Maglev

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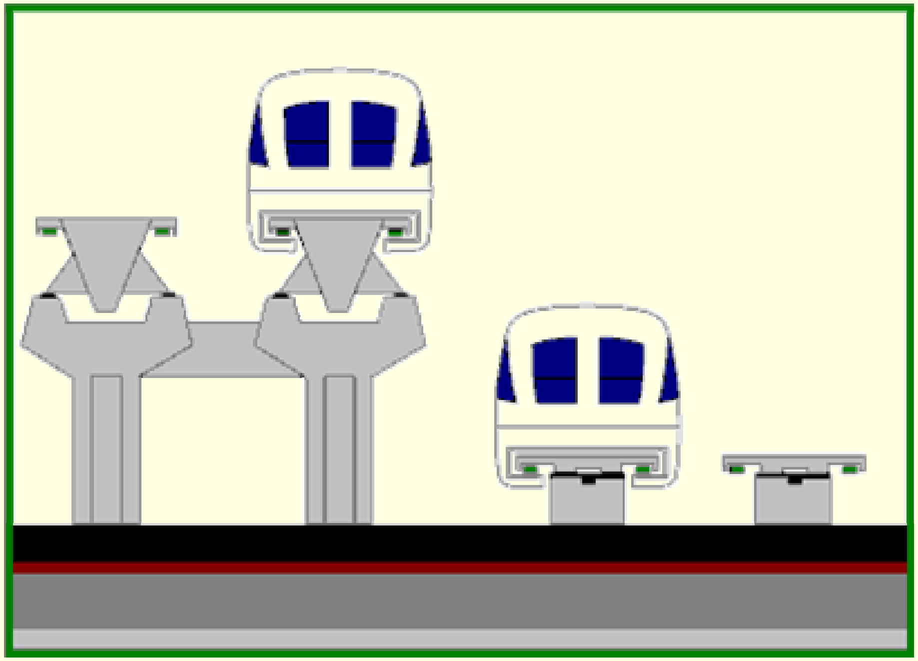
Presentation Content

- Maglev Introduction
- Project Background
- Levitation
- Propulsion
- Questions

Maglev: A Floating Train

Advantages:

- Passive Train Car
- Low Maintenance
- No Rail Friction
- No Wheel Noise
- Speed
- Fail Safe

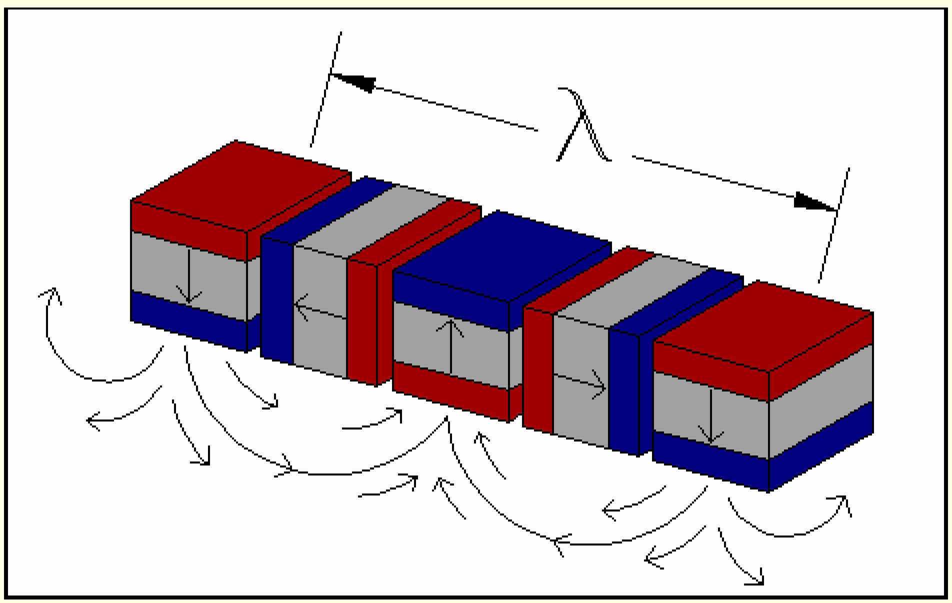


Project Summary

- Phase 1:
  - Prove levitation is possible with a Wheel Track
- Phase 2:
  - Build and test Propulsion System on a Circular Track

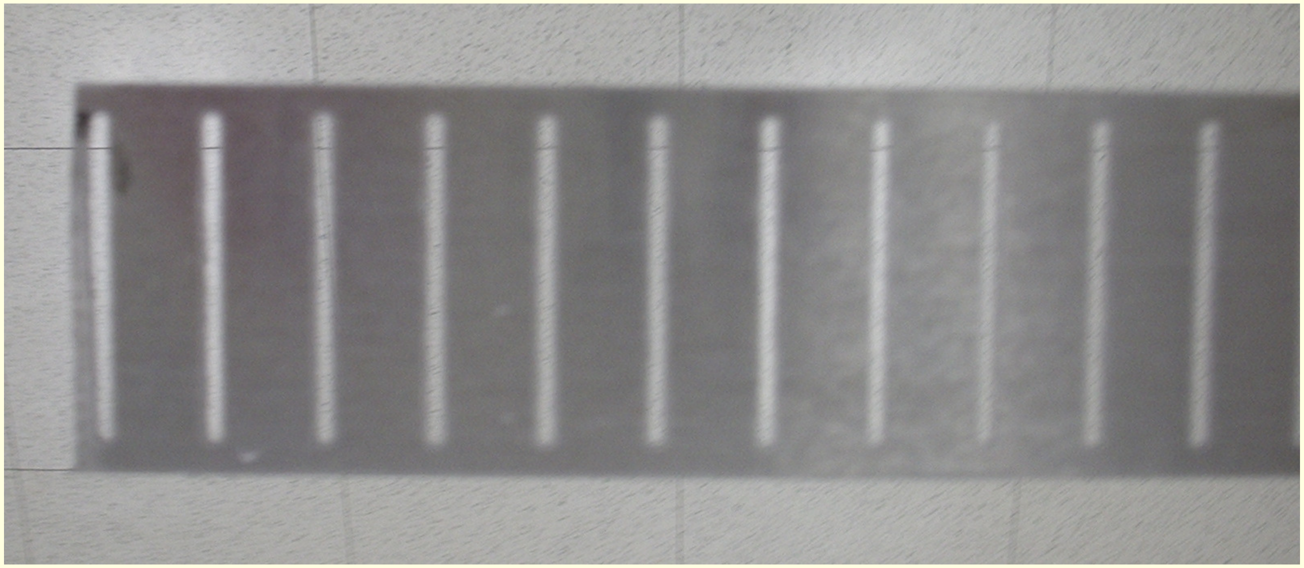
Halbach Array

- Simple Halbach Array
- Magnets oriented 90° w/ respect to each other

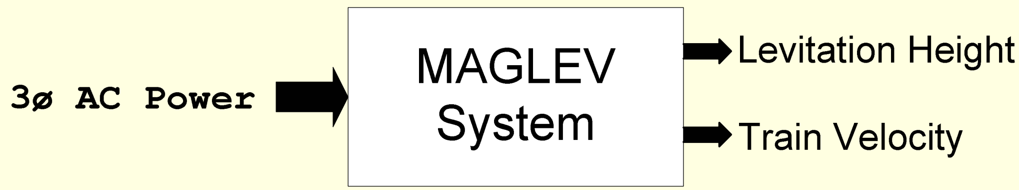


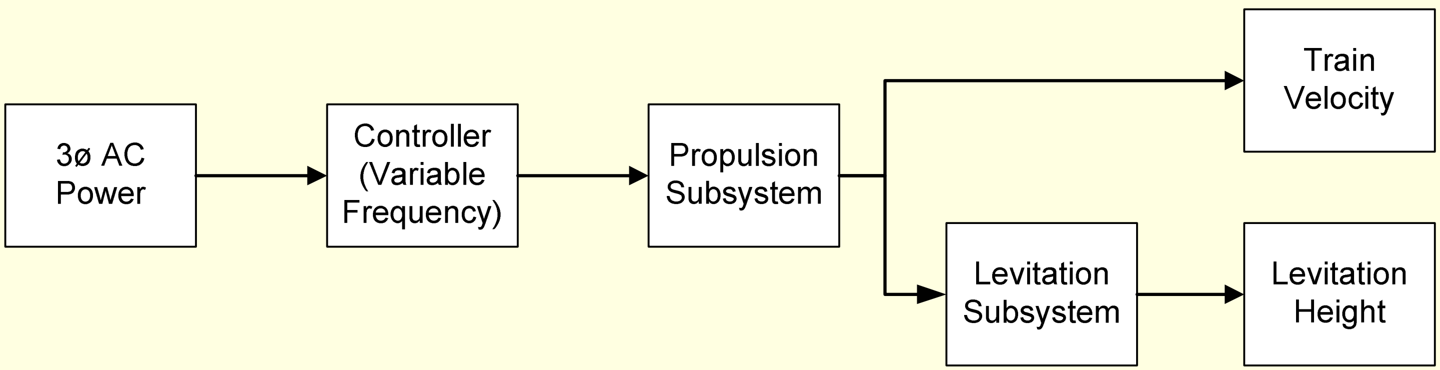
Track

- Copper or Aluminum
- Slits Allow for Current to Flow Transversely
- Magnetic Field is Induced

