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Magnetic Launch Assist

KSC-MM-5093

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Jose Perez/ KSC

"ST Day 2000: Reducing Risk for the Next Generations"

- Jose Perez / Project Manager / KSC
- Dr. Robert Youngquist KSC
- Frederick Adams KSC
- William Jacobs MSFC
- John Hicks DFRC
- Kurt Kloesel DFRC

- To develop a safe, reliable, inexpensive, and minimum operation launch assist system for sending payloads into orbit using ground powered, magnetic suspension and propulsion technologies.
- Improve safety, reliability, operability for 3rd generation Reusable Launch Vehicles (RLV).
- Reduce vehicle weight and increase payload capacity.
- Support operational testing of Rocket Based Combine Cycle (RBCC) engines.

Goals

- **BANTAM Program**
  - **MagLev Development**
    - PRT Advance MagLev Systems
    - Lawrence Livermore National Laboratory
    - Foster Miller

- **Advance Space Transportation Program**
  - **Spaceliner 100 Technology Development Program**
    - Launch Assist Technology Development
      - Development of MagLev Technologies

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Background

Ground Based, Electro-Magnetic Launch Assist

Ops and Range Tech

Major Milestones & Decisions

2000 | 2001 - 2002 | 2003 - 2004 | 2005 - 2006 | 2007 - 2008 | 2009 - 2010

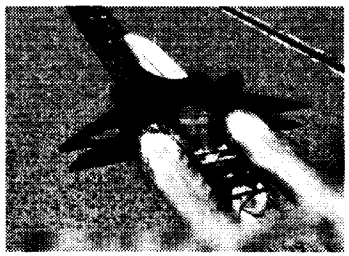
- PRT System Operational
- R/C Flight Test (50 lbm, 80 mph)
- R/P Flight Test (1000 lbm 600 mph)
- Decision to commit to system level development
- D-21 Flight Test 10 klbm, 600 mph

Key Tasks

Technology Research / Solicit
- Levitation / Propulsion
- Energy Storage
- Power Conditioning
- Partnerships
- Army, Navy, Air Force

RPV 2000' Track Development

R/P Vehicle Development 1000 lbm



MSFC Contracts
- PRT Advance MagLev Systems
- Lawrence Livermore Laboratory
- Foster-Miller

Legend
- Component/ Subsystem Demo
- Systems / Integrated Demo
- Flight Demo
- DoD Activity
- Overguideline

Aero Dynamics Modeling - DFRC
R/C Vehicle Development - DFRC
- RC Test Vehicle
- R/P Test Vehicle
- Aerodynamic Modeling
- Separation Dynamics
- Safety scenarios

R/C Vehicle - DFRC
- Existing Track
- MSFC, Holloman, DFRC
- System Controls
- Carrier Integration
- 50 lbm R/C Model,
- Test, powered flight, 50 f/s

RPV Flight Test DFRC 600 Mph

Data Review

Integration / Activation

System Scaling to D-21 Vehicle (Track / RPV 10klbm Drone)
- Track / Carrier Design / Construction
- Energy Storage System Construction
- Design / Modify D-21 Drone (10klbm)
- Install / Test @ 600 mph / Evaluate

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Ground Based, Electro-Magnetic Launch Assis

♦ Ongoing MagLev Contracts

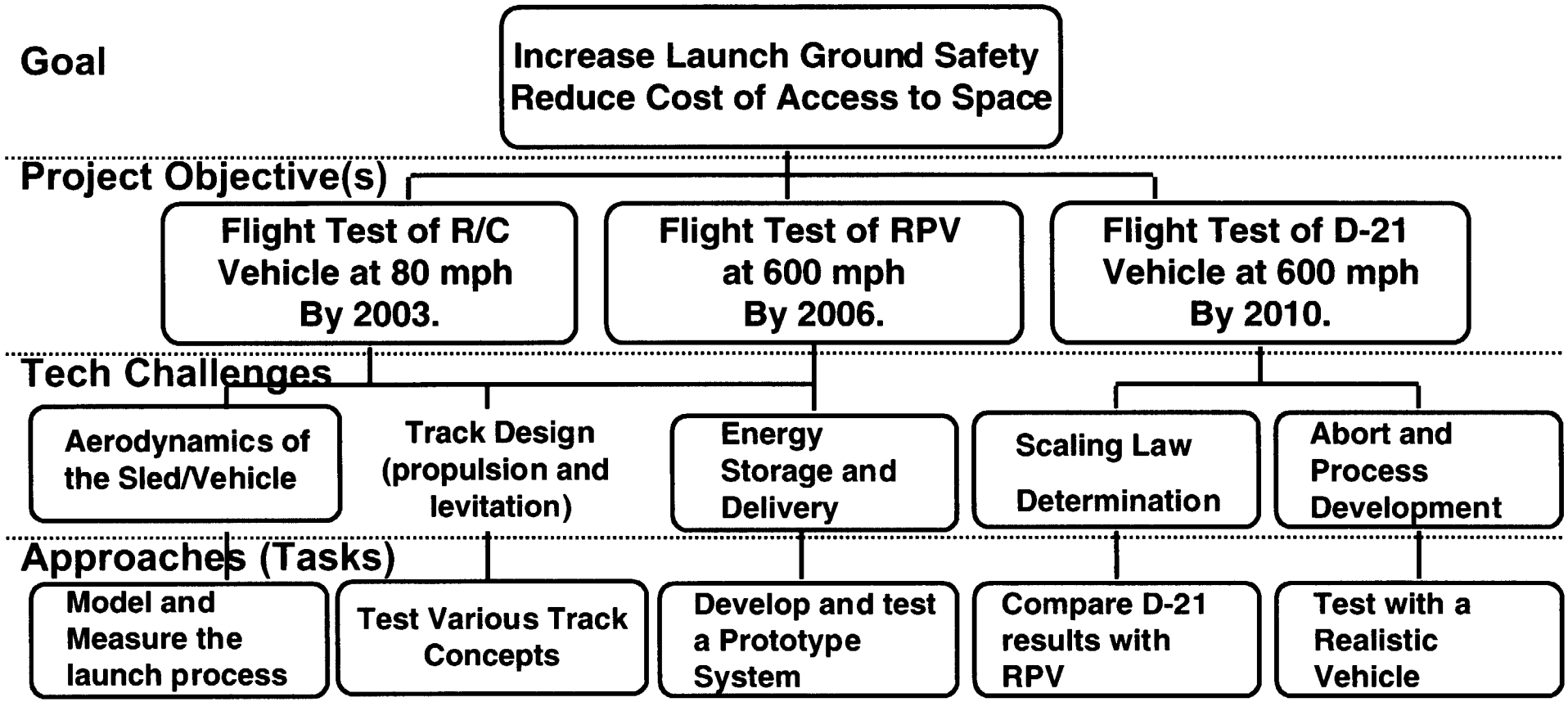
- Lawrence Livermore National Laboratory
  - Inductrack / Halbach Array – Proof of concept completed.
  - Contract extension to built a 7.8 meter (25.5 ft.) track to be tested at 30 m/s (67.2 mph) speeds.

