TSSA and Transport Canada to obtain safety certification then begin commercial operations.

4.2 Budget

Maglev Ride Budget			
15 months			
1) Site-Specific Detailed Engineering	**Cost**	**% of Milestone**	**% of Total**
Project Management/Customer interface	175,000	17.5%	
Systems Engineering Management	90,000	9%	
Vehicles	75,000	7.5%	
Suspension	125,000	12.5%	
Magnetic Tracks	50,000	5%	
Maintenance Yard / Equipment	10,000	1%	
Energy Supply Systems	75,000	7.5%	
Command and Control System	260,000	26%	
Guideway Structure	70,000	7%	
Project Integration	70,000	7%	
Total	**$1,000,000**	**100%**	**5%**
24 months			
2) Construction	**Cost**	**% of Milestone**	**% of Total**
Project Management/Customer interface	850,000	5%	
Systems Engineering Management	700,000	4%	
Manufacture 12 Vehicles	4,200,000	19%	
Suspension	400,000	2%	
Magnetic Tracks	7,500,000	40%	
Energy Supply Systems	530,000	3%	
Command and Control System	368,000	2%	
Guideway Structure	4,000,000	22%	
Station renovations	330,000	1.0%	
Project Integration	368,000	2%	
Total	**$19,246,000**	**100%**	**92%**
7 months			
3) Commissioning	**Cost**	**% of Milestone**	**% of Total**
Project Management/Customer interface	100,000		
Safety Planning 4%	20,000	4%	
Failure Mode Effects Analysis	20,000	4%	
Test Planning 5%	25,000	5%	
Component Acceptance Test	80,000	16%	
System Acceptance Test	90,000	18%	
Training	30,000	20%	
Energy	65,000	13%	
Project Integration	170,000	20%	
Total	**$ 600,000**	**100%**	**3%**
Total Project Value	**$20,846,000**		100.00%
Total with Contingency (20%)	**$25,015,200**		

5. Controls & Constraints

5.1 Project Management Controls

The Magnovate Consortium will deploy the best practices of engineering project management to assure that the new Maglev Ride achieves the highest levels of quality and safety in its construction and operation. The sections that follow are an outline of the methodology that the Consortium will use. We will develop specific detail as part of the System Requirements Review and Preliminary Design Review, described below.

System Requirements Review (SRR)

This review examines the functional and performance requirements defined for the system by Toronto Zoo and the Magnovate Consortium and drafts the preliminary project plan. This is to ensure that the requirements and the selected concept will satisfy the overall mission of both parties.

Preliminary Design Review (PDR)

The preliminary design review documents that the initial design meets all system requirements with acceptable risk and within the cost and schedule constraints while establishing the basis for proceeding with a detailed design. It will show that the correct vehicle, infrastructure and control design options have been selected, and that all interfaces have been identified, and verification methods described.

PDR Objectives:

- Ensure that all system requirements have been allocated, the requirements are complete, and the flow down is adequate to verify system performance
- Show that the proposed design is expected to meet the functional and performance requirements
- Show sufficient maturity in the proposed design approach to proceed to final design
- Show that the design is verifiable and that the risks have been identified, characterized, and mitigated where appropriate

Critical Design Review (CDR)

The CDR demonstrates that the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration, and testing. CDR determines that the technical effort is on track to complete the Magline system development and ride mission operations while meeting performance requirements within the identified cost and schedule constraints.

Objectives:

- Ensure that the "build-to" baseline contains detailed hardware and software specifications that can meet functional and performance requirements
- Ensure that the design has been satisfactorily audited by production, verification, operations, and other specialty engineering organizations
- Ensure that the production processes and controls are sufficient to proceed to the fabrication stage
- Establish that planned Quality Assurance (QA) activities will establish perceptive

verification and screening processes for producing a quality product

- Verify that the final design fulfills the specifications established at PDR

Test Readiness Review (TRR)

Our TRR will ensure that the Magline infrastructure and vehicles, as well as the test facility, support personnel, and test procedures are ready for testing and data acquisition, reduction, and control.