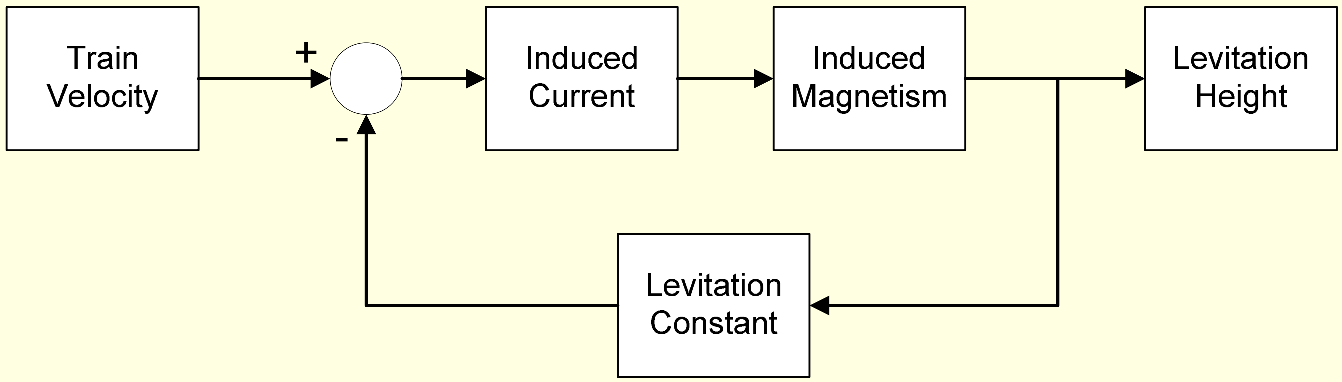


High Level Block Diagrams

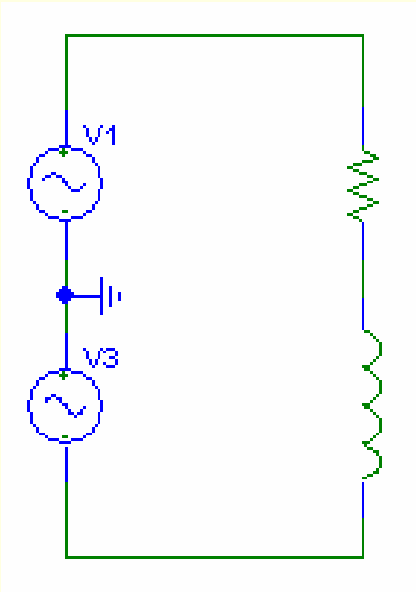


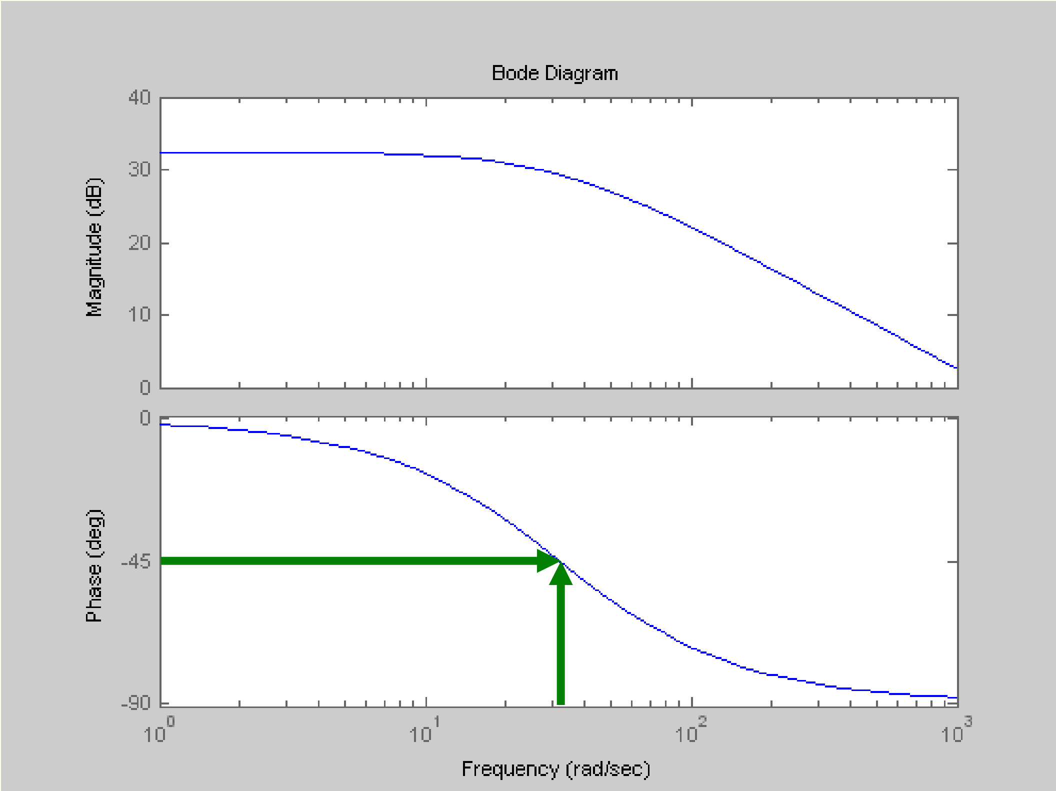


Levitation Height Block Diagram



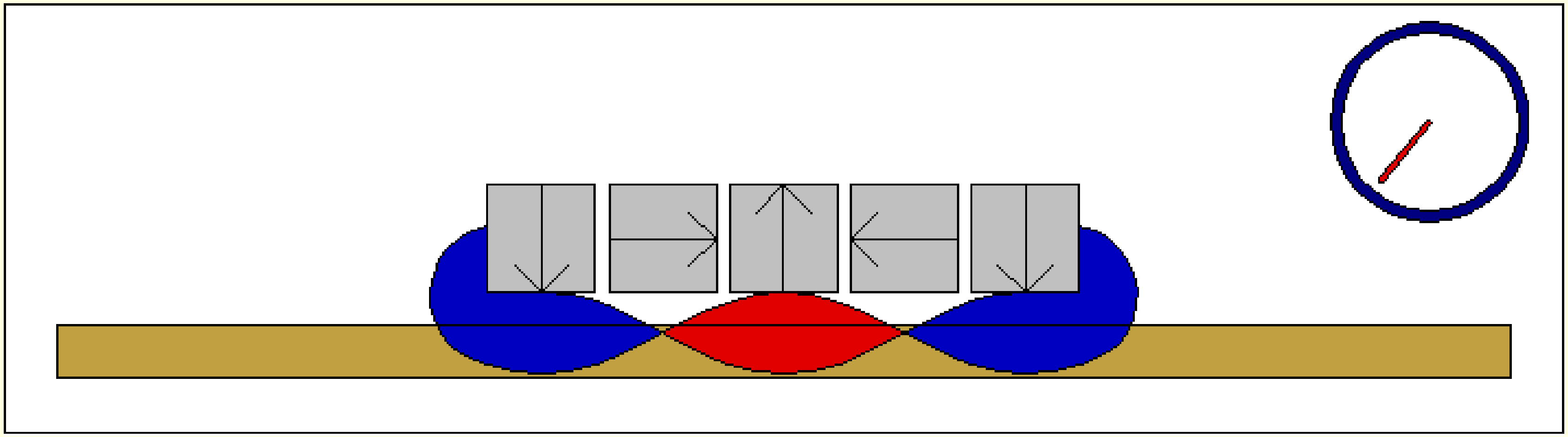
Levitation Train Simulation





Inductrack Technology

- Halbach Array & Track Interact



Presentation Content: Levitation

- Previous Work
- Current Work
- Results
- Future Work

Previous Work with Maglev

- Paul Friend – 2004
  - Received help from Dr. Richard Post, PhD
  - Created a Matlab Program to calculate various parameters (lift-off velocity, levitation height, etc)
  - Constructed Wheel Track to test Levitation