- Foster Miller
  - Linear Synchronous Motor – 44 feet track.
  - Proof of concept completed.
  - Track is located at KSC. Research on the track will start in FY2001.
  - Contract extension for additional studies (June).

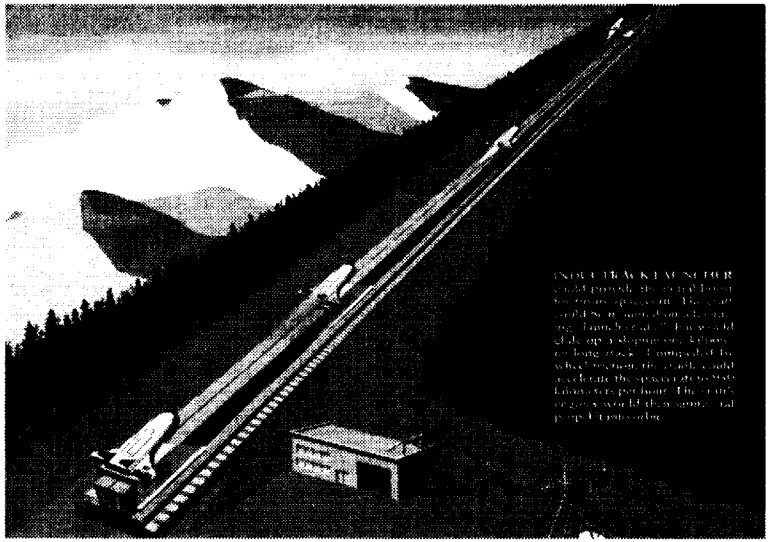
♦ Ongoing MagLev Contracts (continue)

- PRT Advance MagLev Systems
  - Research is being done at the Sussex University, England.
  - Linear induction motor – 50 feet track to be operational by December 2000.
  - Proof of concept completed.
  - Perform flight demonstration by the end of FY2001 using a radio control vehicle.

- Center for Electromagnetic at the University of Texas, Austin
  - Perform studies to determine the fundamental limitations of high speed linear motors.
  - Research existing motors, storage and electronic switches to guide future research.
  - Design and demonstrate a high speed linear induction and a linear synchronous motor segments.

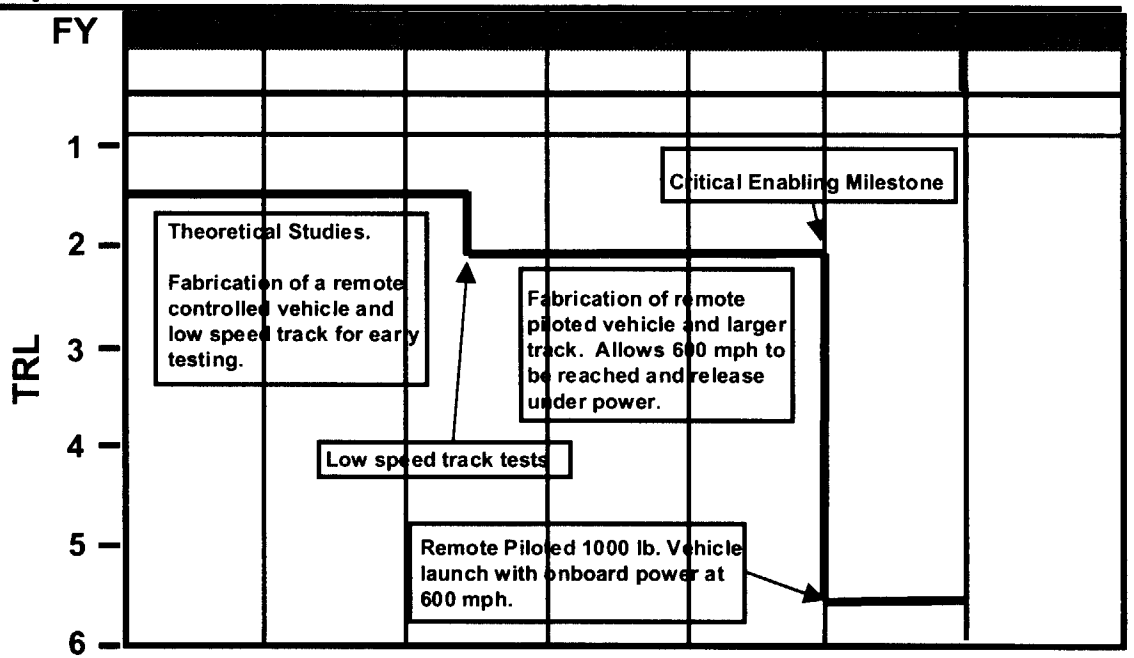


Requirements Flow down



- **FY'01 Milestones**
  - Aerodynamic analysis complete by end of FY01, main issue is flutter
  - Delivery of remote controlled vehicle for test flights
  - Early flutter testing on the Foster-Miller track
- **FY'02 Milestones**
  - Low speed release of remote controlled vehicle.
  - Incorporation of flutter results into CEM effort
- **Prioritized list of Activities**
  - Aerodynamic analysis of the MagLev Sled.
  - Incorporation of these results into the long range design
  - Aerodynamic testing on the Foster-Miller Track