5.2 Independent Review/Oversight

In addition to the best practices described above, the Magnovate Consortium proposes an additional measure to manage risk and help ensure the successful development and safe operation of the new Maglev Ride. The Consortium will arrange for the participation of an independent review/oversight organization, Urban Systems Laboratories (Urban Systems), to represent the interests of the Zoo and the appropriate municipal and provincial agencies throughout the project. The participation of Urban Systems will be funded through a cost-sharing arrangement in which the Consortium share is placed at the disposal of the Zoo and agencies to contract with Urban Systems for activities within the context of this specific purpose.

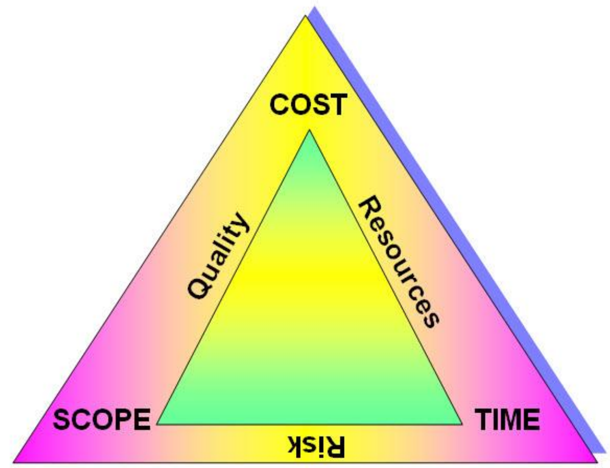
Urban Systems Laboratories is a U.S. non-profit dedicated to assisting governments in their efforts to develop large-scale technologies in support of smart/sustainable cities goals. It is uniquely qualified to serve the interests of the Zoo and government authorities on the new Maglev Ride project as it is the only organization with expertise in Automated Transit Networks that has an expressed non-advocacy, public-interest charter. Under its Pathfinder Cities Program, it is currently working with the City of San José, CA to put in place a comprehensive, full-scale, ATN development program to meet that city's needs.

Urban Systems will perform objective analyses and oversight relating to requirements definition, system architecture and evolution trade studies, technical and programmatic review as part of the design review process described above, independent cost and performance analyses, and, most importantly, interfacing with regulatory authorities to develop the necessary certification program that will ensure the safety and reliability of the attraction.

The inclusion of this independent analysis and review function is also important for another reason: just as the Maglev Ride project will serve as a demonstration of this new technology and add to the Zoo's revenue portfolio, the public-interest regulatory and certification standards that Urban Systems will develop in conjunction with the relevant authorities will serve as a foundation for broader local objectives. It will pave the way for other potentially more expansive and economically desirable applications that the City of Toronto may want to consider as part of its overall mobility and sustainability efforts, all with the confidence that the public's interest has been taken into account.

5.3 Constraints

Magnovate recognizes that the challenge of every project is to make it work within the classic Triple Constraint; the interaction of quality (scope), cost (resources) and schedule (time). These three elements of a project must necessarily work in tandem with one another. Where one of these elements is restricted or extended, the Project Manager must adjust the other two elements to re-balance. The Project Manager shoulders the ongoing responsibility to monitor, analyze, and re-balance the three elements by careful planning, ongoing coordination, thoughtful resourcing and expeditious execution. Magnovate will assure project success for the Toronto Zoo project by coordinating activities and deliverables.



- **<u>Rigorous Review Process:</u>** The Magnovate Consortium will implement a thorough planning, testing and review methodology as outlined in section 5.1. A Gantt chart and resource diagram will be created to monitor the timeline, budget, percentage of completion for each milestone, and dependency relationships.
- **<u>TSSA Approval:</u>** Magnovate will engage with the TSSA in year one of the project to develop a plan for achieving TSSA approval so that the Magline ride will be certified to transport passengers by the end of the project.
- **<u>Environmental Approvals:</u>** Our consortium partner, Stantec Consulting, will work with environmental authorities to obtain all necessary environmental approvals.

6. Reporting & Project Management

6.1 Milestone Reports

As the project proceeds through a series of milestones, the project team will report on the results of the prior milestone and produce specific plans for the upcoming milestone using the format below.