Inductrack

by: Paul R. Friend

Train Parameters

Magnet Strength Br =	1.21	Tesla
Magnet Thickness d =	0.012	meters
Magnets per Halbach Wavelength M =	4	magnets
Number of Vertical Oriented Magnets Is =	3	
Halbach Wavelength lamda =	0.055	meters
Width of Halbach Array w =	0.06	meters
Length of Halbach Array lm =	0.06	meters
Total Train Mass tm =	0.375	kg

Track Parameters

Thickness of One Layer deltac =	0.0005334	meters
On Center Strip Spacing dc =	0.0105	meters
Width of Track Pc =	0.11	meters

Laminated Sheets

Electric Resistivity rc =	171.3	micro p-l/m^2
Width of Conductive Strip Nt =	0.005	meters
Number of Laminated Layers Ns =	1	layers

Inductive Loading

Conductor Bundle Height Loaded al =	0.0005334	meters
Total Ferrite Tile Width h =	0	meters

Train/Track Relation

Rolling Clearance y1 =	0.01	meters

User Input

Train Velocity vu =	10	meters/sec

Create the desired plot in a separate figure:

Plot Bx & By

Train Outputs

Halbach Peak Strength Bo =	0.81281	Tesla
Area Under Halbach Array A =	0.0036	m^2
Force Required for Levitation tf =	3.6788	Newtons

System Outputs

Distributed "1 Turn" Inductance Ld =	5.7619e-008	Henrys
Added Inductance from Loading Ll =	0	Henrys
One Turn Inductance L =	5.7619e-008	Henrys
"1 Turn" Resistance R =	0.00070652	ohms
R/L Pole RLpole =	12261.99	rad/sec
Oscillation Frequency omegaosc =	47.3433	rad/sec
Oscillation Velocity vosc =	0.41442	meters/sec

Break Point Analysis

Levitation Break Point Velocity vb =	23.2038	meters/sec
Levitation Break Point Speed sb =	51.9054	miles/hr
Levitation Break Point Frequency omegab =	2650.7964	rad/sec
Drag Forces at Break Point Fxb =	17.0171	Newtons
Lift to Drag Ratio L2Db =	0.21618	

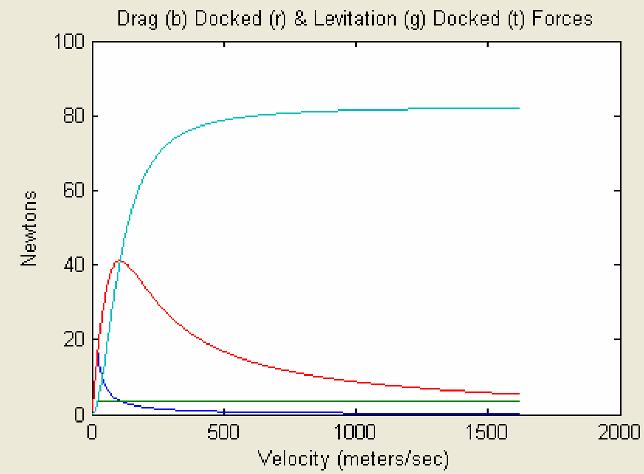
Transition Analysis

Transition Velocity (Lift = Drag Forces) vt =	107.3356	meters/sec
Transition Speed st =	240.1029	miles/hr
Transition Frequency omegat =	12261.99	rad/sec
Levitation Height at Transition Lht =	0.020573	meters
Levitation Force = Drag Force = Fxyt =	41.198	Newtons
Lift to Drag Ratio L2Dt =	1	

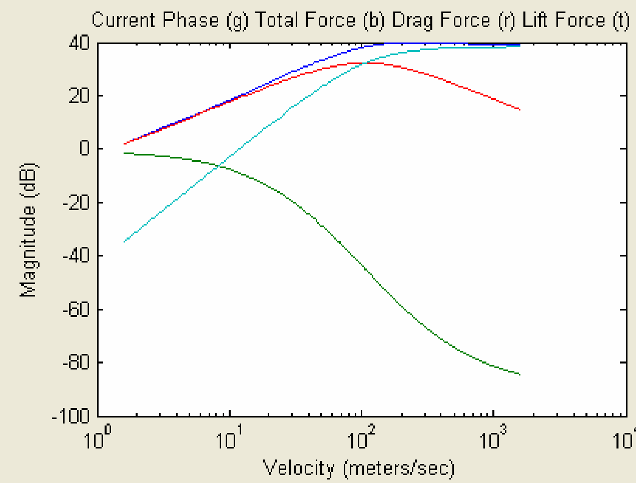
User Outputs

Frequency omegau =	1142.3973	rad/sec
Speed su =	22.3694	miles/hr
Levitation Force Fyu =	3.6788	Newtons
Drag Force Fxu =	39.4861	Newtons
Levitation Height Lhu =	0.002794	meters
Fixed Levitation Force Fyuf =	0.70903	Newtons
Fixed Drag Force Fxuf =	7.6104	meters
Lift to Drag Ratio L2Du =	0.093166	

Plot Forces



Plot Bode

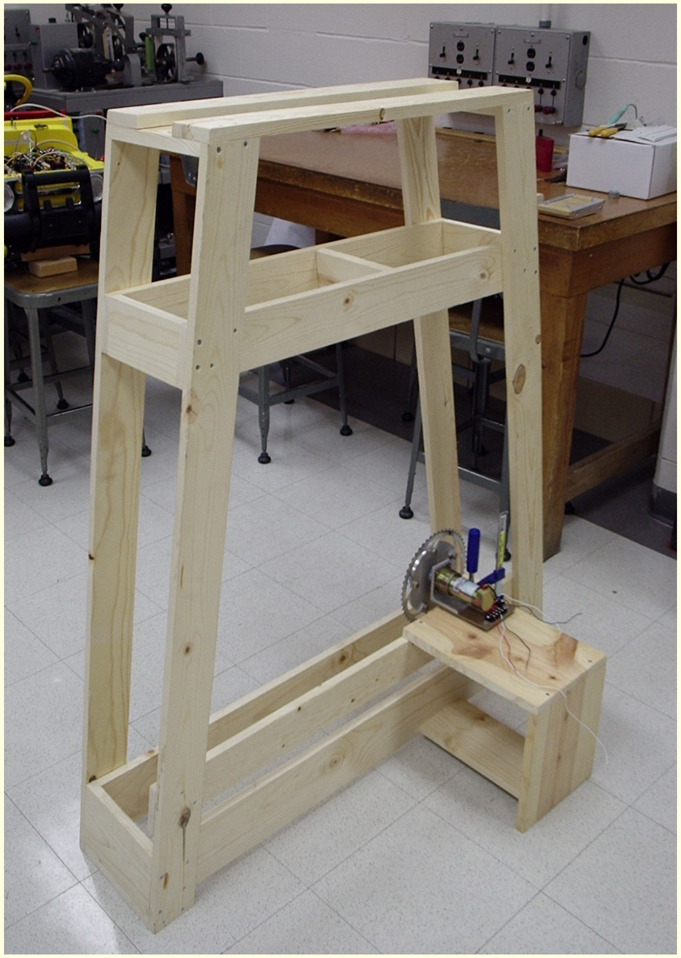
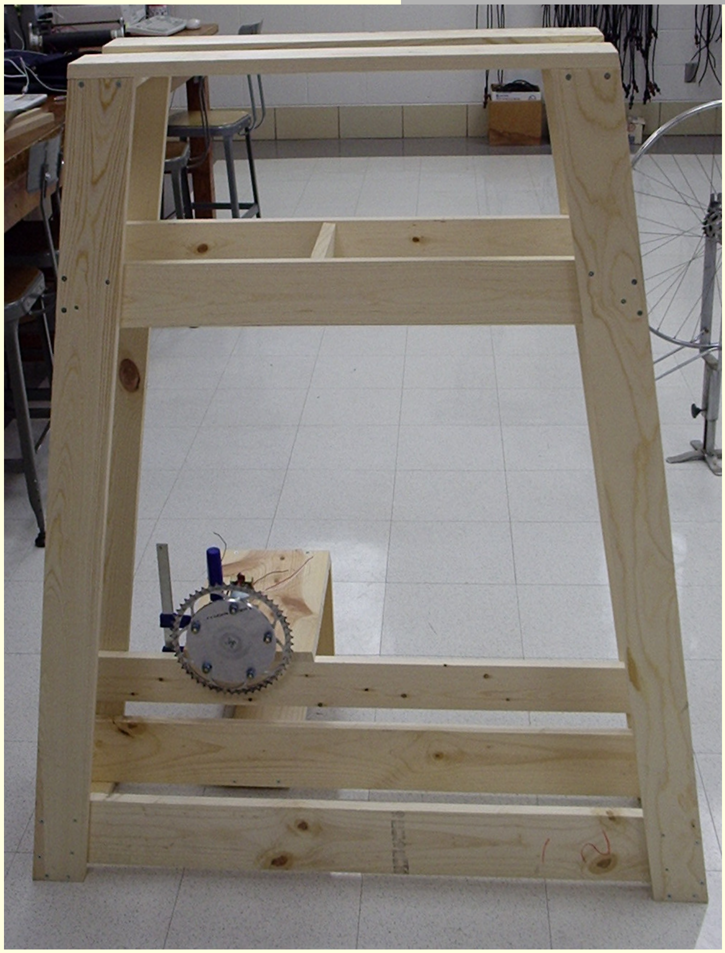