- **Current State of the Art**
  - Negligible. High speed cars and airborne release indicate the complexity and possible dangers.
- **Performance Metrics**
  - Successful and well understood demonstrations
- **Risks**
  - High cost effort which potentially does not address the issue in adequate detail.
- **Participants**
  - KSC,DFRC, MSFC, Holloman Test Track and Florida Institute of Technology



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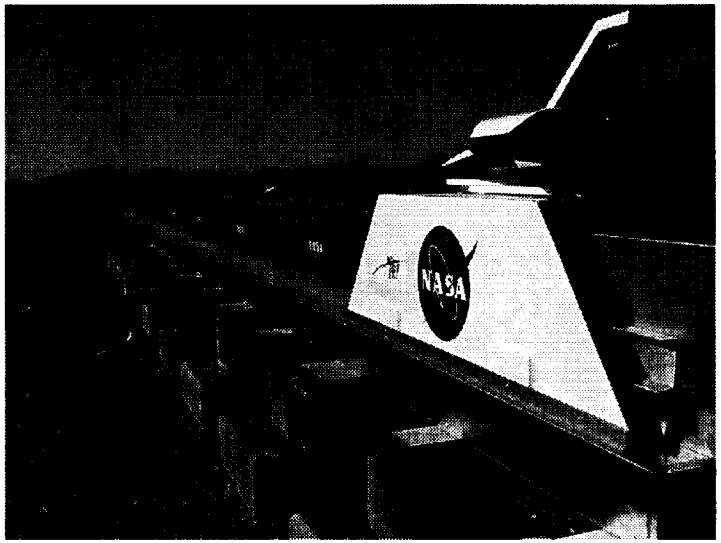
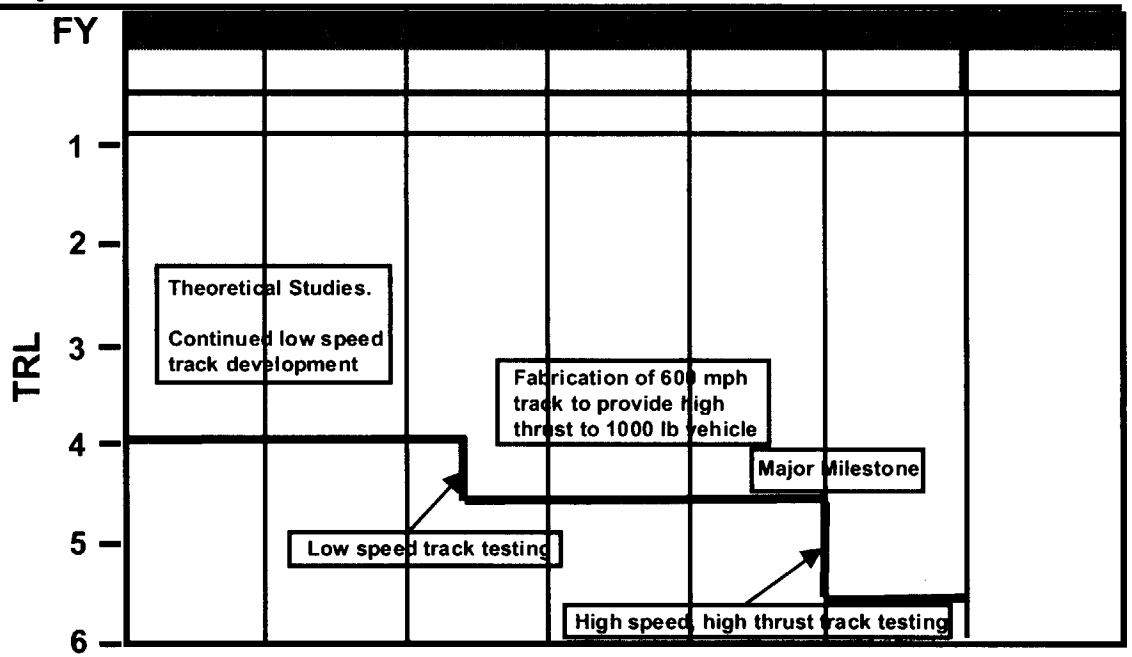
Aerodynamics and Sled/Vehicle Interaction



- **FY'01 Milestones**
  - Results of scaling study by Foster-Miller
  - Results from PRT waffle motor demonstrator
  - Results from CEM linear motor study
- **FY'02 Milestones**
  - CEM linear motor segment high speed demonstrator
  - Possible follow on work with either LLNL, PRT, or Foster-Miller
- **Prioritized list of Activities**
  - CEM effort on understanding the limits of high speed linear motors
  - Demonstrator studies with data acquisition to determine system performance and track operation issues.
  - Scaling and control studies and experiments.

- **Current State of the Art**
  - Linear Induction Motors and Linear Synchronous Motors exist, but not to the scale needed.
- **Performance Metrics**
  - Demonstration of Technology
- **Risks**
  - Minimal since computer simulation is well developed, but technology limited.
- **Participants**
  - KSC, MSFC, Center for Electromechanics, PRT, Foster-Miller, Lawrence Livermore, Navy EMALS,



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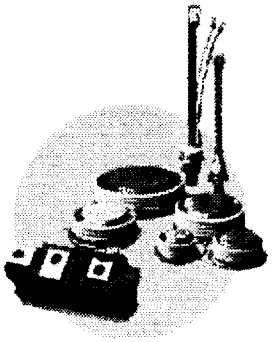
Magnetic Propulsion Technology

