ARES Lessons Learned

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Energy Storage Demonstration Team

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Project Overview

Project Goal: Sandia National Laboratories (SNL) conducted a due-diligence assessment of the Advanced Rail Energy Storage (ARES) Pahrump site to evaluate operational status, engineering challenges, organizational culture, and the economic landscape.

Current Practice: ARES is exploring a novel aspect of gravitational energy storage utilizing rails and mass cars on an incline. At utility-scale, similar competing research is focused on vertically-lifted weight storage systems.

Why Sandia National Laboratories: Sandia is a leader, trusted partner, and advisor across the Energy Storage landscape, and brings unique subject matter expertise to such due-diligence evaluations.

Innovation: ARES's approach leverages modular designs and heavy mass cars, aiming to provide scalable, cost-effective energy storage solutions that integrate with diversifiable energy sources.

Impact: ARES's gravity energy storage technology can enhance energy storage diversity, support long-duration energy storage (LDES), and contribute to grid stability and reliability.

Alignment: As a US company innovating state of the art of gravity energy storage systems, ARES possesses the potential to “unleash American Energy”. Sandia provides a trustworthy, unbiased third party opinion ensuring ARES’ innovation aligns with scientific and technological innovation.

ARES (Advanced Rail Energy Storage) History

Gravity energy storage using mass cars on a slope

Founded in 2010, Washington State corporation

Initial configuration: Tehachapi CA site, completed 2013

- Conventional rail implementation, with electric locomotive
- 5 patents

Current configuration: Gamebird Pit site, NV site, completed 2025

- Novel rail implementation, with stationary drive at slope top and chain drive
- Investor funded
- 1 patent issued and 1 pending

Tehachapi Demonstration site

Purpose of the site

- Validate feasibility and reliability
- Test response to grid, capability for load balancing

Features of the site (completed 2013)

- Electrically powered cars, 12,500 lbs
- Single track: 2 rails, gravel ballast, 15 inch gauge
- Track length: 880 ft

Lessons Learned

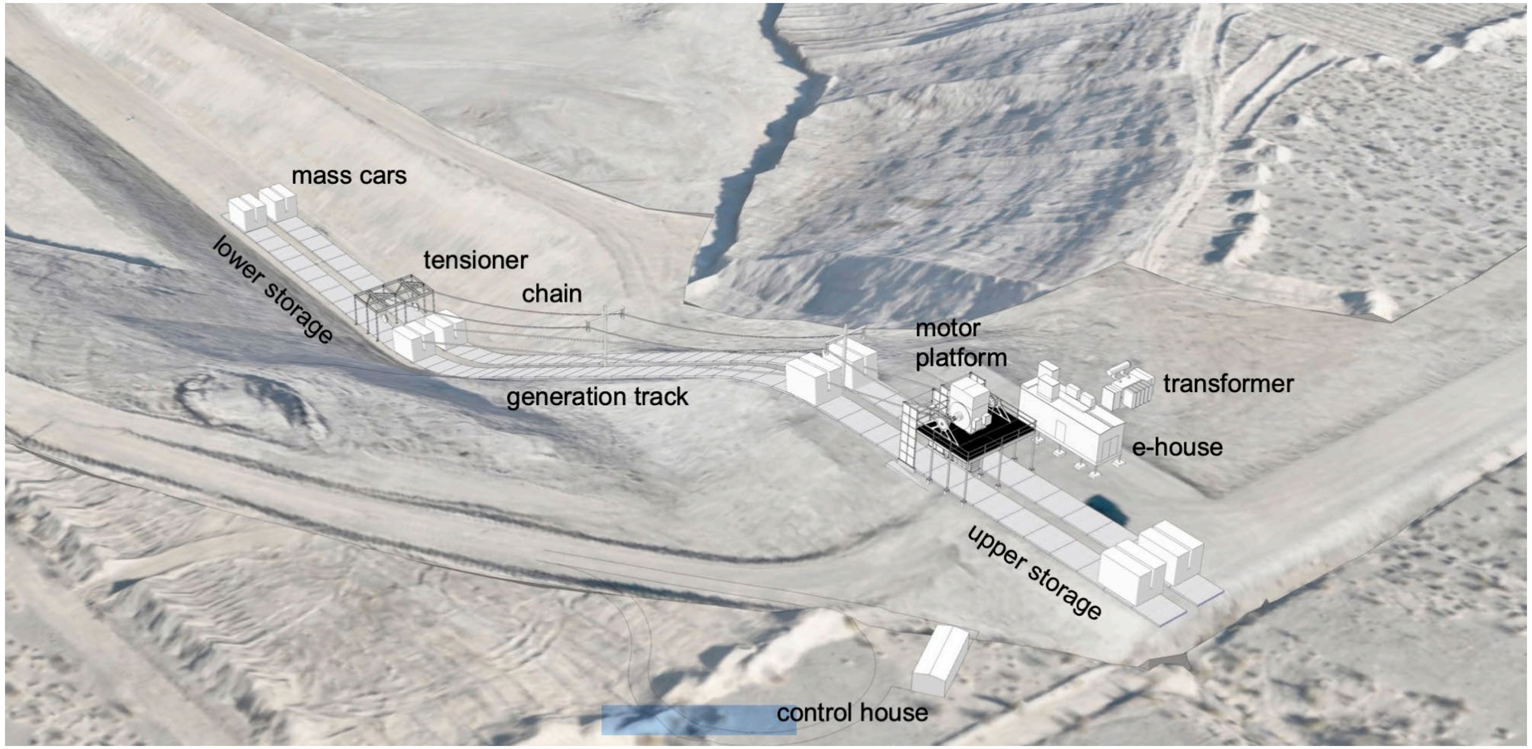
- Efficiency, response, integration demonstrated
- High initial investment required