<table>
<tr><th colspan="2">Milestone #:</th><th>1</th><th>Activity Period</th><th>[DATE]</th><th>to</th><th>[DATE]</th></tr>
<tr><td colspan="2">Objective:</td><td colspan="5">Complete a revised preliminary project plan and determine the functional and performance requirements for the system</td></tr>
<tr><td>Item</td><td colspan="2">Milestone Deliverable</td><td colspan="2">Metrics/Success Criteria</td><td colspan="2">Completion Date</td></tr>
<tr><td>1</td><td colspan="2">System Requirements</td><td colspan="2">System Requirements Review/The requirements and selected concept satisfy all project goals</td><td colspan="2">[DATE]</td></tr>
<tr><td>2</td><td colspan="2">Preliminary Project Plan</td><td colspan="2">System Requirements Review/The plan incorporates any changes due to results of development work prior to project start and includes all tasks required to accomplish project goals within the cost and time allotted</td><td colspan="2">[DATE]</td></tr>
</table>

6.2 Report Format

The project team will produce reports in a form and level of detail as agreed between the team and the Toronto Zoo management.

7. Magnovate& Toronto Zoo Responsibilities

7.1 Magnovate Consortium & Responsibilities

The Magnovate Consortium will assume responsibility for design, construction and testing of the Toronto Zoo project, with the following understandings:

- **Collaboration on Design:** The Consortium and the Toronto Zoo will collaborate and cooperate in good faith to achieve the agreed project mission.
- **Costs:** Magnovate will assume full responsibility for financing the project and for coordinating, and raising, all necessary funding to complete the project.
- **Operations:** Magnovate will be responsible for the maintenance of the equipment and infrastructure after implementation.
- **Difference Resolution:** The Consortium and the Toronto Zoo will conduct ad hoc meetings as necessary and regular scheduled meetings to discuss all aspects of the project. The parties agree to negotiate in good faith to resolve any and all differences that may arise. Where negotiations prove ineffective, the parties agree to an informal mediation process.

7.2 Pricing/Ridership & Revenue

The Toronto Zoo offers several rides/climb, the prices of these are as listed below.

- TundraAir Ride, Cost per ride is $12.00 or four tickets for $40.00
- Gorilla Climb Ropes Course, Cost per climb is $8.00
- Zoomobile Ride Ride-all-day pass costs $8.00, and four ride-all-day passes cost $28.00

The estimated optimal price for the Maglev Ride at the Toronto Zoo is $12.00, which is reasonable compared to above benchmarks. However, due to the high-quality service and excellent view of the zoo provided by the Maglev Ride, it is possible that the revenue could be further enhanced if more information is available such as a preference survey conducted on existing and potential zoo visitors.

Historical Domain Ride Ridership

The Toronto Zoo Domain Ride was in service from 1976 to 1994. The historical Toronto Zoo Domain Ride ridership is shown below. It can be seen from that the percent of Toronto Zoo visitors that chose to ride the Domain Ride was 27 to 30 percent of the total zoo attendance with the average capture rate of 28%. The ridership ranged from 298,039 to 353,995 from 1990 to 1993.

Toronto Zoo Domain Ride Ridership

Year	Zoo Attendance	Domain Ride Ridership	Percent of Zoo Visitors for Domain Ride
1990	1,194,143	353,995	30%
1991	1,282,595	353,203	28%
1992	1,122,700	298,039	27%
1993	1,186,001	327,029	28%

Source: Attendance and ridership data provided by Toronto Zoo

Historical Toronto Zoo Attendance

The Zoo attendance from 2009 to 2013 is shown below:

Year	Zoo Attendance
2009	1,459,574
2010	1,308,788
2011	1,241,695
2012	1,286,673
2013	1,462,910
Average	**1,351,928**

Source: Attendance data provided by Toronto Zoo

Ridership and Revenue Projection

Magnovate has based the ridership projections on the assumption that the Maglev Ride will have the same average capture rate as the Domain Ride (28%) and that the average attendance (1,352,000) will result in annual ridership of **378,560**. Therefore, with a ticket price of $12, the annual revenue is expected to be **$4,542,720**.

