MagneTruck™: A New Concept for Zero-Emission Goods Movement

Presentation to Port of Los Angeles
18 March 2009
Agenda

• **General Atomics Overview**
  - Company History
  - Relevant Programs and Technologies

• **Concepts for Port-Related Transportation**
  - Overview
  - ECCO™ Maglev Systems
  - LIM-Rail™ Systems
  - Road Systems

• **Business Considerations**
  - Risk and Return
  - Strategy
  - Open Discussion of Port Needs and Potential Opportunities
GENERAL ATOMICS OVERVIEW
### Key General Atomics Business Areas

**Founded:** 1955  
**Ownership:** Privately Held  
**Employees:** Over 5,000 Worldwide

<table>
<thead>
<tr>
<th><strong>Defense</strong></th>
<th><strong>Energy</strong></th>
<th><strong>Transportation</strong></th>
</tr>
</thead>
</table>
| - UAV Systems  
- Advanced Sensors  
- Naval Ship Electrification  
- Weapons Destruction  
- EMALS/AAG  
- Rail-Guns  | - Fusion  
- Fission Reactors (HTGR)  
- Uranium Mining  
- Algae Synfuels  | - Linear Motor Transportation Technologies  
- Maglev Systems  
- Streetcar Refurbishment  
- Mining Truck Drives  |
Electric Transportation Technologies Use Core GA Competencies

Inverters for 400-ton mining trucks, light and heavy rail

Linear electric propulsion, control, and train protection systems for ECCO Maglev

Launch systems with 50-year design life in full-scale development

All electric truck uses existing chassis replacing the diesel engine with an all-electric drive-train and onboard energy storage system (patent pending).

Linear motor imbedded below road surface propels the vehicle and charges the energy storage system while vehicle is automatically transported to its destination (patent pending).
ElectroMagnetic Aircraft Launch (EMALS) and Recovery (AAG) Systems

GA EMALS Land-Based Testing Using Full-Scale 150 ft Long Launch Motor in Lakehurst, N.J.

9,800 lbs. @ 150 knots (173 mph)
GA Maglev Projects

FTA Urban Maglev

California-Nevada Maglev

Air Force Holloman

ECCO System

< 100 mph

> 240 mph

Mach 10
CONCEPTS FOR PORT-RELATED TRANSPORTATION

• Overview
• ECCO Maglev Systems
• LIM-Rail™ Systems
• Road Systems
Evolution from Maglev to MagneTruck™

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009

Urban Maglev Program
- Funded by FTA and Penn DOT, with GA cost share
- Licensed Livermore “Halbach Array” maglev technology
- 400-foot test track demonstrates proof-of-concept in 2004
- Developed levitation, propulsion, guidance, control, and ATP

Electromagnetic Cargo Conveyor (ECCO)
- ECCO concept using maglev for goods movement originated by CSULB
- Developed for port applications using same GA passive maglev (“Halbach Array”) technology as Urban Maglev Program

Existing Infrastructure Solutions
- Concepts using existing rail (e.g., LIM-Rail)
- Concepts that can operate at port terminals
- Concepts that can operate on existing roads
## Family of Linear Motor Applications

<table>
<thead>
<tr>
<th>New Rolling Stock</th>
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<tbody>
<tr>
<td><strong>ECCO™ Maglev</strong></td>
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<tr>
<td>• Long-distance routes</td>
</tr>
<tr>
<td>• Regional solution</td>
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<table>
<thead>
<tr>
<th>Existing Rolling Stock</th>
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<tbody>
<tr>
<td><strong>ECCO-Truck™ Maglev</strong></td>
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<tr>
<td>• Medium-distance routes</td>
</tr>
<tr>
<td>• Eliminates extra “lifts”</td>
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<table>
<thead>
<tr>
<th>Maglev Guideway</th>
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</thead>
<tbody>
<tr>
<td><strong>UM-Rail™ (Train Retrofit)</strong></td>
</tr>
<tr>
<td>• Rail yards</td>
</tr>
<tr>
<td>• Shuttle Trains</td>
</tr>
<tr>
<td>• Alameda Corridor</td>
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<table>
<thead>
<tr>
<th>Conventional Rail</th>
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</thead>
<tbody>
<tr>
<td><strong>UM-Rail™ (Truck Carrier)</strong></td>
</tr>
<tr>
<td>• Short to medium routes</td>
</tr>
<tr>
<td>• Roll-on/Roll-off</td>
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<table>
<thead>
<tr>
<th>Maglev Guideway</th>
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</thead>
<tbody>
<tr>
<td><strong>MagneTruck™</strong></td>
</tr>
<tr>
<td>• Terminal operations</td>
</tr>
<tr>
<td>• Freeway truck lanes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conventional Roadway</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MagiCarpet™</strong></td>
</tr>
<tr>
<td>• Weigh stations</td>
</tr>
<tr>
<td>• Border crossings</td>
</tr>
</tbody>
</table>
CONCEPTS FOR PORT-RELATED TRANSPORTATION

- Overview
- ECCO Maglev Systems
- LIM-Rail™ Systems
- Road Systems
ECCO™: Maglev for Freight Movement

