Thinking Outside the Transportation Technology Box
(or "How can Rocket Science Benefit Transportation?")

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Example of Transportation Inefficiency: The Space Shuttle

- Early concepts incorporated fully reusable design
- Low-maintenance, fast turn-around times (every 1-2 weeks)
- Limited budget drove final design that is high-maintenance, limited flight rate, and higher cost

Sacrificing Efficient & Sustainable Technologies for Near-Term Savings Costs More for Future Generations
Our Current Transportation Systems

- Depend primarily on century-old internal-combustion
- Should be just a means to an end (tool), not an end in itself
- Require large consumption of energy, land, other resources
- Inextricably tied to the economy ("Too big to fail")
  - Recall railroads of early 20th century
  - $8K per year per person to own a vehicle
  - $181 billion spent annually on highways alone
- Socially "unjust" for elderly, handicapped, youth
  - 3,500 teens killed in crashes (2008)
  - Over 2.3 million injured in accidents
- Highly inefficient
  - Energy (est. 80% of 171 bgal of fuel wasted)
  - Maintenance (infrastructure & vehicles)
  - Time (billions of hours wasted in traffic)
- Significantly impact the environment
  - Air, water, land, climate
  - Mitigations must be assessed for net impact
Why Do We "Settle" for What We Have

• What we imagine is primarily based on what we see or know
  - Surrounding environment, media

• We've become complacent, tolerant, and desensitized
  - Impacts on quality of life and environment
  - Gridlock, inefficiencies in service (among all sectors)

• "Solutions" only interim, not long-term
  - e.g., plug-in hybrids, single-engine taxi, biofuels

• We focus on enhancing existing, low-efficiency technologies

• We limit our own possibilities and miss opportunities for improvement

• We're stuck thinking "within the box"

• Robert Goddard: First liquid-fueled rocket (1926)
Start Thinking "Outside the Box"

What's possible is only limited by our imaginations
NASA Electromagnetics Launch (EML) Technology

- Studied and tested for over a decade
  - Idea has been around since 1970's
- EML for launch "assist"
  - Enable greater mass to orbit, fast-turnaround
- Recent collaboration focuses on two-stage-to-orbit (TSTO) and hypersonics

EML technology enables a robust, reusable launch system to provide greater mass-to-orbit capability
EML Technology: 3 Key Components

- **Linear Motors**
  - Induction
  - Synchronous

- **Magnetic Levitation**
  - Electrodynamic
  - Superconducting

- **Inductive Power**
  - "Wireless"
  - High power, large gap

These 3 technologies can help transform our transportation future.
Advantages of EML Technology for Space Vehicle Launch Assist

• More efficient and reliable
  - Less on-board fuel required >> Greater vehicle efficiency, more mass to orbit
  - Few or no moving parts >> Low maintenance, high multi-mission reliability
  - Fast turn-around/repeatability >> Operationally efficient; multiple launches/day
  - Fewer resource/personnel requirements >> Lower recurring costs

• Safer for ground and launch
  - Horizontal, low-elevation >> Easier prelaunch accessibility
  - Fewer hazmats >> Safer ground operations
  - Prerelease system health assessment, aircraft-type landing >> Safe-abort feature

• Truly "green" technology
  - Electric power for launch >> Can use renewable power
  - Ground-based first-stage >> Fully reusable
  - Regenerative power capability >> Energy not wasted

• Versatile architecture
  - Environment-independent >> Deployable locations, terrestrial and non-terrestrial
  - Scalable >> Can be sized as requirements demand and resources allow

So . . . What does this have to do with us?
EML Technology Has Great Potential For Application to Other Transportation Sectors
EML Technology Transfer Opportunities

• Technology "spinoffs" to other transportation sectors
  - Emission-free aircraft taxi; takeoff assist and landing with power regeneration
  - Energy assist for internal-combustion vehicles, unlimited range for EV's
  - Transfer containerized freight between ports and intermodal hubs
  - Implementation of maglev for high-speed and urban transport

• Inductive power coupling used in conjunction with LIM's
  - Enables power transfer to vehicle without physical contact
  - Enables in-transit recharge of EV's, and powering aircraft while idling
  - Currently used for powering industrial electric locomotives

The time has come to seriously consider this technology for terrestrial transportation solutions
EML Technology for Green Aviation

- Idling planes waste over 740 Mgal of fuel annually
  - Equates to over 7M mt of CO₂ (2007)
- Linear motors can be used for taxi, takeoff, & landing
- Existing aircraft can be retrofitted with retractable skids, or towed by linear-motor vehicles
- Incorporate IPT to power aircraft while on tarmac
  - Can be integrated with linear motors as part of propulsion system
  - No connectors: highly reliable, low maintenance, contamination-proof, safe
- Less fuel consumption; could help eliminate fuel waste
  - Reduced emissions, assuming increased renewable power generation
- Increased safety, particularly for ground operations
- Highly reliable, low-maintenance
- Reduced operating costs for fuel and maintenance
- Reduced airport noise