7.3 Benefits/Risk Sharing

- Magnovate has paid for a guideway inspection that was performed by Stantec which concludes that the existing structure is in very good condition.
- The Liability is solely Magnovate's for the first 5 years. Magnovate will assume full responsibility for expenses caused by or arising out of the acts, omissions, errors or negligence of Magnovate during the 5 year period. The Zoo will assume liability when the Maglev Ride is accepted by the Zoo after 5 years.
- Magnovate will be responsible for the maintenance of the equipment and infrastructure after implementation. After 5 years Magnovate agrees to continue maintaining the Maglev Ride on a service agreement basis and provide access to replacement parts and to qualified technicians to perform regular maintenance and repairs. Subsequent to the completion of the Maglev Ride at the Toronto Zoo, Magnovate has a number of significant maglev deployments lined up that will be deployed from 2020-2030, so the Toronto Zoo can be assured that it will have access to replacement parts and a robust team of technicians to ensure that the Maglev Ride is serviced properly.
- Magnovate and the Toronto Zoo will share the revenue on a 50/50 basis with financing costs coming out of operating revenue.
- In recognizing that visitor attendance drops in the off-season Magnovate will establish an operating reserve fund as a contingency to ensure that operations can be paid for in the case that revenue from ticket sales is not sufficient in certain months.
- The term of the revenue share agreement shall be 5 years.

7.4 Contract Terms

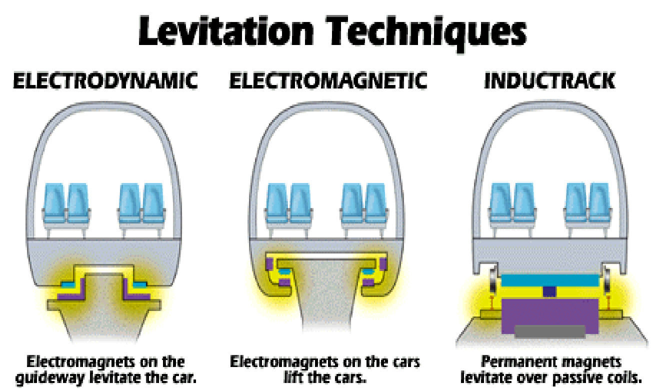
- Magnovate will assume full responsibility for raising and coordinating funding to complete the Project.
- Magnovate and the Toronto Zoo will cooperate on securing pending government grant funding and other relevant sources of financing.
- Specifications and milestones for the project plan will be agreed on in advance.
- Magnovate will operate and maintain the ride for a fee that is agreeable to Magnovate and the Toronto Zoo. Operations and financing will be paid out of the total revenue and then Magnovate and the Toronto Zoo will share the revenue on a 50/50 basis.

Appendix A: MaglineTechnology

Maglev Technology

Magnetic levitation (maglev) using magnetic forces to float a vehicle on a guideway eliminates traction and friction and so enables quick acceleration and deceleration and very high speeds. Maglev is also unaffected by weather and uses less energy than conventional high speed rail. Cars riding on magnetic cushions are quiet, smooth and comfortable. Reduced friction has made maglev trains that were built as demonstration projects to showcase the technology to hold the speed record for rail transportation for decades. Eliminating friction also reduces energy use quite substantially, especially in low speed installations. Presently, there are two commercial maglev trains in operation, with two others under construction. The Transrapid in Shanghai, began commercial operations in 2004, and the Linimo began relatively low-speed HSST operations in Japan in March 2005.

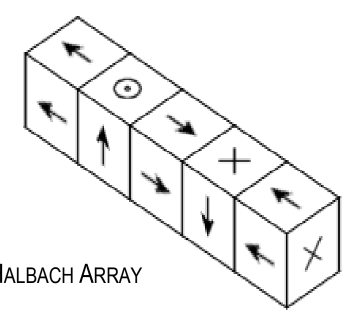
Generally, a horizontal set of magnets levitates the vehicle vertically above the track and a vertical set at the sides stabilizes the vehicle from side to side and keeps it on the track. With conventional maglev, narrow levitation gaps must remain in precise and stable alignment. In virtually all current designs, either the suspension components must wrap around the track edges or the tracks must wrap around the suspension, making switching cumbersome, slow and expensive. Due to these and other technical limitations, only two maglev systems are currently under construction; one in China and another in South Korea.