First's First Cargo Maglev Move – June 8, 2006
LSM Coils Being Assembled on Guideway Weldment
New Optimized Maglev Chassis on Track
• Eliminates need for container lifts - trucks roll on and off system
• Uses 2 ECCO chassis units - can operate without levitation for on-port operations
• Uses a two-bogie system for tight turn radius
• Supports both diesel and alternative fuel trucks - including electric
• Charges electric trucks with on-board charger driven by the LSM
CONCEPTS FOR PORT-RELATED TRANSPORTATION

• Overview
• ECCO Maglev Systems
• LIM-Rail™ Systems
• Road Systems
LIM-Rail™ - Truck Carrier Option

- Runs on standard rails - elevated or at grade
- Uses standard 2-bogie flat car - allowing for tight turn radius
- Trucks can roll on and off - no container lifts!
- Supports both diesel and alternative fuel trucks - including electric
- Charges electric trucks with on-board charger driven by the LSM
“Circulator” System Configuration
**LIM-Rail™ - Train Retrofit Options**

- **Freight trains**
  - Rail yards
  - Ports
  - Alameda Corridor

- **Commuter rail**
  - Replace diesel engines
  - Replace overhead electric “catenary” lines

Aluminum reaction plate, mounted to bottom of vehicle, is “pulled along” by the moving magnetic field generated by the linear motor in the track.
CONCEPTS FOR PORT-RELATED TRANSPORTATION

- Overview
- ECCO Maglev Systems
- LIM-Rail™ Systems
- Road Systems
LSM Motor Modules for Road Applications*

- Simple modular design - minimum impact during construction
- Efficient electric linear motor - minimizes operating costs
- No moving parts - minimizes maintenance costs
- Provides continuous all-electric operation - no plug in required
- Automated operation - high throughput capabilities

* Patent Pending
1. During manufacturing, linear motor is encased in a concrete mold.

2. In road to be electrified, excavate a trench (~18” deep x 71” wide).

3. Install linear motor block segments into roadway and connect electrical windings.

4. Equip existing or new electric trucks with reaction plates or magnets.
MagiCarpet™ Truck-Mover Concept

- Accommodates existing trucks
  - Trucks drive onto rolling platform
  - Engine is turned off
  - Permanent magnets in platform react against linear motor in road to pull truck

- Applications
  - Short low speed routes
  - Examples: border crossings, weigh stations, possibly port terminal applications?
Electric vehicle uses onboard batteries while operating on conventional roadways.

While operating on linear motor-retrofitted road (or elevated guideway) segment, power is supplied by road/ guideway and batteries are simultaneously recharged.

**Benefits**
- Trucks operate in zero-emission mode 100% of time
- Eliminates need for heavy, expensive battery packs
- Vehicles are recharged “on the go” - do not need to be removed from service to recharge batteries
Typical Terminal Operating Scenario/ Energy Balance

Energy Balance for 1 Lap

<table>
<thead>
<tr>
<th>Energy (J)</th>
<th>Total energy input by LSM</th>
<th>Braking energy</th>
<th>Rolling resistance</th>
<th>Acceleration</th>
<th>Wind resistance</th>
<th>Net energy gain</th>
</tr>
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<tbody>
<tr>
<td>0.E+00</td>
<td>4.E+06</td>
<td>5.E+06</td>
<td>6.E+06</td>
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<td>1.E+06</td>
<td>2.E+06</td>
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<tr>
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<td>2.E+06</td>
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LEGEND
- BATTERY/MOTOR
- ACCELERATION
- LSM/GENERATOR
- DECELERATION

STOP TO UNLOAD
- Bridge Cranes
- 3-Empty 350m

STOP TO LOAD
- Deck Cranes
- 1B-Loaded 225m
- 1A-Empty 225m
- 4, Empty 450m**

* 0.6 mile range
** Minimum LSM length
MagneTruck™ Freeway Example: I-710

• **Getting onto I-710**
  - Driver maneuvers truck onto dedicated truck lane with linear motor in ground
  - Engine is turned off
  - Road provides power - driver just steers
  - Batteries are recharged

• **Getting off I-710**
  - Onboard electric drive motor activated
  - Vehicle steers onto offramp
  - Battery power used to get truck to its destination and then back to I-710
BUSINESS CONSIDERATIONS
GA Business Approach to Port Opportunity

• **Private Financing**
  - Meet port desire for private investment in system
  - Assemble strong financial team (ITSC, Macquarie, AECOM)

• **Technical Approach**
  - Must be driven by business considerations
  - Minimize up-front investment, technical risk
  - Capture enough business to yield an attractive return
  - Phase in more advanced capabilities as justified economically

• **Logical Evolution**
  - Near Term - Systems like MagneTruck™ that can use existing infrastructure
  - Longer Term - Systems like ECCO maglev with added benefits
Linear Motors: Already Proven in Transportation

Urban Light Rail Systems
- “Short-stator” linear motors installed on vehicles
- React against metal plate in track
- In passenger transport operations since 1987
- Examples: JFK AirTrain (New York), Detroit People-Mover

