High Speed Sled Track & Capture Mechanism

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Mission/SOW

Design and development of a novel penetration mechanics testing apparatus focused on test repeatability, ease of use, low maintenance, and high frequency operation with minimal downtime.

System Requirements:

- Supports a **200 lb** sled with a **500 lb** payload
- Accelerates to **150 ft/s** within the first **50 feet** of track
- Decelerates sled within the final **30 feet** using capture mechanisms
- Fits within **narrow gauge** track dimensions
- Ensure no interference along payload trajectory with impact target

Our team collaborated closely with LANL Sled Track Team 1 where we worked in coordination to integrate their sled vehicle, propulsion system, and release mechanism into our complete sled track design.

Research

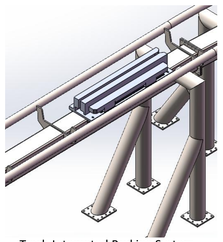
Research geared towards test repeatability, ease of use, low maintenance, and high-frequency operation

- Studied track profiles, structural support methods, and narrow-gauge rail standards to determine an optimal design.
- Examined track adherence mechanisms including multi-wheel assemblies, friction slippers, and modular designs for smooth and controlled motion similar to a roller coaster.
- Investigated roller coaster style friction braking systems for decelerating high speed vehicles safely and reliably with fin brakes.
- Explored eddy current braking systems for non-contact deceleration, reducing wear and maintenance with magnetic brakes.
- Analyzed high-force capture systems used to stop jets on aircraft carriers, focusing on cable based and hydraulic energy absorption methods with an arresting gear.
- Investigated fail-safe mechanisms to ensure emergency braking functionality under power loss or control system failure conditions.
- Evaluated optimal materials for track construction based on strength, durability, and manufacturability, and for wheel tread concerning track adherence while minimizing wheel slipping

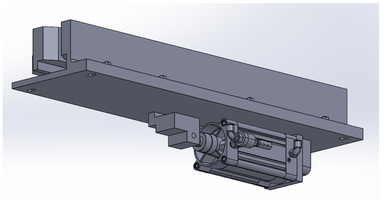
Final Design

The final design features multiple subsystem specifications including:

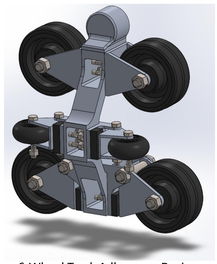
- Capture mechanisms designed to arrest a 200 lb sled with 500 lb payload travelling at 150 ft/s within 30 ft
- Track diversion capable of supporting the maximum expected radial forces
- Designed for high-frequency usage while maintaining full functionality and ensuring structural integrity
- Zero-moment 6-wheel track adherence design including running, glide, and upstop wheels
- Subsystems' mechanical design ensures full-functionality in the absence of electricity
- Modular design for ease of assembly and disassembly, and simplified maintenance



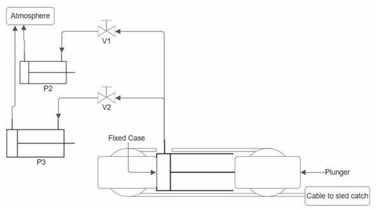
Track-Integrated Braking System



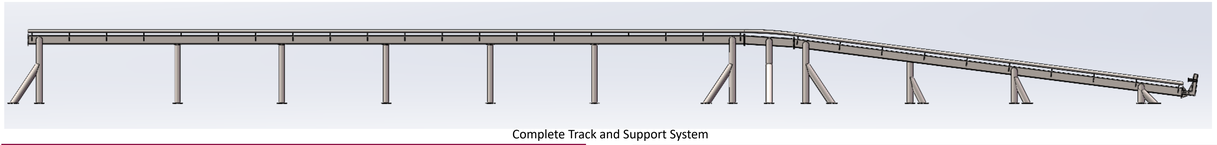
Magnetic Brake System



6-Wheel Track Adherence Design



Arresting Gear P&ID diagram



Complete Track and Support System

Validation Results

Sled Track:

- The sled track can handle the maximum expected forces from sled maneuver along track diversion.
  - FoS of 17.9 when subjected to 75,000 N radial forces using low carbon steel

Magnetic Brakes:

- Sled speed reduction from 150 ft/s to 120 ft/s prior to track diversion
  - System rated for 30,000 N of braking capable over the 5 ft braking length

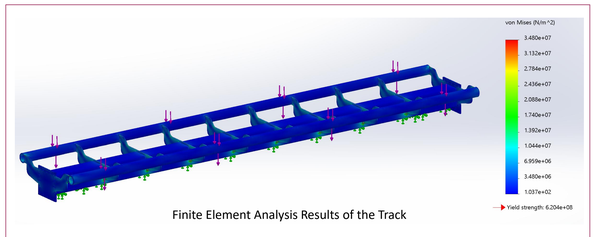
Arresting Gear/End Bumpers

- Sled speed reduction following track diversion from 120 ft/s to rest within 25 ft
  - Arresting gear rated for 80,000 N peak braking force
  - End bumpers capable of arresting sled at 30% the maximum speed

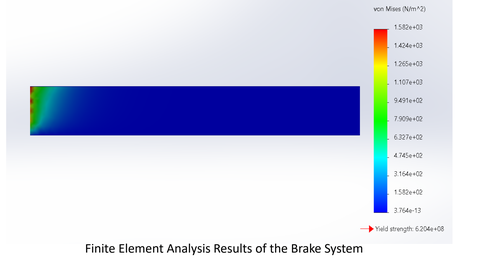
Wheel assembly:

- Frame structure withstands expected force loading and wheel slipping
  - FoS of 7.2 when subjected to 17,000 N radial forces using Al 6061-T6
  - Current wheel tread material ensures proper adherence to the track with no slipping

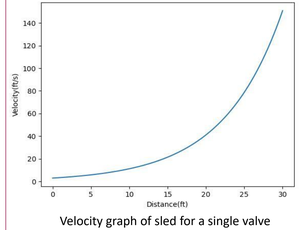
FEA/Simulation Test Results



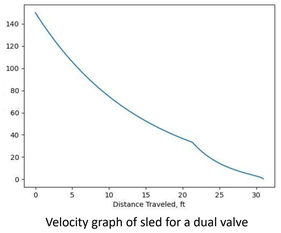
Finite Element Analysis Results of the Track



Finite Element Analysis Results of the Brake System



Velocity graph of sled for a single valve arresting gear



Velocity graph of sled for a dual valve arresting gear

Concept Development

Main track structure:

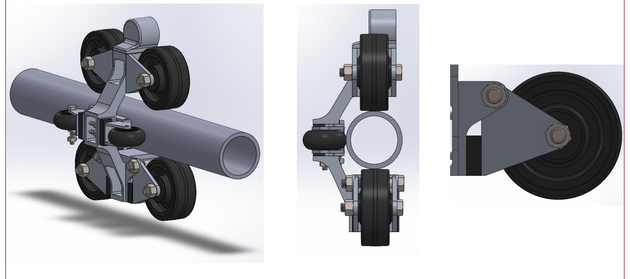
- Steel rollercoaster-based design with a long sturdy box spine and welded running rails
- 30 ft turning radius path diversion for proper payload trajectory
- Safety stop bumper after braking section for added safety precaution
- Track elevated 5 ft above ground with steel track supports and bolted connection to concrete anchor for stability

Capture mechanisms:

- Magnetic eddy current brakes for initial deceleration before track diversion
- Arresting gear hydraulic piston system for smooth deceleration and minimal wear
- Safety stop mechanism positioned at the track's end to mitigate vehicle overrun in failure events

Track adherence approach:

- Zero-moment 6-wheel assembly for stability and vibrational control and roller bearing supported pitch freedom for navigating track diversion
- Polyurethane wheel tread used for form-fitting properties and for added vibrational control
- Hinged and polyurethane rubber-padded glide and upstop wheels to allow for variable rail profile



Detailed 6-Wheel Track Adherence System

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