Prefabricated, robust sections of precision concrete rail with magnetic materials embedded are expensive to fabricate, to transport to building sites, and to assemble and maintain in precise alignment. They also present enormous switching challenges. Tiny levitation gaps mean that heavy, cumbersome sections must be moved mechanically and realigned perfectly in order to direct a vehicle from one track to another. Slow switch speeds limit the performance and efficiency of high speed rail and so most installations comprise a single line connecting stations. Magline makes complex, intricate networks feasible as it cuts infrastructure costs.

Magline Solutions

Magline technology fundamentally alters the state of the art and vastly broadens the range of applications possible for maglev transit. The vertical levitation gap of Magline design is an order of magnitude larger than those of existing designs, obviating the need for close-tolerance track alignment, and permitting the use of lighter rails, bridges and other infrastructure to substantially reduce costs.

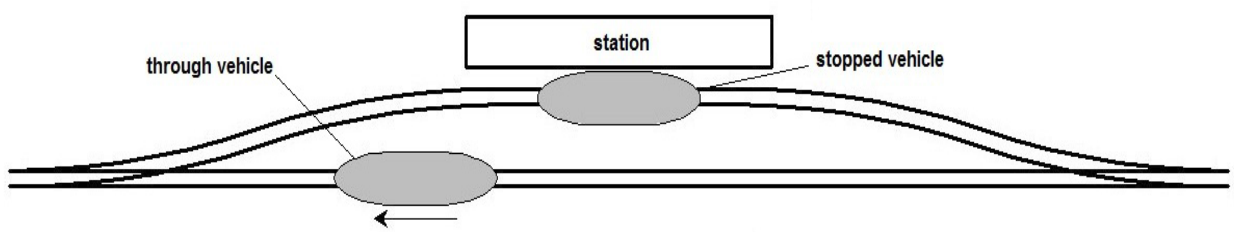


HALBACH ARRAY

Based on a "Halbach Array" of magnets, Magline technology can switch tracks without mechanically moving the guideway. It thus can achieve high-speed passive switching while maintaining lateral stability and directional control using much lighter guideways. Magline automation enables vehicles to run safely with short headways.

Lightweight Infrastructure

Lightweight infrastructure brings several advantages, especially when systems operate using off-line stations and individual vehicles instead of trains. Eliminating massive, heavy trains of cars further reduces the need for mammoth bridges and other extra heavy infrastructural components. Computer controlled individual vehicles running at short headway distances and high speeds can create many new operating efficiencies because they are able to bypass one another at stations and employ network routing. Off-line stations enable vehicles with no disembarking passengers to bypass stations where vehicles ahead may have stopped. That creates smooth traffic flows and stop-start efficiencies. Vehicles arrive more frequently and stop only where passengers aboard hold tickets, reducing wait and travel times.



Substantially less expensive infrastructure means developers can add more links, loops and hubs to create a larger network and to serve more populations even those remote from major cities. Bypassing "loops" off the main line bring operating advantages similar to off-line stations. The greater the number of hubs in the network, the greater the number of possible paths between destinations. Computers can reroute vehicles at every hub to avoid slow-downs.

Friction

Although most vehicles consume most energy to overcome air drag at speeds over 100 kph, thermal and frictional losses are also quite significant even at low speed. Maglev converts relatively small amounts of its power to heat losses and virtually none to mechanical friction. A maglev vehicle carrying four passengers and cruising at 120 kph would require about 7.5 kilowatts of power, or about 0.06 kWh per kilometer, costing about half a cent per km. An automobile that gets 50 km/gal costs more than 8 cents/km. Fuel savings and limited heat losses combine with low maintenance costs to achieve unprecedented low operating costs. Magline is the perfect choice for the Toronto Zoo, and it will herald many other new possibilities because it is sustainable, safe and automated transit with low power consumption while being very quiet and having smooth operation.

Appendix B: Maglev Ride Safety Features

Magnovate recognizes that safety is of primary importance to the Toronto Zoo. The following section provides an overview the Maglev Ride safety features and demonstrates how the safety and redundancy of the technology are clearly aligned with the safety priorities of the Toronto Zoo.