Compute

Default

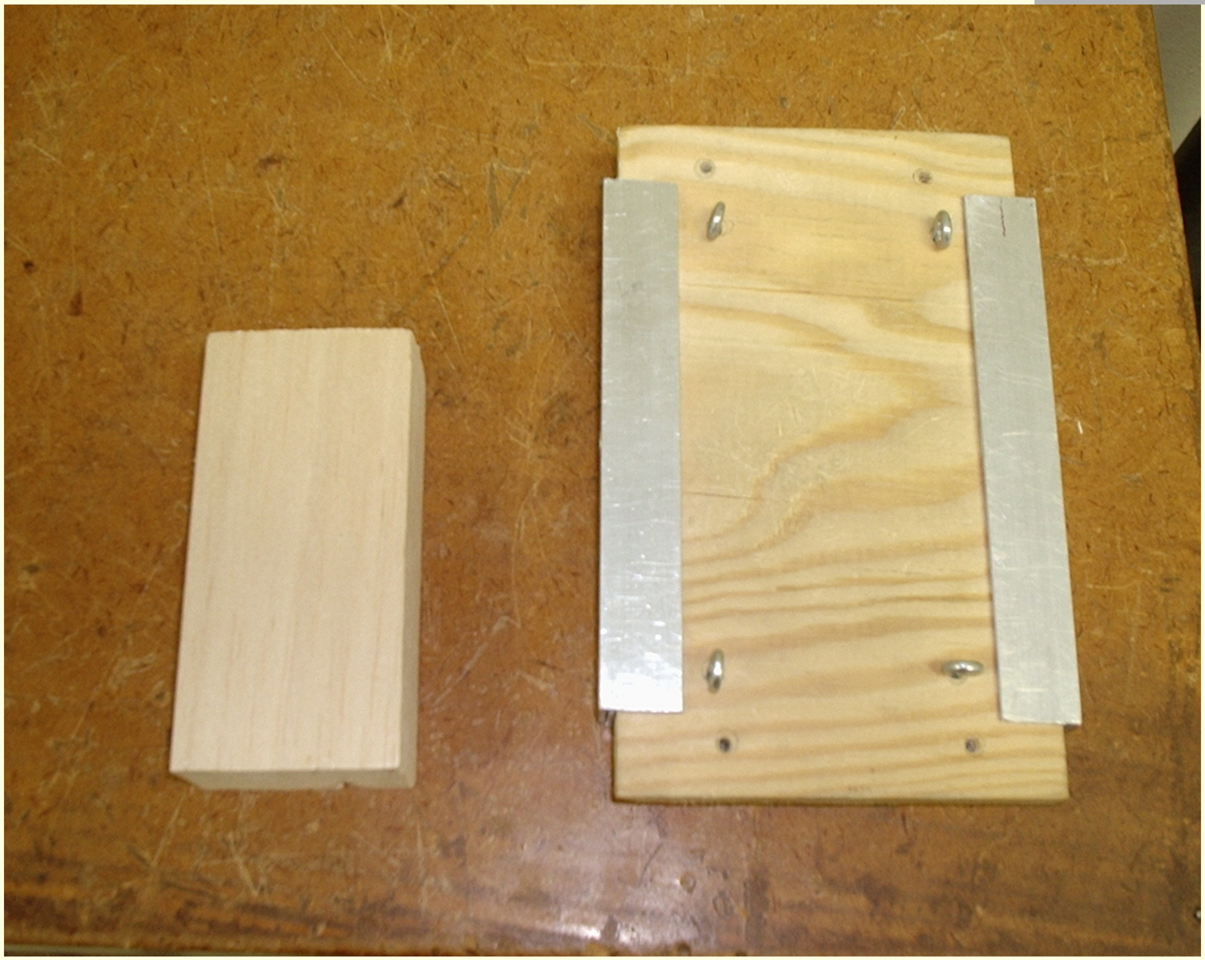
The New Wheel

The New Frame

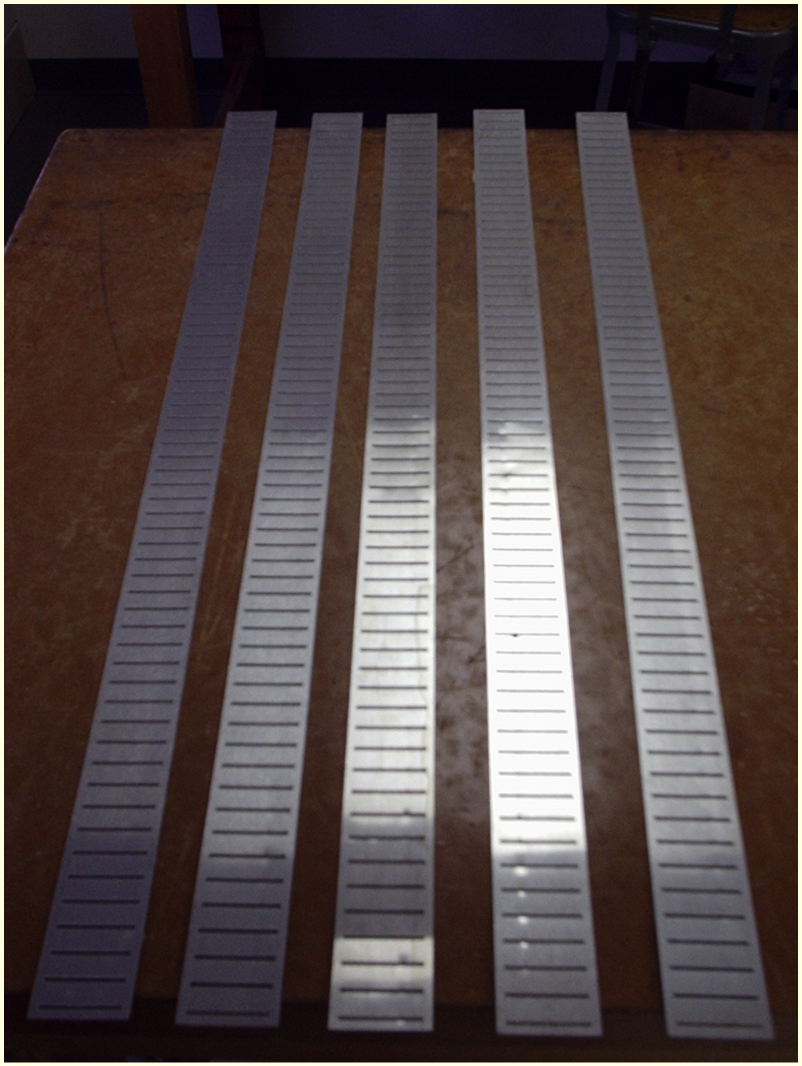
Wheel Inside Frame

The New Car



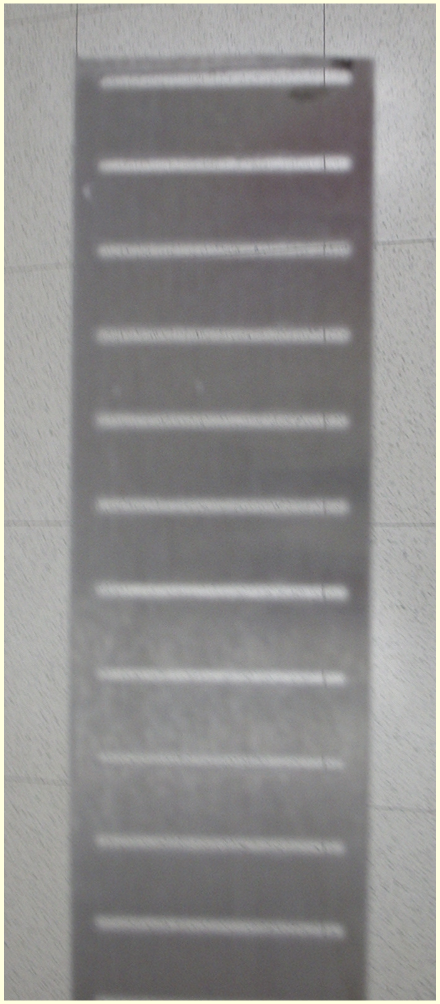
Car vs. Wheel

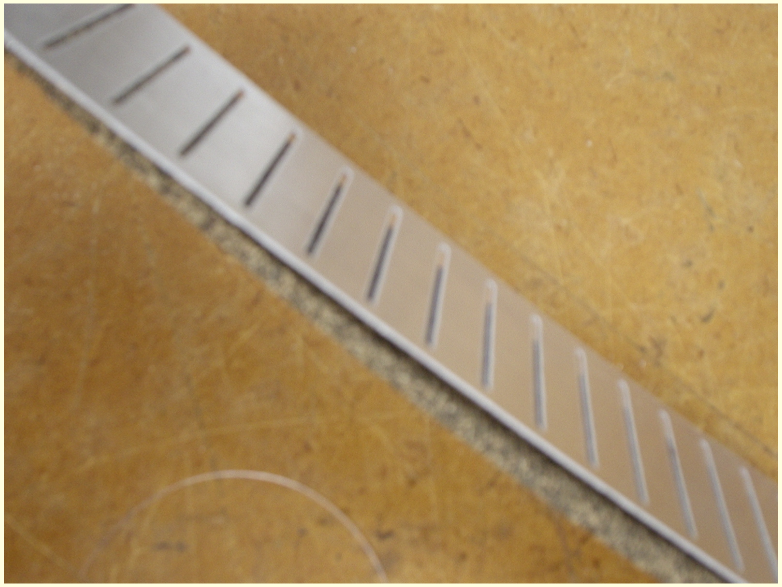
The New Track



- Aluminum
- Double Layer
- Chicago WaterJet

The New Track

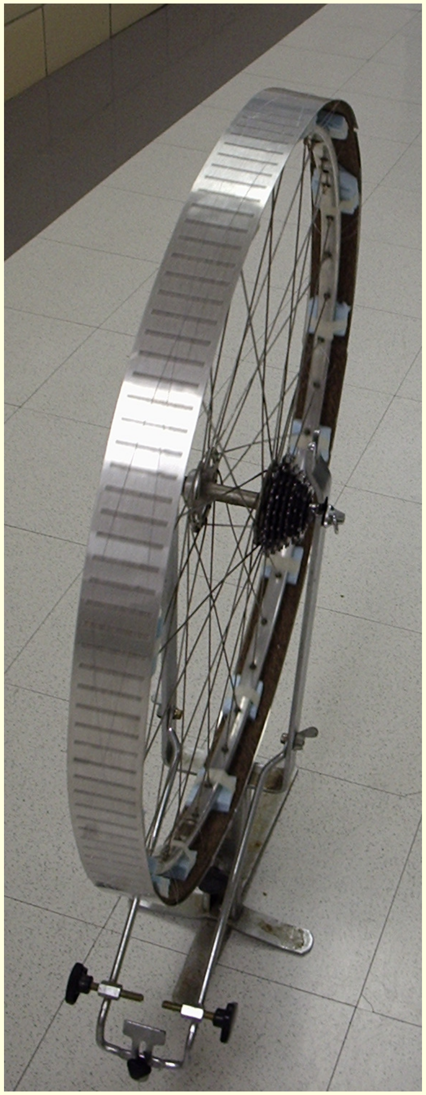


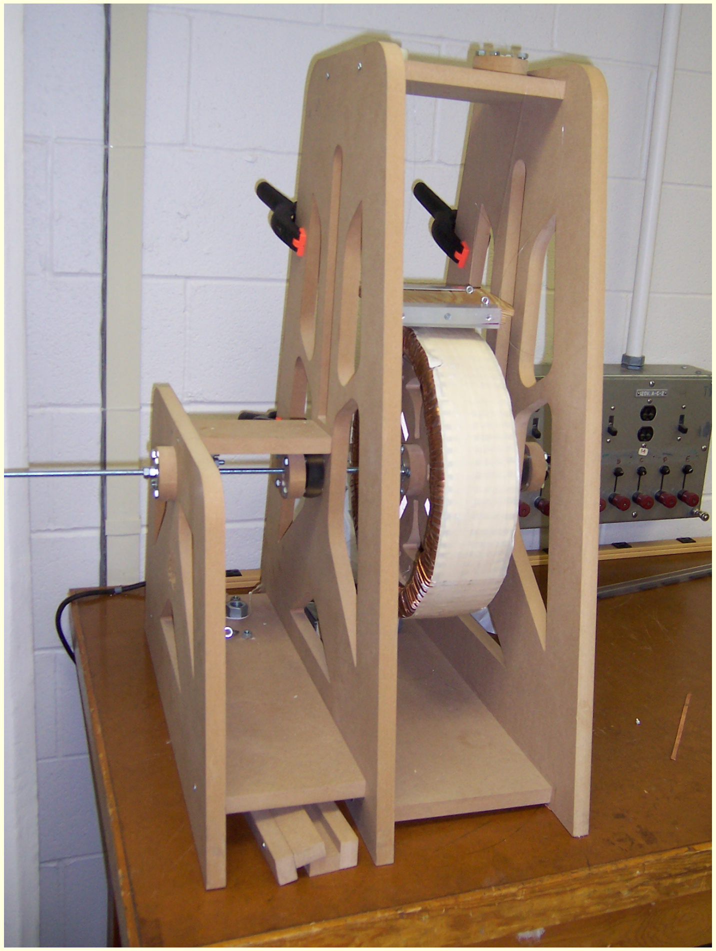


Already smallest slots possible

Better with more slots per centimeter

Wheel & Track





Levitation Summary: New vs. Old

- Lightened the car: 160g vs. 630g
- Shrunk size of car (better curve fit)
- Increased wheel speed & stability
- Increased car stability