Las Vegas prototype manufacturing site

- 7000 sq ft in mixed use park near Harry Reid airport
- Main resource is a laser cutter
- Many components made from steel plate
- Vertical integration reduces cost
- In house manufacturing helps them understand “pain points” and innovate improvements

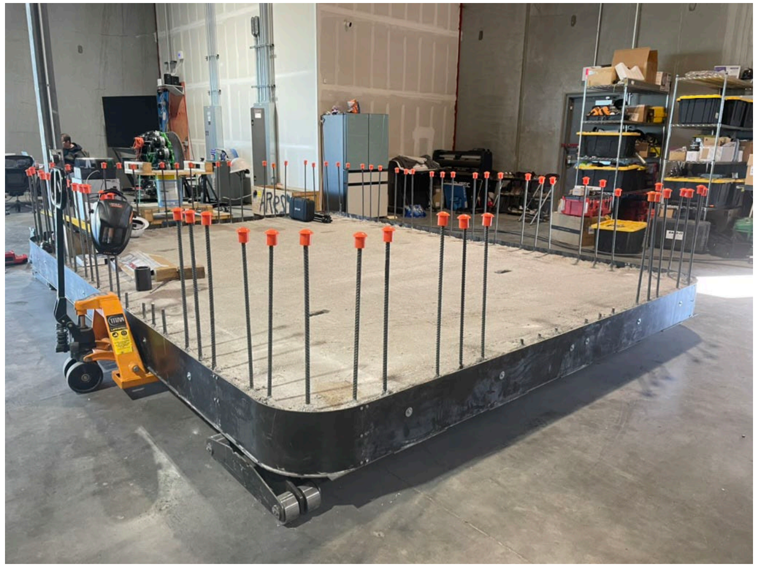
Gamebird Pit Demonstration site

- Track pair shares drive
- Mass cars operated in pairs
- Mass car pair: 720 klb
- Elevation delta: 115 ft
- Track inclination: 26.8°
- Chain speed: 8.48 mph
- Load on chain: 170 klb
- Requires a slope with a usable grade
- Upper and lower storage areas
- No need to build a skyscraper



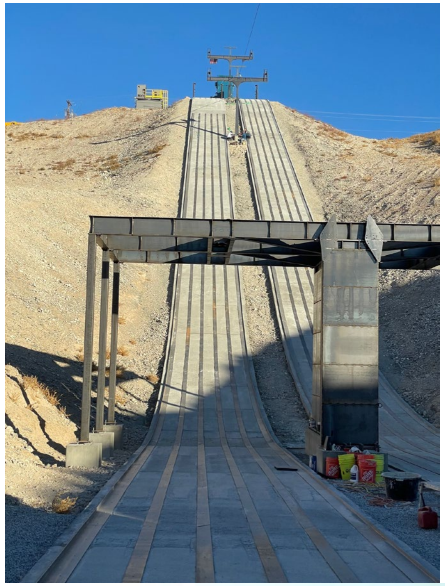
Mass Cars

- Reinforced concrete base
- Built on site as they are too heavy to be transported by road
- Numerous roller assemblies per car
- Cars eventually filled with gravel ballast
- Center opening remains clear for haul chain (creates a "Dune" aesthetic)