Safety and Redundancy of Magline

The vehicle control system architecture will be such that the probability of a complete power failure will be extremely low. Electronics will be implemented with the safety critical design tools used in commercial aircraft control design. In such flight control systems, the death rate associated with electronic system failures is less than one death per billion passenger hours of travel. By way of comparison, overall road travel and air travel numbers are ~330 and ~380 deaths per billion hours respectively. Conventional rail is much better with an overall death rate of ~20 deaths per billion hours [Norman Bradbury, "Face the facts on transport safety," Railwatch, pages 6-7, November 2002]. When expressed on a per-mile basis, air travel is very safe as is well-known.

The key system-level methods to ensure safe and reliable operation of electronic systems are *redundancy* and *fault-isolation*. In reference to the Figure 1 below, a non-redundant system has a given mean-time to failure (MTTF) and fails when a single subsystem has a fault. A brute force approach to improving safety is to add a copy of the original system in parallel and, assuming simple failure statistics, the MTTF is increased by only 50% as the rate of failure doubles until the first redundant system fails. However, by including means to isolate faulty subsystems and switch in back-up subsystems, a large number of faults can be tolerated as shown. As a result of fault-isolation architectures, extraordinary reliability and safety are achieved in commercial aircraft (see FAA FAR25.1309 and advisory circular AC25.13091A).

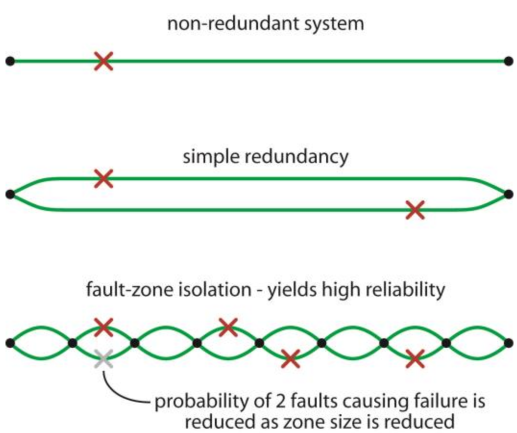


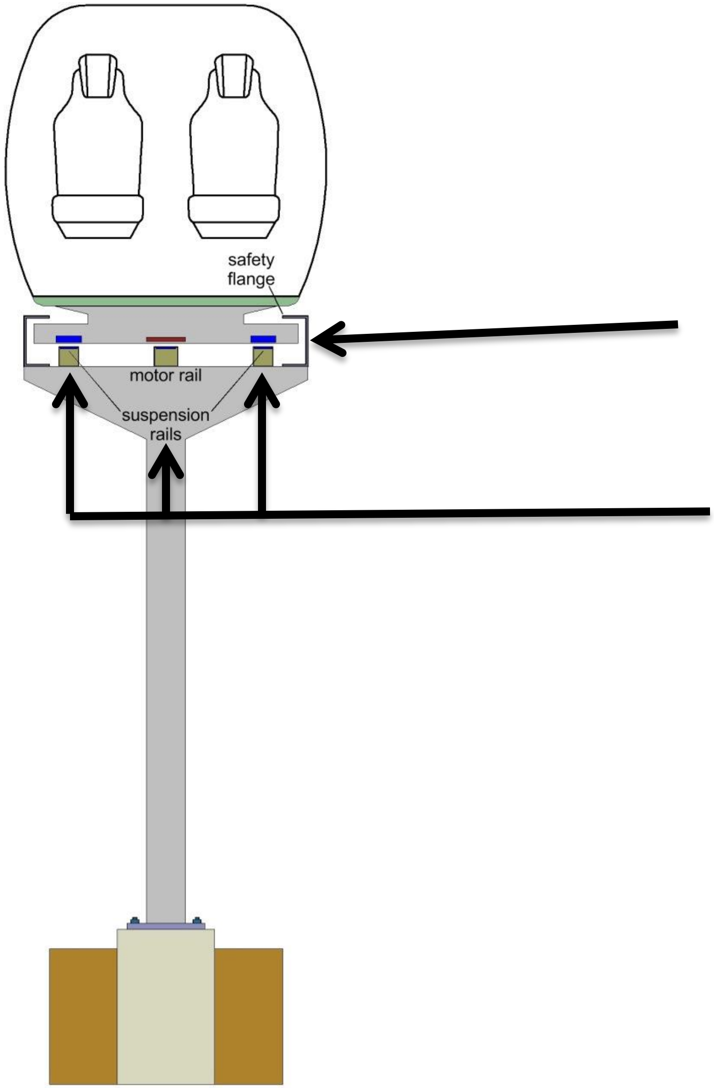
***Figure1*. Schematic diagram of electronic systems and fault tolerance.**

