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DOE Peer Review

September 2012
Ed Chiao, CEO

Amber Kinetics: Our Flywheel History

Stanford University	Start-up launched in 2009, Stanford University Cleantech Entrepreneurship class
Lawrence Livermore National Laboratory	Established a technology licensing & flywheel development partnership with LLNL; Amber Kinetics identified new material & lower-cost rotor designs for commercialization
U.S. Department of Energy	Awarded a Smart Grid Energy Storage Demonstration grant award for flywheels
California Energy Commission	Awarded a matching grant for development & demonstration of flywheel technology

World-class institutions | innovative, deep flywheel technology owned by Amber

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Program Schedule

Technology Milestones
Prototype Proof of Concept

High Cycle Testing
Commercial-Scale R&D

Commercial-Scale
Flywheel System

0 months

16 months

32 months

48 months

2010 | 2011 | 2012 | 2013 | 2014

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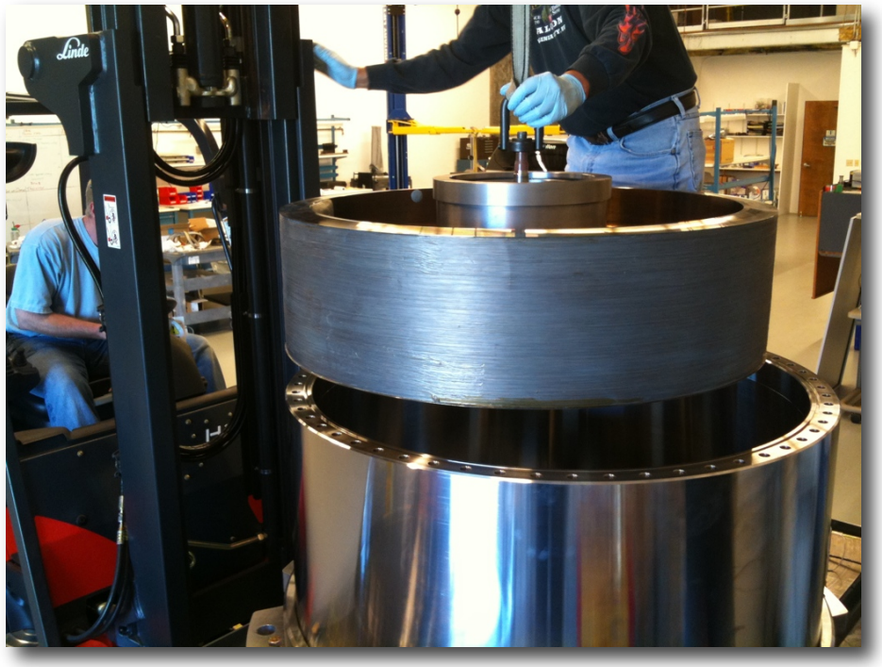
Technology Milestone #1 – Spin Testing



Spin Testing

Reinforced Spin Pit Assembly

- **Two 750-lb flywheel rotors constructed**
- **Maximum operating design speed: 365 m/s and 7700 RPM**
- **Spin testing accelerates rotor to: 530 m/s and 11,000 RPM**

- **Rotor stores 10 kWh of kinetic energy @ 11,000 RPM (2x more than design speed)**
- **All testing conducted in start-of-the-art spin testing facility in Hudson, MA**