Maglev Systems
- Can use “short-stator” linear motors on vehicles or “long-stator” motors in guideway
- Transrapid system in passenger transport operations since 2005
- Other systems in development in U.S., Japan, Korea
## Electric Truck Capital Cost Comparison

<table>
<thead>
<tr>
<th></th>
<th>Battery-Electric Truck</th>
<th>Magne-Truck™</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery-electric operating range</td>
<td>50 miles</td>
<td>5 miles</td>
<td>All destinations are within 2.5 miles of linear motor roadway</td>
</tr>
<tr>
<td>Battery pack size</td>
<td>150 kWhr</td>
<td>15 kWhr</td>
<td>Truck consumes 3 kWhr of energy per mile</td>
</tr>
<tr>
<td>Battery pack cost</td>
<td>$150,000</td>
<td>$15,000</td>
<td>Battery pack costs $1,000 per kWhr of usable energy capacity</td>
</tr>
<tr>
<td>Magnet array and pickup system cost</td>
<td>$0</td>
<td>$35,000</td>
<td>$27,500 for magnets + $7,500 for supporting equipment</td>
</tr>
<tr>
<td>Total truck cost</td>
<td>$250,000</td>
<td>$150,000</td>
<td>Balance of truck costs $100,000 ($50K glider + $50K drive system)</td>
</tr>
</tbody>
</table>

ROM planning estimates - example only
## Life-Cycle Economics Comparison

<table>
<thead>
<tr>
<th></th>
<th>Battery-Electric Truck</th>
<th>MagneTruck™</th>
<th>Assumptions</th>
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</thead>
<tbody>
<tr>
<td><strong>10-year mileage</strong></td>
<td>500,000 miles</td>
<td>625,000 miles</td>
<td>Battery Truck: 4 RT/day x 250 days/year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MagneTruck™: 5 RT/day x 250 days/year</td>
</tr>
<tr>
<td><strong>Capital cost</strong></td>
<td>$250,000</td>
<td>$150,000</td>
<td>From previous page</td>
</tr>
<tr>
<td><strong>Battery replacement costs</strong></td>
<td>$150,000</td>
<td>$15,000</td>
<td>One battery pack replacement during 10-year operating life</td>
</tr>
<tr>
<td><strong>Maintenance costs</strong></td>
<td>$75,000</td>
<td>$45,000</td>
<td>3% of capital cost per year</td>
</tr>
<tr>
<td><strong>Energy costs</strong></td>
<td>$225,000</td>
<td>$281,250</td>
<td>45 cents/mile based on 15 cents/kWhr</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td>$700,000</td>
<td>$491,250</td>
<td></td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>$2,000,000</td>
<td>$2,500,000</td>
<td>$200 per round trip</td>
</tr>
<tr>
<td><strong>NET REVENUE</strong></td>
<td>$1,300,000</td>
<td>$2,008,750</td>
<td>Over 10 years, revenues minus costs</td>
</tr>
</tbody>
</table>

ROM planning estimates – example only
Transportation Electrification: Cost Impact
(Cargo Transport, Based on $8/gallon for Diesel Fuel)
# Public-Private Partnership Concept

<table>
<thead>
<tr>
<th><strong>Public Sector Role</strong></th>
<th><strong>Private Sector Role</strong></th>
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<tbody>
<tr>
<td><strong>Provide seed funding to mitigate risks</strong></td>
<td></td>
</tr>
<tr>
<td>- Environmental</td>
<td></td>
</tr>
<tr>
<td>- Right-of-Way</td>
<td></td>
</tr>
<tr>
<td>- Economic/Legal</td>
<td></td>
</tr>
<tr>
<td><strong>Grant maglev operating “concession”</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Establish Joint Powers Authority (JPA) to achieve above</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Build and operate maglev system</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Arrange for most of maglev construction financing</strong></td>
<td></td>
</tr>
<tr>
<td>- Debt</td>
<td></td>
</tr>
<tr>
<td>- Equity</td>
<td></td>
</tr>
<tr>
<td><strong>Bill users (passengers, shippers) for maglev use</strong></td>
<td></td>
</tr>
<tr>
<td>- Repay debt</td>
<td></td>
</tr>
<tr>
<td>- Earn return on equity investment</td>
<td></td>
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</table>
Electric Cargo Mover Business Model

Joint Powers Authority

JPA (Ports of L.A. & Long Beach, SCAG, other public entities)

Special Purpose Company

ITSC & Infrastructure Finance Partner(s) (e.g., Macquarie)

Finance

• Grants
• Bonds
• Loans
• Equity investors

Drayage Company (e.g., TTSI, UP, BNSF, Terminal Operator)

Operator

General Atomics

Technology Provider & Systems Integrator

Steamship Operators
Beneficial Cargo Owners (e.g., NYK, Target, SONY)

Users

TBD (e.g., AECOM, Parsons, Bechtel, ACS)

Construction Contractor
Conclusions

• Maglev and linear motor technologies have advanced considerably over the past decade

• Many innovative options exist for meeting port-related transportation needs

• We seek a business partnership with the ports and other stakeholders to determine the most cost-effective, profitable way to evolve linear motor-based systems