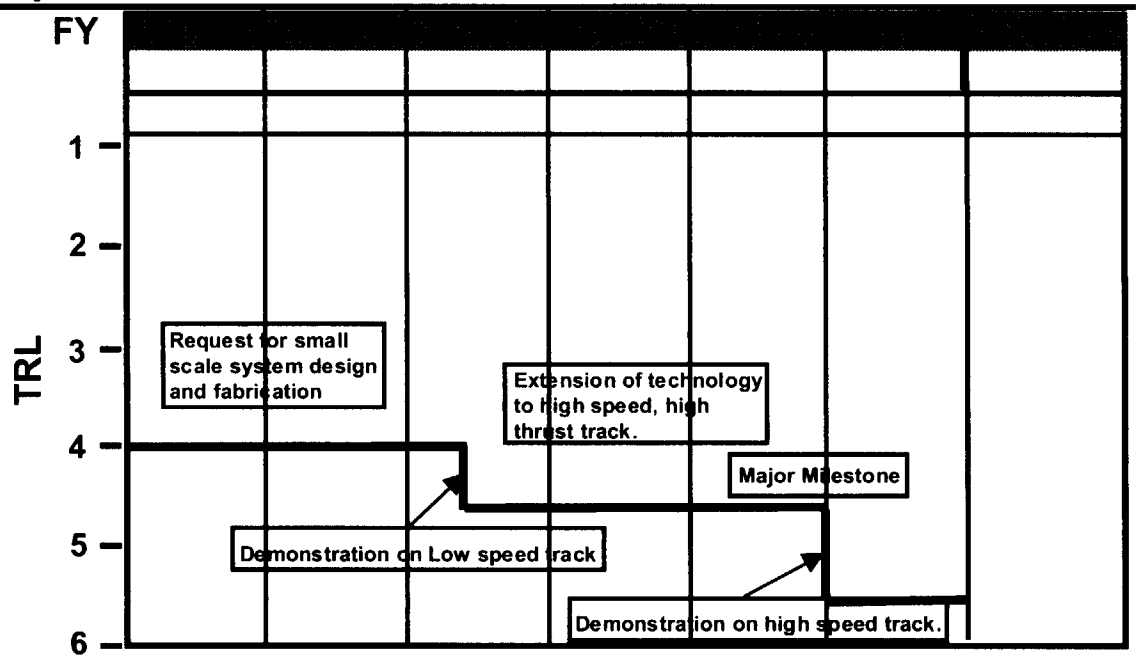
Composite Flywheel



High Power Electronic Components

- **FY'01 Milestones**
  - PRT 50' track inverter installation and demonstration
  - Possible PRT 200' track Compulsator installation and demonstration
- **FY'02 Milestones**
  - CEM study results on flywheels and electronics for the high speed linear motor demonstrator
  - Internal effort on LN2 superconductrors
- **Prioritized list of Activities**
  - CEM effort – high TRL– flywheels and electronics
  - KSC effort – low TRL – superconducting energy storage and delivery
  - PRT demonstrators

- **Current State of the Art**
  - Flywheel technology appears adequate. Power semiconductors are nearly adequate. Cost is high.
- **Performance Metrics**
  - Demonstration of Technology
- **Risks**
  - Fairly high TRL but cost must come down.
- **Participants**
  - KSC, CEM, NAVY EMALS, PRT



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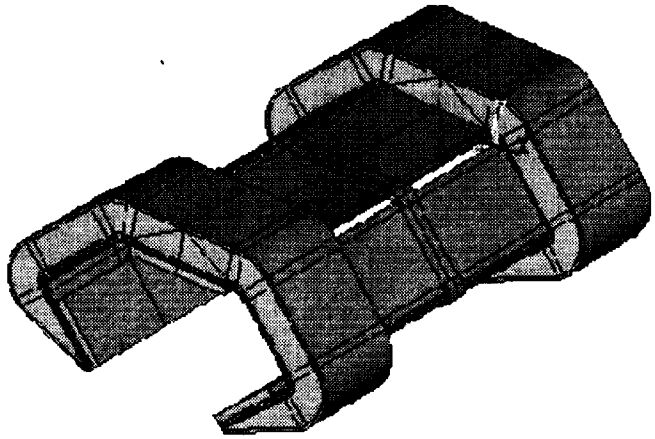
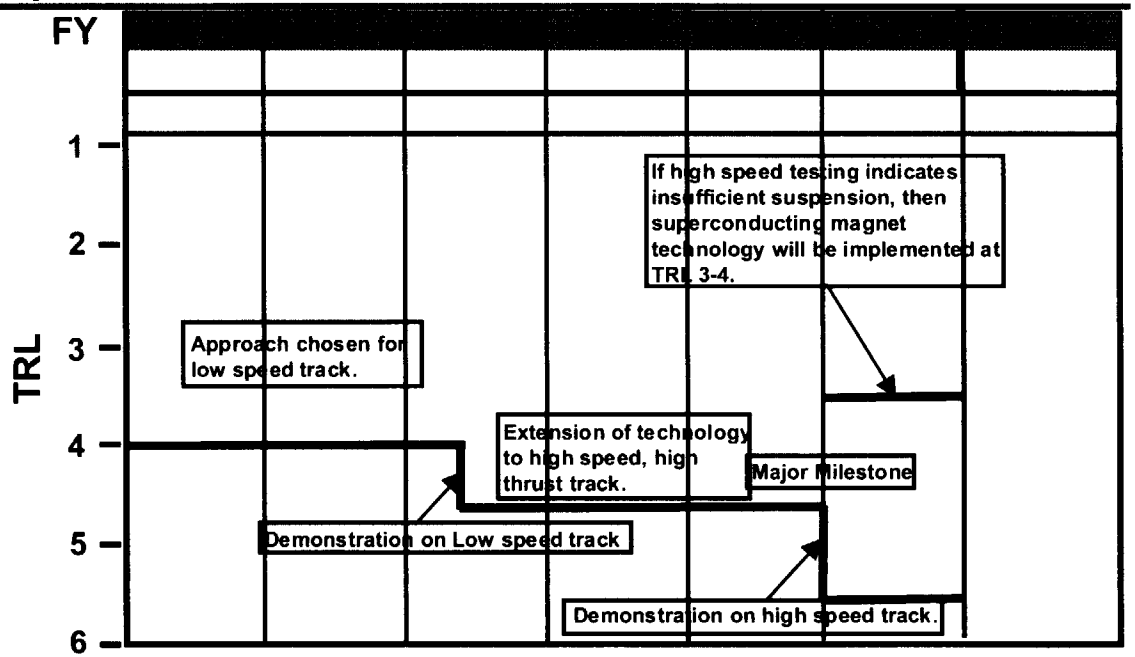
Energy Storage and Delivery