- Similar track parameters

- Required Velocity for 1cm of levitation:

  Previous: 23 m/s   My Goal: 9 m/s

Current Results

- Track spins smoothly up to 15 m/s alone.
- Unable to achieve even 5 m/s with car.
- Drag force too much for the Pittman motor
- Implementing an A/C servomotor

Other Work To Do

- Data collection
- Compare results to Matlab GUI
- Add 2nd Layer of Track
- Create theoretical design to implement levitation with propulsion

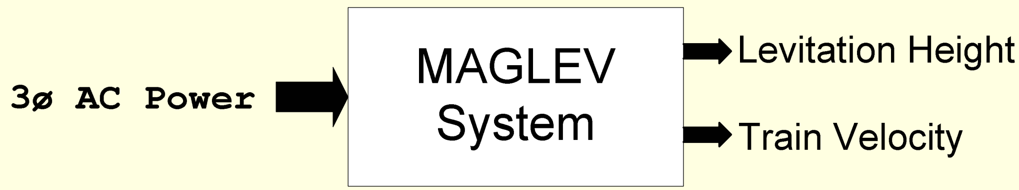
Presentation Content: Propulsion

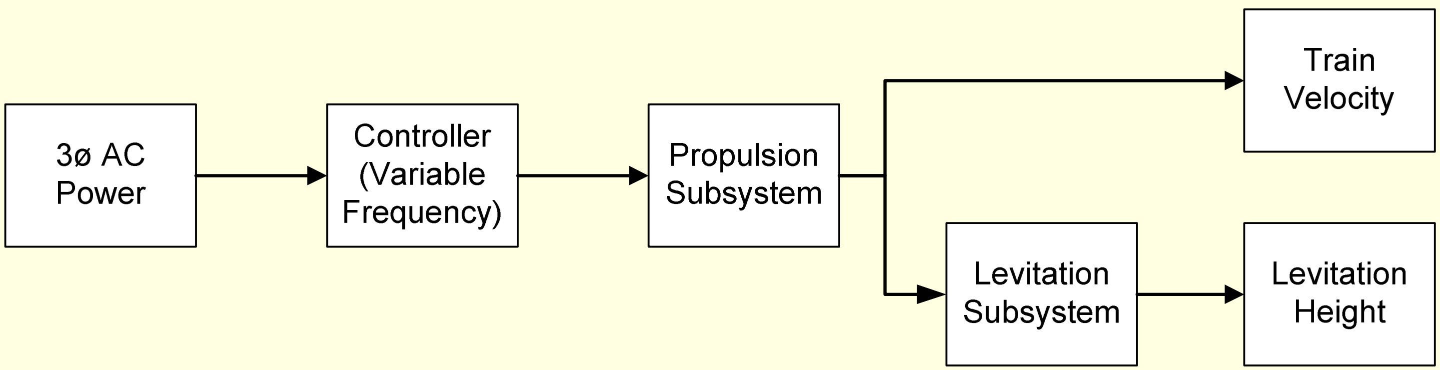
- Concepts
- Implementation
- Work Accomplished
- Future Work

Goal

- Goal
  - Be able to propel a car to 9 m/s (20.1 MPH)