Consider, for example, the reliable operation of the Maglev vehicle power supply to the lateral control coils. The architecture consists of 3 power sources: a 3rd rail, generator coils on the vehicle coupled to the linear (short-stator) motor magnet array on the track, and back-up batteries. If the 3rd rail power or pick-up system fails, this subsystem is disconnected ("fault-isolated"), and the generator coils are used to convert kinetic energy of the vehicle to power for the electrical systems. The vehicle can then be safely decelerated and at some minimum threshold the back-up batteries provide power to a complete stop. Further, the back-up battery system will not be comprised of one large pack of cells and one large power electronics unit. Rather, it will consist of N smaller subsystems of which N-1 or N-2 are sufficient to power the lateral control. The details of such designs are assessed via a fault-tree analysis where probabilities are assigned to the branches and architectures are modified to meet specifications. Such analyses are based on well-established field data on electronic component failures.

Magnovate Transportation Inc

Toronto Zoo Maglev Ride – Safety Features

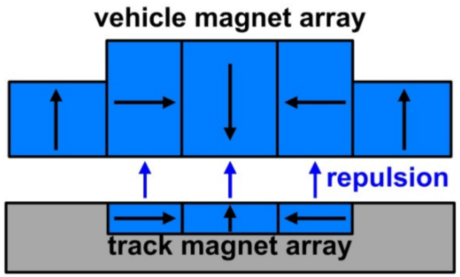
Guideway Configuration



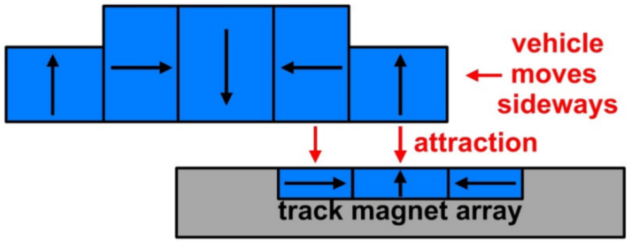
A safety flange prevents the vehicle from leaving the guideway under any circumstances.

The track consists of two suspension rails and one motor rail.

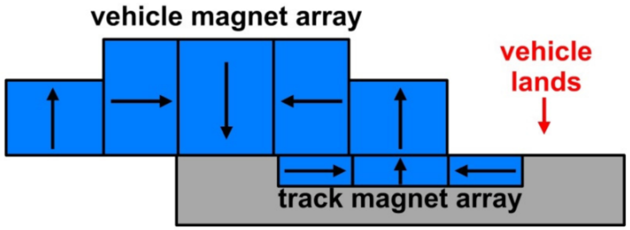
Emergency Brake Operation



Each suspension rail interacts with a magnet array on the vehicle. In normal operation electromagnets keep the vehicle arrays centered above the rails, where repulsive magnetic force levitates the vehicle.



Power cannot be interrupted unless there are multiple failures in the control system. Such an event would result in the magnetic levitation becoming magnetic attraction and cause the vehicle to move sideways and slowly come to a stop.



Brake pads control friction between the vehicle and rails while the safety flange limits sideways motion. After the cause of the problem is corrected, the vehicle can be re-levitated and returned to service.

Safety Features

Fail safe emergency braking requires no action by an operator or the vehicle control system – it happens automatically if the control system or vehicle power fails.

Regenerative electrodynamic brakes are highly reliable due to few moving parts and will be included on the vehicles for use during normal operation.

Redundant systems ensures there's always a backup.

Levitation eliminates friction resulting in higher reliability due to less wear and tear.

Automated control eliminates driver errors.