Triple Halbach Array Sled-Levitation Concept

- **FY'01 Milestones**
  - Foster-Miller scaling study results
  - Lawrence Livermore Inductrack demonstrator results
  - PRT invertor controlled levitation
  - MIT STTR complete on Liquid He superconducting magnets
- **FY'02 Milestones**
  - Internal KSC concept study and demonstrator
  - Results of CEM effort
- **Prioritized list of Activities**
  - CEM study, levitation incorporation into high speed linear motor segment
  - Demonstrator Track experimentation and study, includes Foster-Miller, LLNL, and PRT
  - Continued new concept studies and experiments

- **Current State of the Art**
  - Small scale demonstrations at high acceleration, large scale systems at low acceleration.
- **Performance Metrics**
  - Demonstration of Technology
- **Risks**
  - Minimal, unless superconducting approach required.
- **USG Participants**
  - KSC, PRT, Lawrence Livermore, Foster-Miller, CEM



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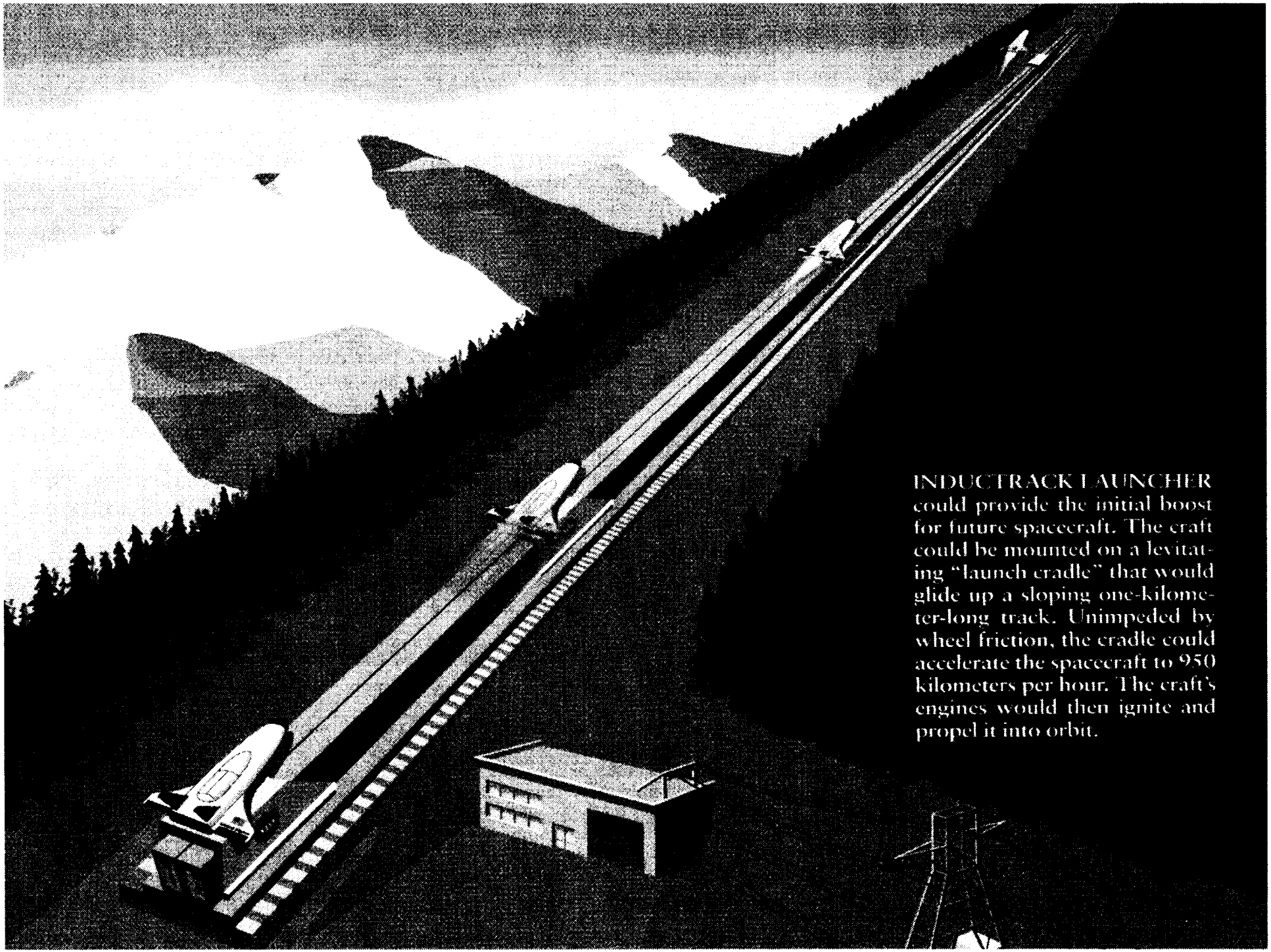
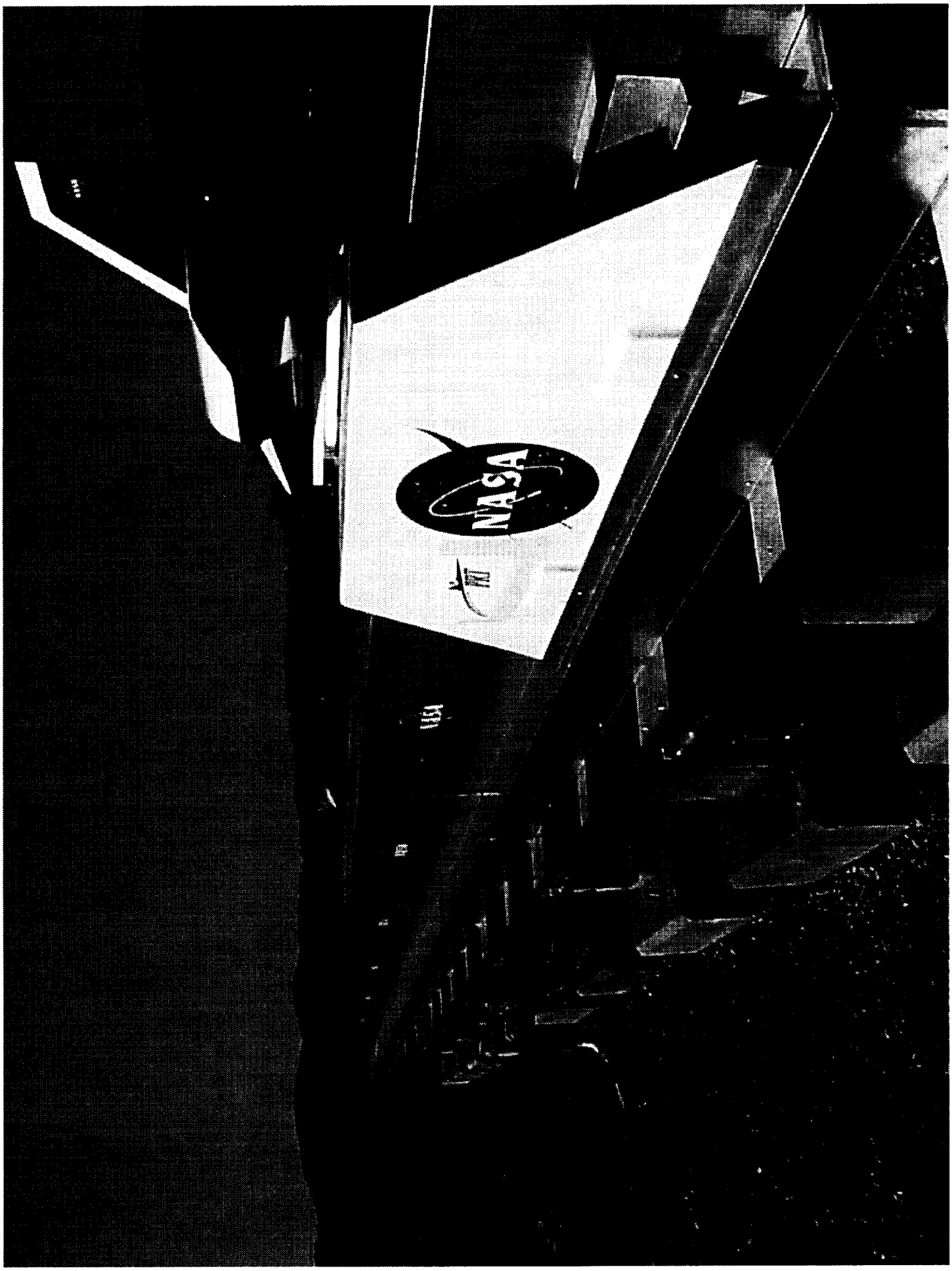
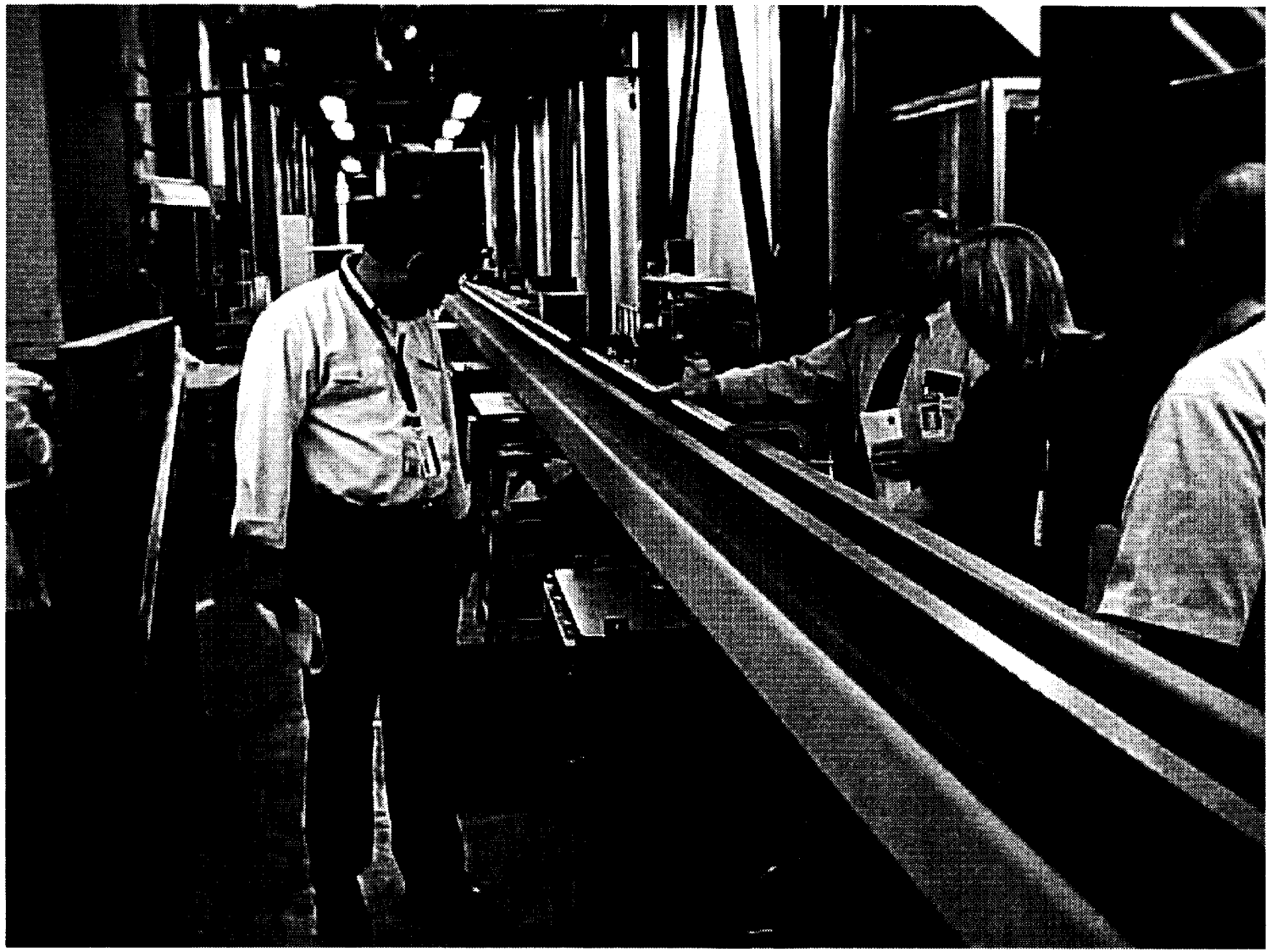
Magnetic Levitation