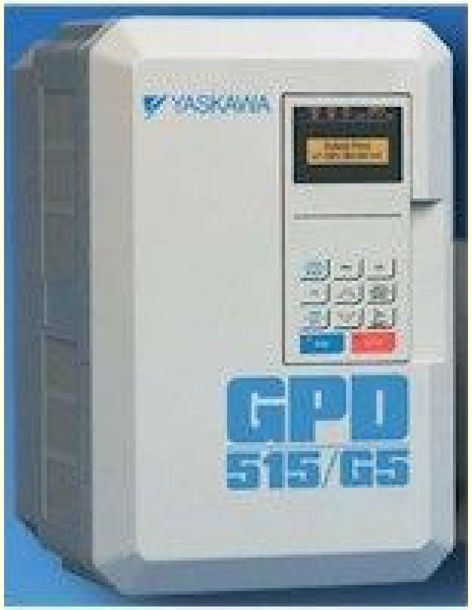
High Level Block Diagrams



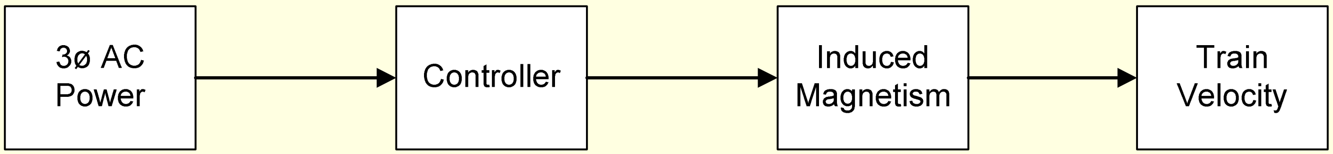


Controller

- Ratings: 2 -> 200 HP at 600 VAC
- Output Frequency: 0.1 -> 400 Hz

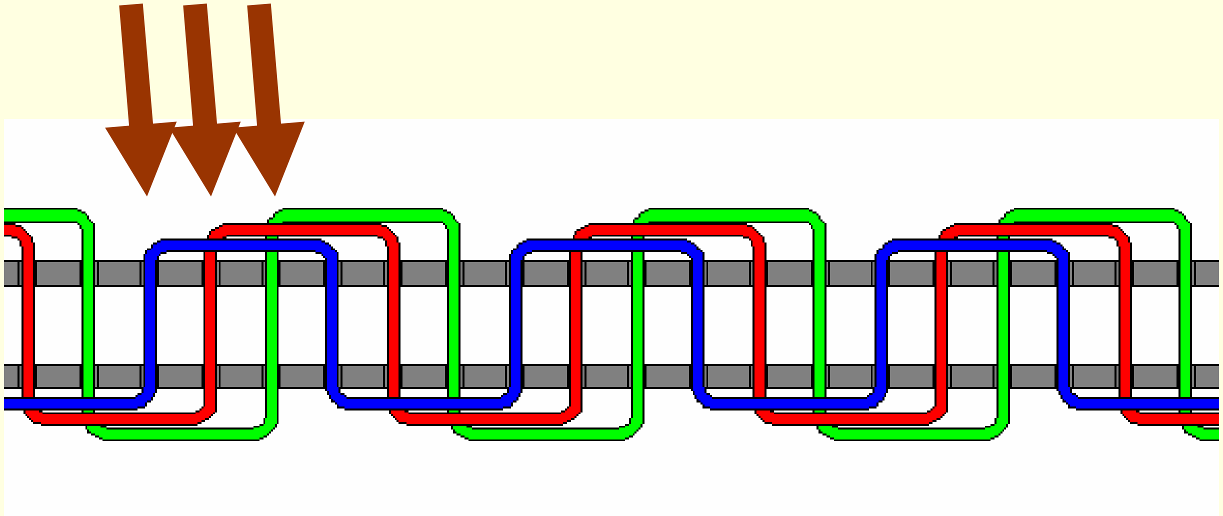


Propulsion Block Diagram



Propulsion

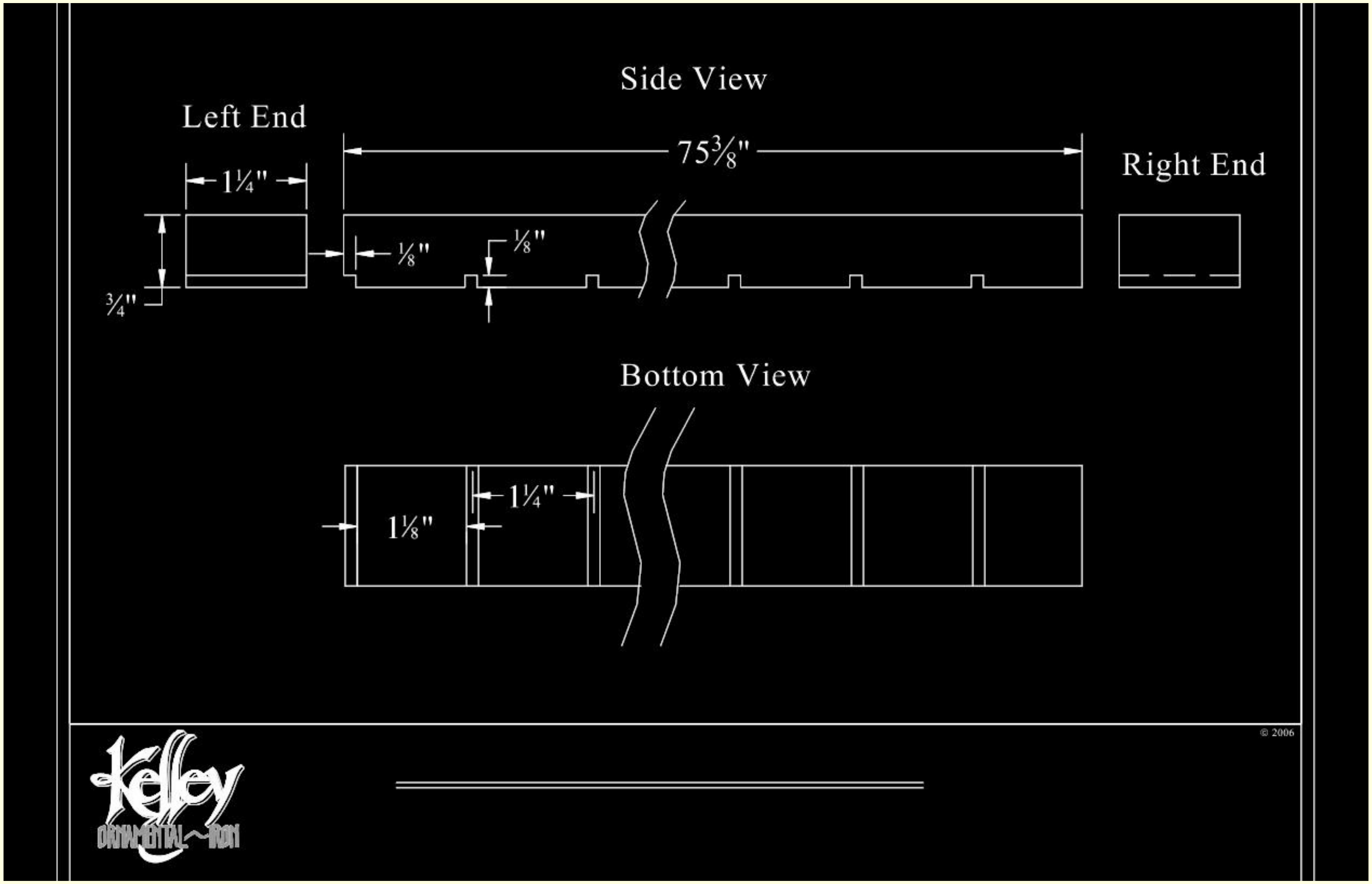
- Linear Synchronous Motor (LSM)
  - Used for Low-Speed Urban Maglev Program
  - Solid copper cables and laminated iron rails
  - Halbach arrays on train
  - Varied 3-phase frequency for control
  - Allows for large air gap between train and coils ~ 25 mm



Circular Synchronous Motor

- Magnet Wire (3 - 18 gauge twisted)
- Built in Quarter Sections
- Built by Kelley Ornamental and Peoria Awning w/ Hot Rolled Steel