Appendix C: Gantt Chart

Gantt Chart - Toronto Zoo Maglev Ride Development

Task	Task Lead	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1. Project Management/Customer interface	Magnovate																																	
2. Safety Planning/Test Planning	Urban Systems																																	
3. Systems Engineering Management	Magnovate																																	
4. Environmental Approval	Stantec																																	
5. Vehicle Development	MetalBoss																																	
a. Vehicle exterior design	MetalBoss																																	
b. Cabin interior design, selection of components	MetalBoss																																	
c. Tooling design	MetalBoss																																	
a. Build tooling for one prototype vehicle	MetalBoss																																	
b. Procurement of components	MetalBoss																																	
c. Assemble 1 prototype vehicle	MetalBoss																																	
d. Test prototype vehicle	Magnovate																																	
e. Design iteration (if necessary)	MetalBoss																																	
f. Manufacture 11 production vehicles	Magna																																	
Chassis/Frame	Magnovate																																	
a. Structural design/analysis	Magnovate																																	
b. Detailed design	Magnovate																																	
c. Generate drawings and specifications	Magnovate																																	
d. Fabrication and assembly	MetalBoss																																	
Propulsion	Magnovate																																	
a. Propulsion system trade studies	Magnovate																																	
b. Motor specifications	Magnovate																																	
c. Motor electronics design/analysis	Magnovate																																	
d. Motor electronics procurement/assembly	Magnovate																																	
e. Build and test demonstrator coil/magnets	Magnovate																																	
f. Incorporation of lessons learned into final design	Magnovate																																	
g. Motor coil assembly manufacture	Magnovate																																	
Lateral control	Magnovate																																	
a. Lateral control system design/analysis	Magnovate																																	
b. Procurement, assembly & test of a demonstrator	Magnovate																																	
c. Design improvements	Magnovate																																	
d. Lateral control subsystem manufacture	Magnovate																																	
Vertical control	Magnovate																																	
a. Verticalcontrol system design/analysis	Magnovate																																	
b. Procurement, assembly & test of a demonstrator	Magnovate																																	
c. Design improvements	Magnovate																																	
d. Vertical control subsystem manufacture	Magnovate																																	
On-vehicle power generation/storage	Magnovate																																	
a. Develop procurement specifications	Magnovate																																	
b. Detailed design of mechanical parts, test equip	Magnovate																																	
c. Manufacturing/procurement of components	Magnovate																																	
Signaling System	Lockheed Martin																																	
a. Requirement generation	Lockheed Martin																																	
b. Design modeling and simulation program	Lockheed Martin																																	
c. Develop modeling and simulation program	Lockheed Martin																																	
d. Develop signaling system	Lockheed Martin																																	
e. Install and test signaling system	Lockheed Martin																																	
6. Track Development	Magnovate																																	
a. Suspension rail magnet design/analysis	Magnovate																																	
b. Motor rail magnet design/analysis	Magnovate																																	
c. Prototype magnet fabrication (short test track)	Magnovate																																	
d. Manufacture straight track sections	Magnovate																																	
e. Bifurcation fabrication	Magnovate																																	
f. Installation of track on guideway	Magnovate																																	
7. Guideway	Stantec																																	
a. Guideway drawings	Stantec																																	
b. Design pre-cast concrete forms	Armtec																																	
c. Construction planning	Armtec																																	
d. Clean/pressure wash existing guideway	PCL																																	
e. Manufacture guideway	Armtec																																	
f. Install guideway	Armtec																																	
8. Station Renovations	PCL																																	
a. Renovation planning/Materials list	PCL																																	
b. Order materials	PCL																																	
c. Renovate stations	PCL																																	
9. System level assembly, integration, preliminary testing	Lockheed Martin																																	
a. Single vehicle tests on track	Lockheed Martin																																	
b. Vehicle performance limit testing	Lockheed Martin																																	
c. Multiple vehicle tests on track	Lockheed Martin																																	
10. Commissioning	Urban Systems																																	
a. Safety testing	Urban Systems/Transport Canada																																	
b. Failure Mode Effects Analysis	Urban Systems																																	
c. Component Acceptance Test	Urban Systems																																	
d. System Acceptance Test	Transport Canada																																	
e. Employee Training	Magnovate																																	
11. Grand Opening	Toronto Zoo/Magnovate																																	