INDUCTRACK LAUNCHER could provide the initial boost for future spacecraft. The craft could be mounted on a levitating "launch cradle" that would glide up a sloping one-kilometer-long track. Unimpeded by wheel friction, the cradle could accelerate the spacecraft to 950 kilometers per hour. The craft's engines would then ignite and propel it into orbit.


NASA



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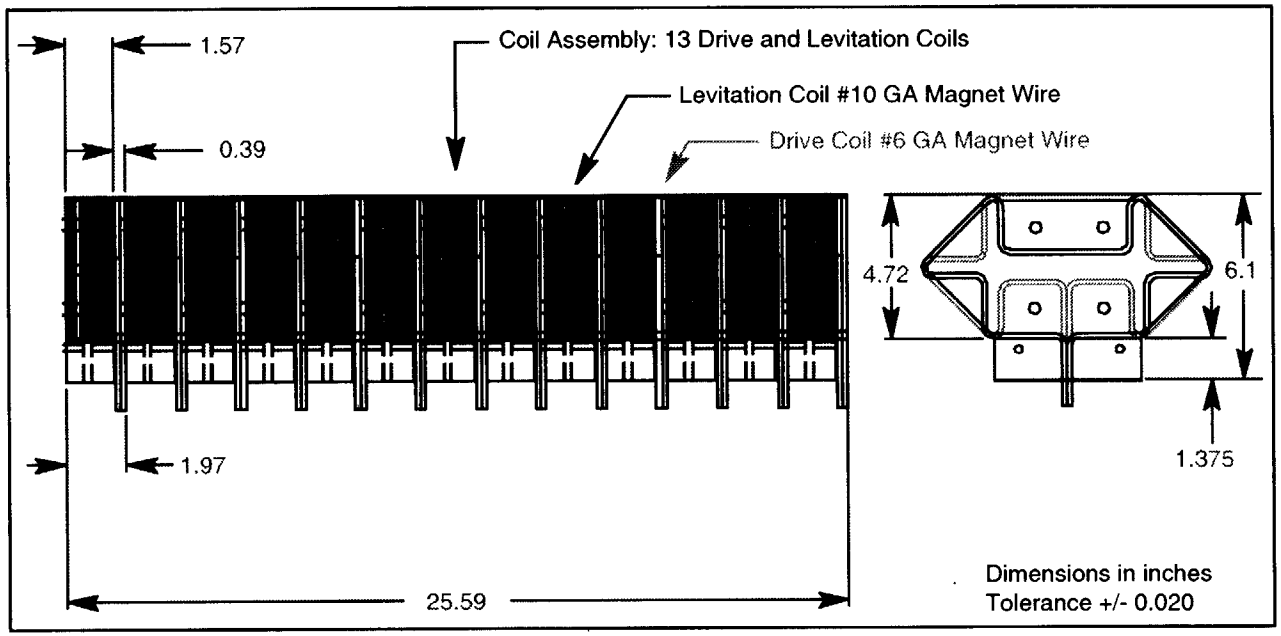
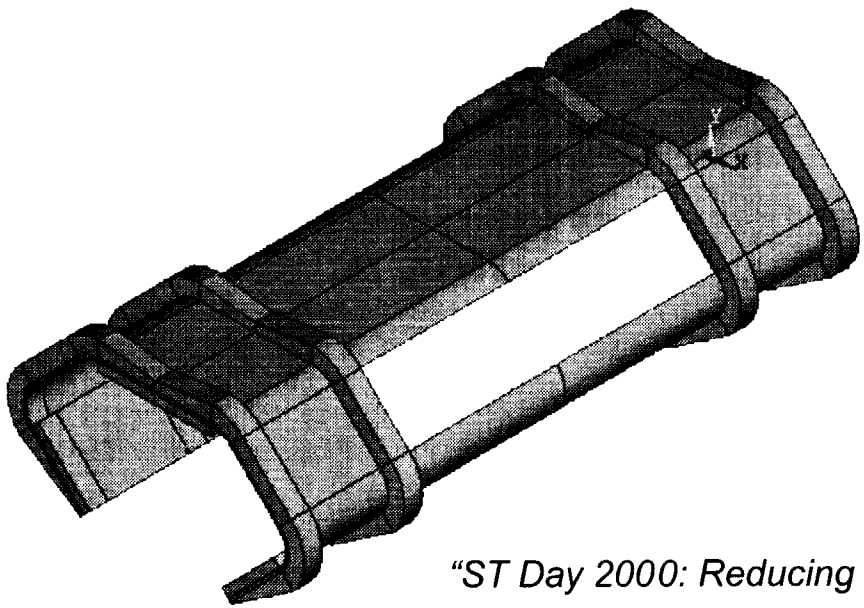
Lawrence Livermore Inductrack