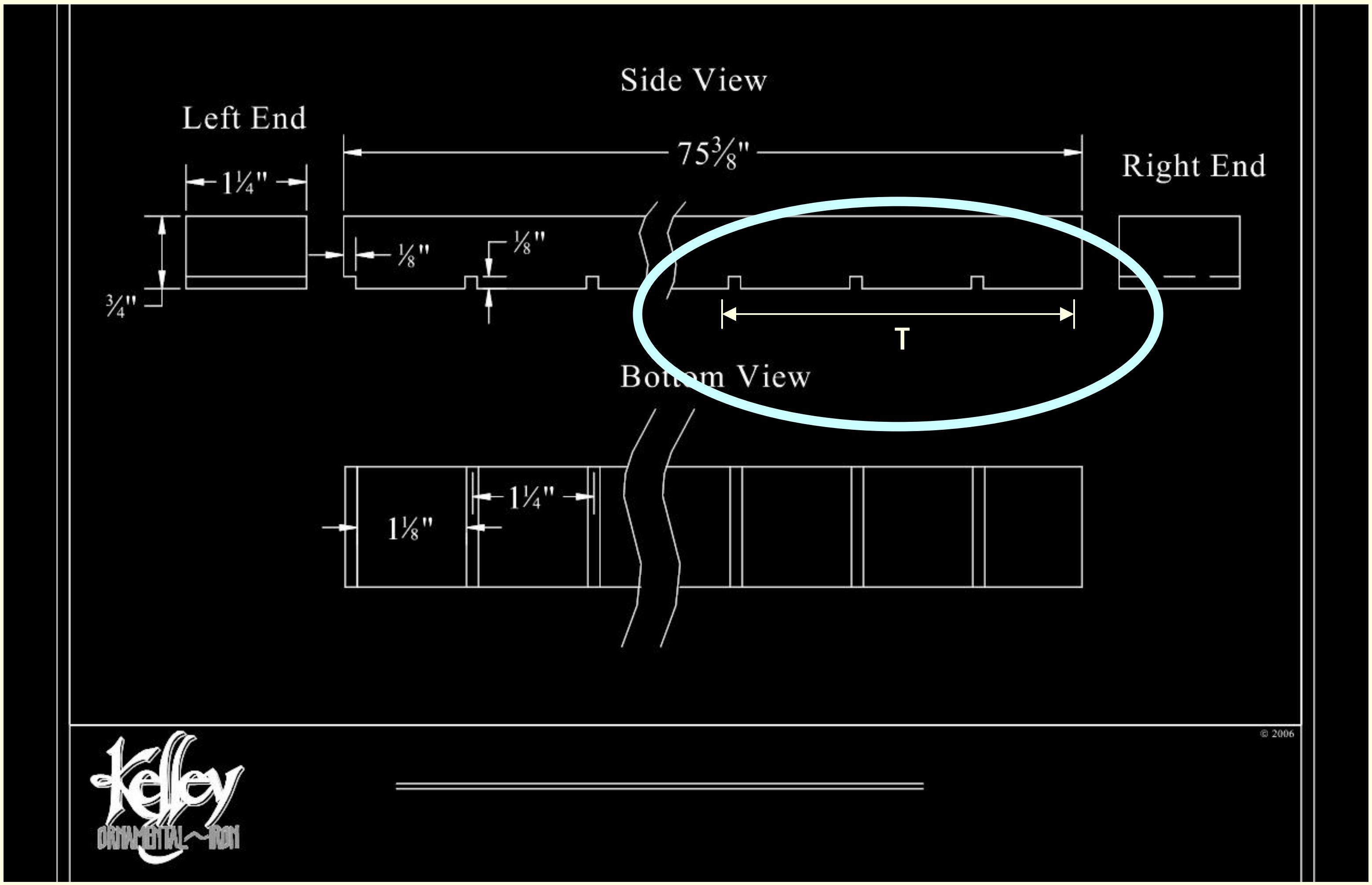
Circular Synchronous Motor



Equations

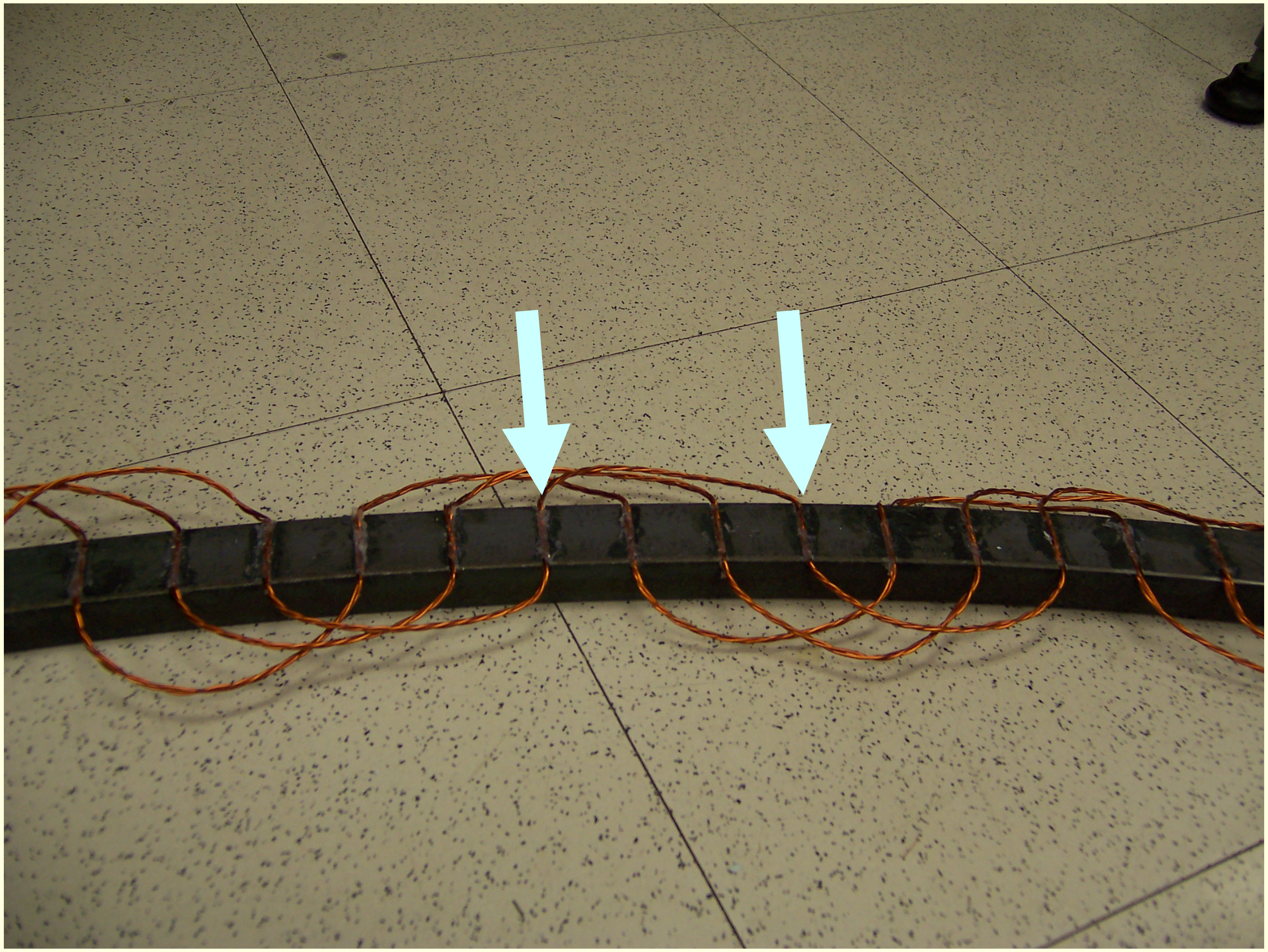
- Train Velocity
  - $V = 2\tau f$
    - V = synchronous speed (m/s)
    - τ = pole pitch (m)
    - f = supply frequency (Hz)
- Requires f = 47.24 Hz to reach 9 m/s