Track and rail details

- Flat steel plates for mass car roller assemblies to move along
- Plates mounted to concrete beds with studs
- End plates have rails for lateral control
- Towers for chain between tracks
- ARES claims the load on the track is less that 3000 lbf/ft^2 greatly reducing cost
- Claiming 40 year life because nobody does LCOS for longer. Hardware should last much longer.



Drive system

- 5.5 MW motor from WEG (Brazil)
- VFD drive can provide inertia as it is “less electronic” than an inverter
- Drive sprocket pairs pick up chain on the outside
- Chain losses are lower than cable losses
- A strong enough cable would be too heavy to be transported, subject to elongation, and not modular for maintenance

Parameters calculated from observations and notes

Parameter	Tehachapi	Gamebird Pit
Track length between upper and lower terminals	880 ft (268 m)	246.5 ft (75.1 m)
Track Design	Conventional pair of rails, 15 inch gauge	6 parallel flat plates with guides at outer edges
Mass car configuration	Self-powered	Chain hauled
Mass car weight	12,500 lb (5,670 kg)	750,000 lb (340,000 kg) for pair

Parameter	Value
Elevation change between upper and lower terminals	118 ft (36 M)
Maximum track inclination	26.8 degrees (54.5% grade)
Length of chain (assuming uniform grade)	246.5 ft (75.1 m) = Elevation change / sin (inclination angle)
Elevation for a chain length of 2000 ft at track inclination	957 ft (292 m) = 2000 ft * sin (28.6 degrees)
Mass car weight (pair of mass cars)	750 klb (340,194 kg mass, 3,333,901 N weight)
Maximum potential energy	120 MJ (33 kWh) = m g h
Chain speed	7.99 mph (constant) (3.57 m/s)
Vertical component of speed	1.71 m/s = chain speed * sin (inclination angle)
Transit time for mass car pair	= chain length/speed = 81 seconds
Power (= F * V = m * g * V)	5.7 MW (one mass car pair at vertical component of chain speed)
Motor rating	5.5 MW (actual output 5 MW, 10% loss)
Mass car stored energy at 1000 ft of elevation gain	1.0 GJ (282 kWh)
Nominal incremental cost per unit energy stored	250 $/kWh
Nominal maximum mass car cost – upper limit for $250/kWh (1000 ft elevation delta)	= stored energy * 250 $/kWh = $70,5658
Mass car cost per unit weight – upper limit for $250/kWh	Mass car cost/weight = $0.094/lb
Kinetic energy of mass car pair at chain speed	= 0.5 m V^2 = 2.17 MJ = 0.60 kWh

Observations from calculations and discussion

- ARES says there's strong pull for bulk storage between AI/Data Centers and utilities
- PPA and tolling agreements let ARES assume risk
- Plan is to build the plants and own them for a period of time
- Privately funded: high motivation to attain commercial viability
- BLM has been very supportive
- Every detail of mechanical design shows a strong focus on reducing cost
- The project is a demonstration and not economic by itself (only 32 kWh per car pair)
- Competing constraints
- A rule of thumb for any gravity energy storage system:
  Assuming 1000ft elevation delta and incremental cost of < $250/kWh (putting aside decoupling of power and energy): the lifted mass must cost < $0.093/lb
- ARES claims actual mass car costs are half of this limit

Overarching lesson learned

- Sizing mechanical energy storage for bulk storage scale drives design outside of established engineering ecosystems
  - Mass cars are far heavier than trams, gondolas, and most material handling so the lift and crane industries have no economic solutions.
  - Same is true for flywheels: materials, bearings, motors all are extreme
  - System developers must innovate in a space that could reasonably have been expected to be mature.
  - With one important exception: pumped hydro technology and equipment is available at utility scale.

Thank You

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