Lawrence Livermore concept of
Inductrac and Carrier

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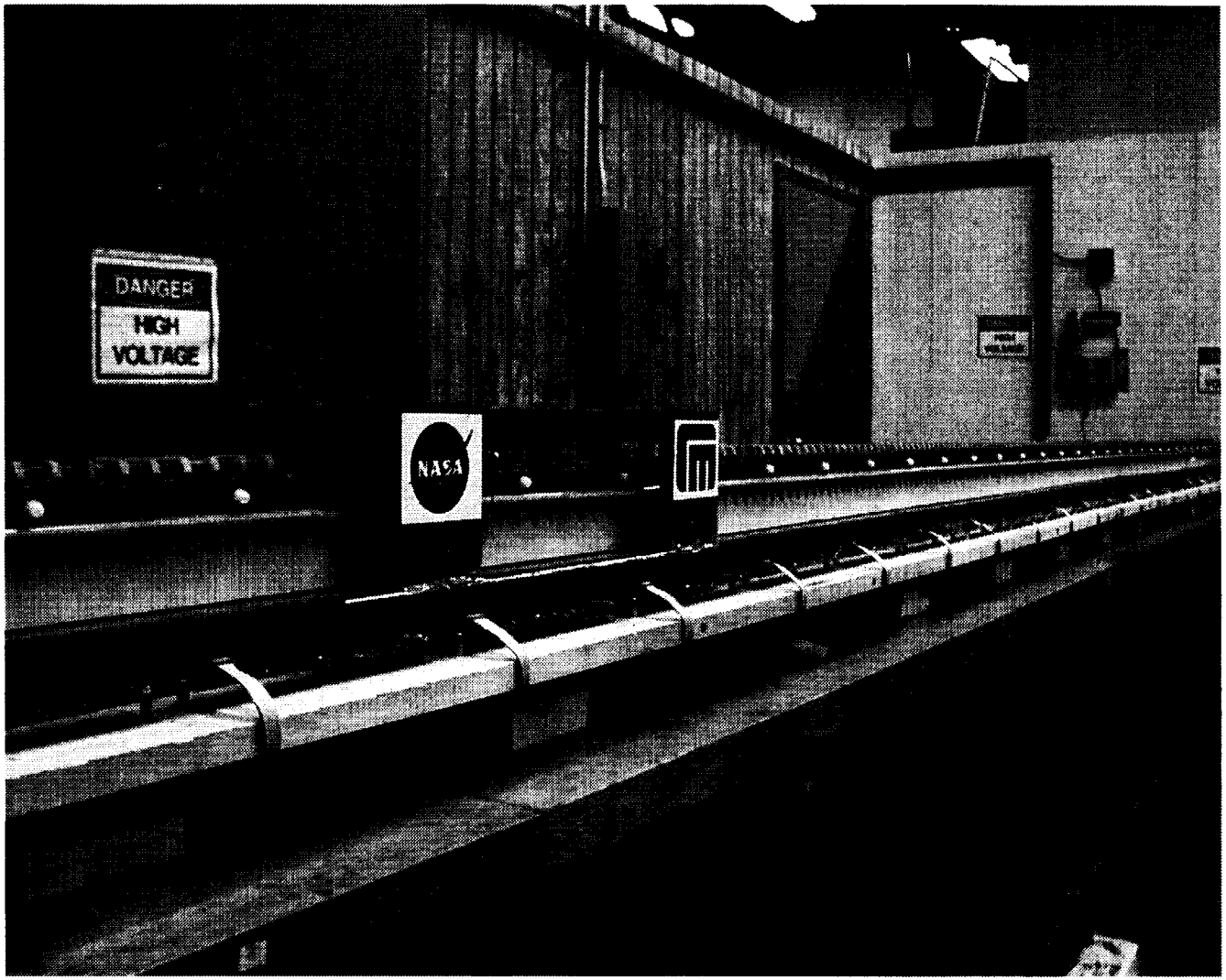
Lawrence Livermore Inductrack



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Foster Miller Track

- MSFC – PRT track testing.
- DFRC – Aerodynamics / Flight Dynamics / Flight Test.
- Ames – Computational Analysis / Wind Tunnel Testing.
- Florida Space Institute (FSI) – Foster Miller track testing.
- DoD (Navy) – EMALS and Arrestor program.
- Academia – Magnetic levitation/propulsion and energy storage system studies.
- Industry - LLNL / Foster Miller / PRT Advance Maglev Systems.
- KSC - STTR Phase I (Advance Magnet Labs and MIT) Study on superconducting systems.

Partnerships for the project

- **Proposal**
  - During the first year the project will research, test, and develop partnerships to understand the technical feasibility of using magnetic suspension to launch prototype vehicles to test technologies for the development of the 3rd generation RLV.

- **Technical Approach**
  - Research available magnetic launch systems.
  - Research available energy storage systems.
  - Research switching, power distribution, and controls.
  - Follow ongoing MSFC contracts.
  - Develop partnerships with DoD and Academia.

Proposal / Technical Approach

- **Accomplishment this year**
  - Formed a partnership with the Navy to participate in the development of the EMALS and Arrestor program.
  - Formed a partnership with DFRC to perform fly dynamics and demonstrations for the project.
  - Extended the Lawrence Livermore National Laboratory contract to built and test and Inductrack at their facilities.
  - Extended the Foster Miller contract for additional studies on the Linear Synchronous motor track they built.
  - Developed a 10 year road map for the project and got it approved by the program.
  - Formed a partnership with Florida Space Institute and relocated the Foster Miller 44 ft track to KSC. We will use graduate student under our guidance to do research.
  - Signed a grant with the Center for Electromagnetic at the University of Texas in Austin to evaluate the existing high speed motors available for the MagLev System.

- **Plans for next fiscal year**
  - **Perform flight testing from the PRT 50 ft track located at MSFC using a Radio Control powered vehicle.**
  - **Investigate aerodynamic problem due to wing "flutter".**
  - **Participate in the development of the EMAL system with the NAVY.**
  - **Design and commence fabrication of a test bed to test various configurations of linear motors at the Center for Electromagnetic.**
  - **Modify and test different coils configuration for propulsion and levitation using the Foster Miller 44 ft track.**

- **Risks**
  - **Long term funding, Program survival.**
  - **Energy storage systems.**
  - **Aerodynamics.**
  - **Scaling.**