Circular Synchronous Motor



Linear Synchronous Motor

Linear Synchronous Motor



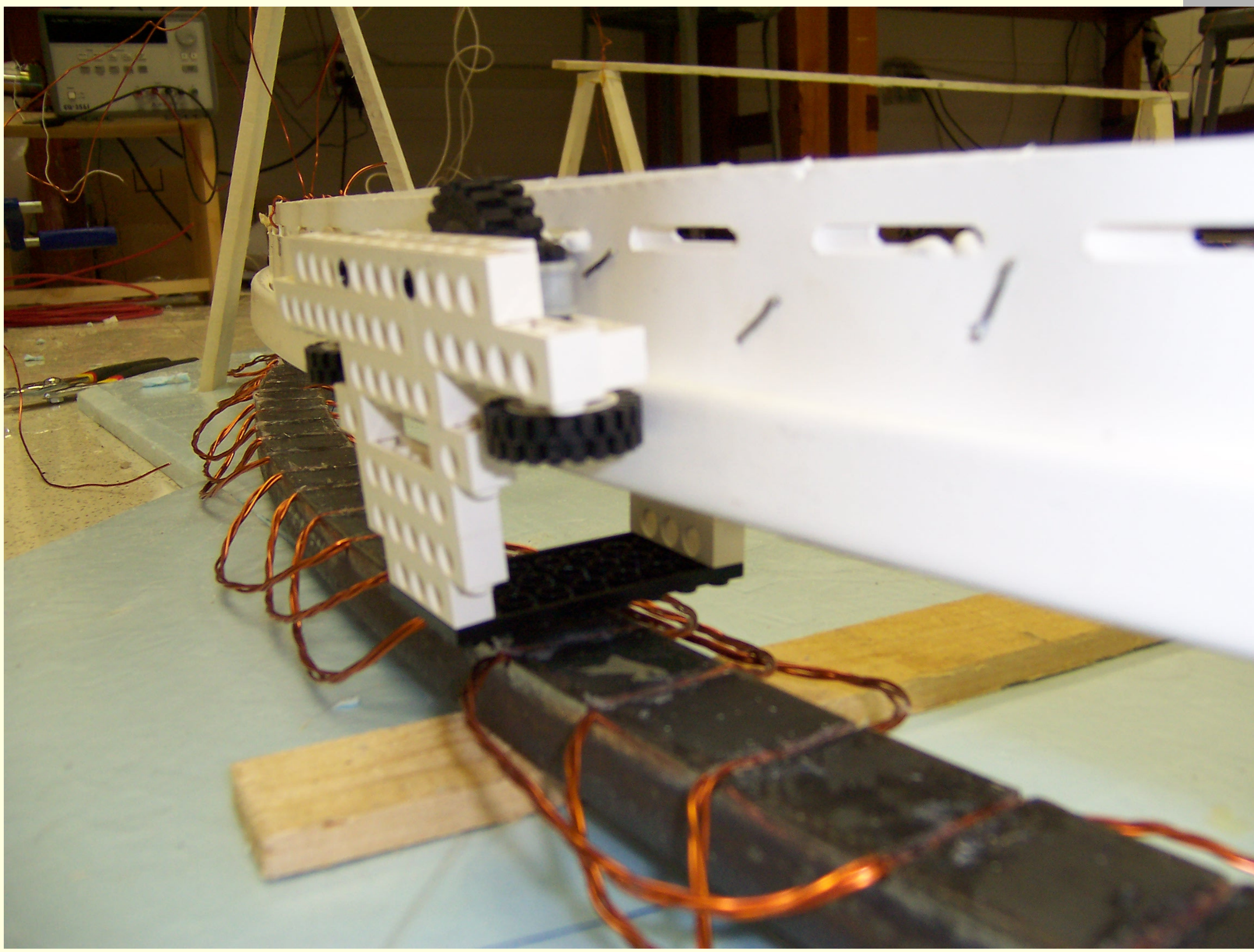
Circular Track

- J-Channel Vinyl Siding
- Car will wrap underneath track

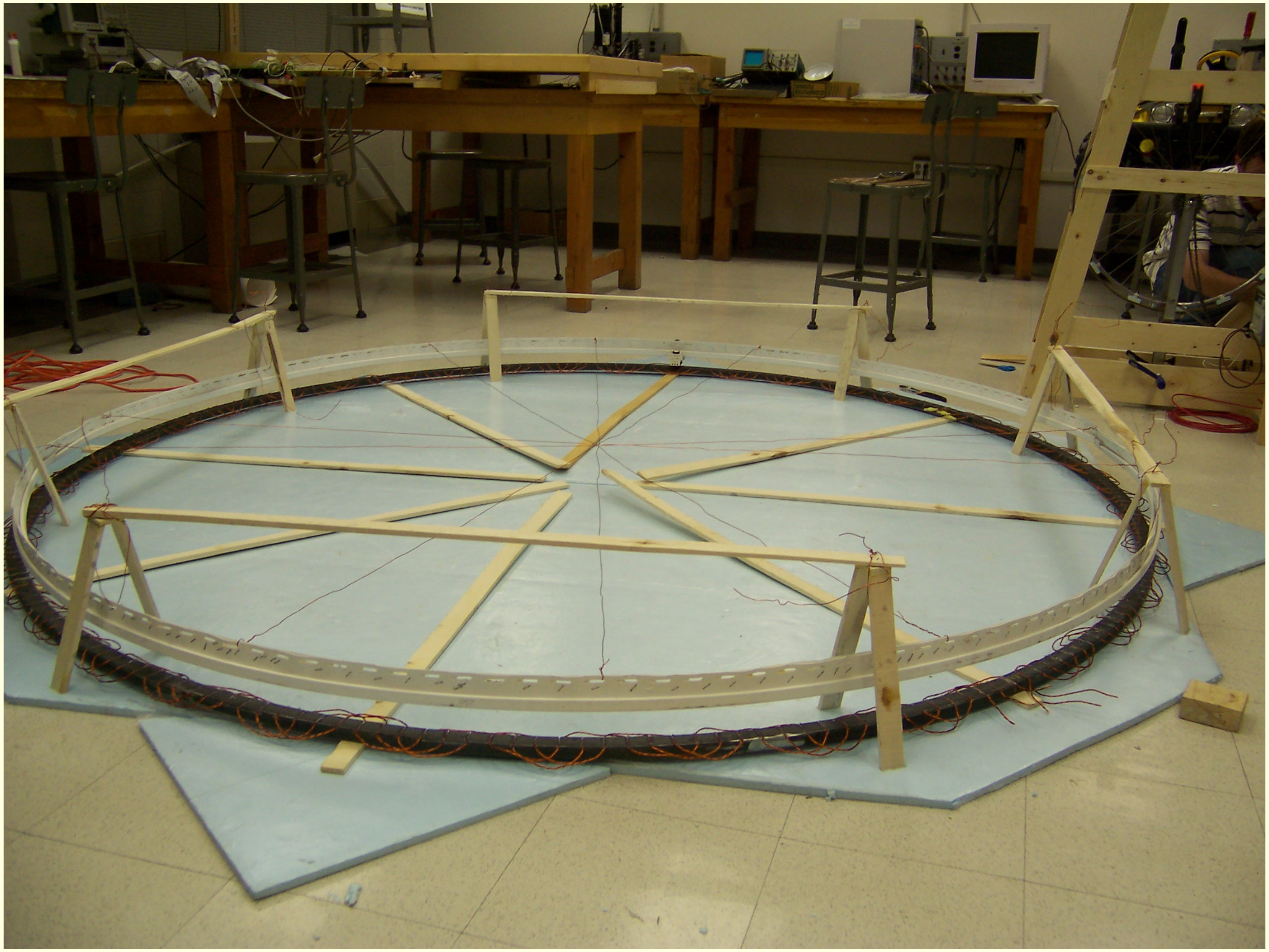
Propulsion Car

- Legos
- 10x3 Double Halbach Array (1/8” cube magnets)
- Halbach Array Glued to Lego Piece and Placed on top of car

Car on Track



Track System



Work Accomplished

- System has been completely built
- Testing of the system is in progress

Possible Future Work

- Combine Levitation design w/ Propulsion design
- Design a controller to control train movement on track (stop, reverse, forward)

Thank You!

Companies:

- Chicago WaterJet
- Kelley Ornamental
- Peoria Awning

Faculty:

- Dr. Anakwa
- Mr. Gutschlag
- Mr. Schmidt
- Mr. Mattus
- Mr. Miller
- Dr. Irwin

Thanks to all supporters!

Questions?

Standards

Standards used by the Low-Speed Urban Maglev Program

Max. Speed	160 km/hr	Max Jerk	2.5 m/s^3
Throughput	12000/hr/direction	Inside Noise Level	< 67 dB
Max Acceleration	1.6 m/s^2	DC Mag. Field in Car	< 5 Gauss
Min Curve Radius	18.3 m (60 ft.)	Availability	> 99.99%
Max Grade	10%	Ride Quality	ISO 2631 (1987)

Will be used for concepts to keep in mind

Patents

Richard F Post
Magnetic Levitation System for Moving Objects
U.S. Patent 5,722,326
March 3, 1998

Richard F Post
Inductrack Magnet Configuration
U.S. Patent 6,633,217 B2
October 14, 2003

Richard F Post
Inductrack Configuration
U.S. Patent 629,503 B2
October 7, 2003

Richard F Post
Laminated Track Design for Inductrack Maglev System
U.S. Patent Pending US 2003/0112105 A1
June 19, 2003

Howard T Coffey
Propulsion and stabilization for magnetically levitated vehicles
U.S. Patent 5,222,436
June 29, 2003

Howard T Coffey
Magnetic Levitation Configuration Incorperating Levitation, Guidance and Linear Synchronous Motor
U.S. Patent 5,253,592
October 19, 1993

Enrico Levi, Zivan Zabar
Air cored, linear induction motor for magnetically levitated systems
U.S. Patent 5,270,593
November 10, 1992

Karl J Lamb, Toby Merrill, Scott D Gossage, Michael T Sparks, Michael S Barrett
U.S. Patent 6,510,799
January 28, 2003