Photo courtesy of Power Superconductor Applications Corp.
EML Technology for Highways

- Utilize linear motors for acceleration, cruise, braking (with regen)
- For traditional internal-combustion (IC) & electric vehicles (EV's)
- Existing vehicles retrofitted with aluminum plates, powered lanes
  - Conventional motors can still be used "off-track" in unpowered areas
  - Power consumption from grid tracked via either onboard meters or remotely
- IPT to power vehicles while idling, and recharge EV's in transit
  - Would improve fuel economy for IC vehicles and allow unlimited range for EV's
  - Eliminates need to develop plug-in hybrids, or more advanced batteries
- Improved traffic safety
  - Linear motors enable controlling vehicle separation distance
  - Can be utilized for tractor-trailer downhill braking and runaway truck ramps
- Less environment impact, from reduced emissions and runoff
- Highly reliable, low-maintenance
- Reduced highway noise, savings in sound barrier construction

Illustrations courtesy of General Atomics
EML Technology for Port Operations

• Utilize linear motors to move shipping containers between ports and intermodal facilities up to 100 miles distance
• First full-scale test completed (2006)
  - 5,000 container per day capability
• More volume of containerized freight can be accommodated by such a maglev-based system
• Reduced demand for freight via highway
• Highly reliable, low-maintenance

Illustrations courtesy of General Atomics
EML Technology for Guided Rail Systems

• Utilize linear motors for locomotives, urban maglev, intercity
• Locomotives can be easily retrofitted with aluminum plates
• Incorporate IPT to power vehicles
  - Currently being used for traditional electric locomotives, buses in Italy
• Maglev over 90% energy efficient at cruising speeds (300 mph +)
  - For traditional rail motive power, LIM's would reduce fuel waste
  - High- and low-speed maglev systems can be integrated (commonality benefit)
• Reduced energy & emissions of overall transportation system
  - Can utilize renewable power and incorporate regeneration
  - Would offload demand/volume from other modes
• Improved safety and security
  - LIM's enable controlling vehicle separation, externally powered and controllable
  - Enables elevated rail to reduce at-grade accidents and smaller land footprint
• Highly reliable, low-maintenance

Illustrations courtesy of General Atomics and Transrapid International
Prime Opportunity for Collaboration

• The advantages of electromagnetic technology are obvious
• Admittedly, a "chicken-and-egg" situation
  - Difficult to justify building infrastructure without sufficient demand
  - Demand won't materialize without sufficient infrastructure
  - Can be overcome with sufficient systems-level design and implementation
• Strong potential for collaboration both within and outside NASA
  - DOD, LLNL: EMALS, linear motors, energy generation/storage, aeronautics
  - DOT (FAA, FHWA, FRA): aircraft, highways, guided rail systems
  - DOE: power generation and storage, superconductors
  - Industry: automobile, airline, shipping, construction, manufacturing, tourism
  - International community: EML systems developers, high-speed guided rail
  - Academia
• Tangible societal benefits
  - Air travel would be safer, cheaper, cleaner, and quieter
  - Transferable technology to improve car fuel economy, enable unlimited range for EV's, and provide more efficient braking with power regen
  - Increased capacity for port freight movement
  - Improved urban & intercity transport > less traffic, greater workforce efficiency
  - High-tech job creation, stronger economy, reduced dependence on oil
  - Reduced air pollution, carbon emissions, and runoff
For Your Consideration

• Be "agents of positive change" within your own organizations
• Don't be satisfied with the "status quo" or "We've always done it that way"
• Leverage the ideas of the visionaries
  - Both within and outside your organizations
• Take a systems approach to transportation
  - Look at the "big picture"
• Consider non-traditional transportation technologies and systems that have worked well
  - Both domestically and internationally
• Educate yourself regarding the facts of climate change, and what needs to be done to help mitigate it (350 ppm goal)
• Before embarking on a "new" technology, perform a comprehensive assessment of the net carbon footprint

"There's a way to do it better - find it."
  - T. Edison
Open NASA Solicitation

• Aeronautics and "environmentally responsible aviation" research opportunity
• http://nspires.nasaprs.com/external/solicitations
• Solicitation NNH10ZEA001N
• NOI due date: June 14, 2010
• Proposal due date: July 15, 2010
• Partnering with NASA and other agencies encouraged
Transportation Technology for the Future
Questions?

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