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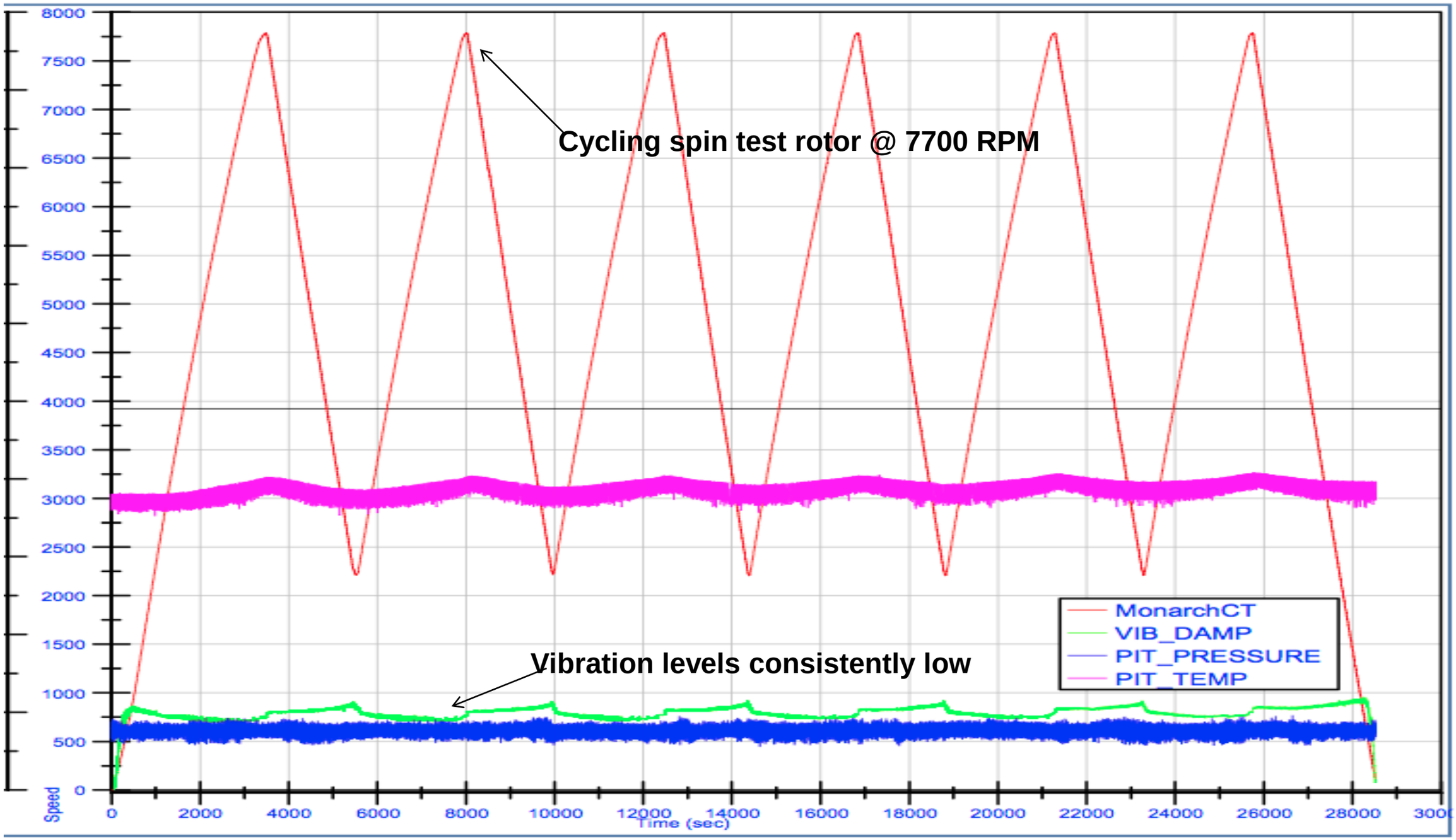
Spin Test Cycling Results



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Technology Milestone #2 – Flywheel System Activation

Generation One: Prototype 20 kW | 5 kWh Flywheel System

5 kWh, steel wire-wound flywheel rotor activated & operating in prototype system

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Technology Milestone #3 – Fatigue Testing Results

- Observed over 350,000 test cycles cycles
- One cycle tests from 0-100-0% of operating design stress
- Testing across a pre-defined range of material specs
- Testing across multiple supply vendors
- Material cost: ~$0.50 per pound, simple to MFG
- 1/20th the cost of carbon fiber
- Material sources are mature; rotor design is scalable

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Commercial-Scale Flywheel System & Facility Design

Amber Kinetics 500kW | 125kWh
Generation 2 Flywheel

20 MW Facility
10,000 sq ft Buliding

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Challenge - High Balance of System (BOS) Costs

Dimensions: 5 ft x 12 ft (Diameter x Length)

- Vacuum Vessel
- Upper & Lower Stator Support Assemblies
- Motor-Generator System
- Magnetic Bearing System
- Upper & Lower Touchdown Bearing Assemblies
- Power Converter & Control Electronics
- Temperature & Position Sensors
- Ancillary Components
    - Vacuum Pump
    - Vacuum Feed-Through
    - UPS
    - Motor & Bearing Drives

BOS costs generally scale with respect to physical size & weight of the machine

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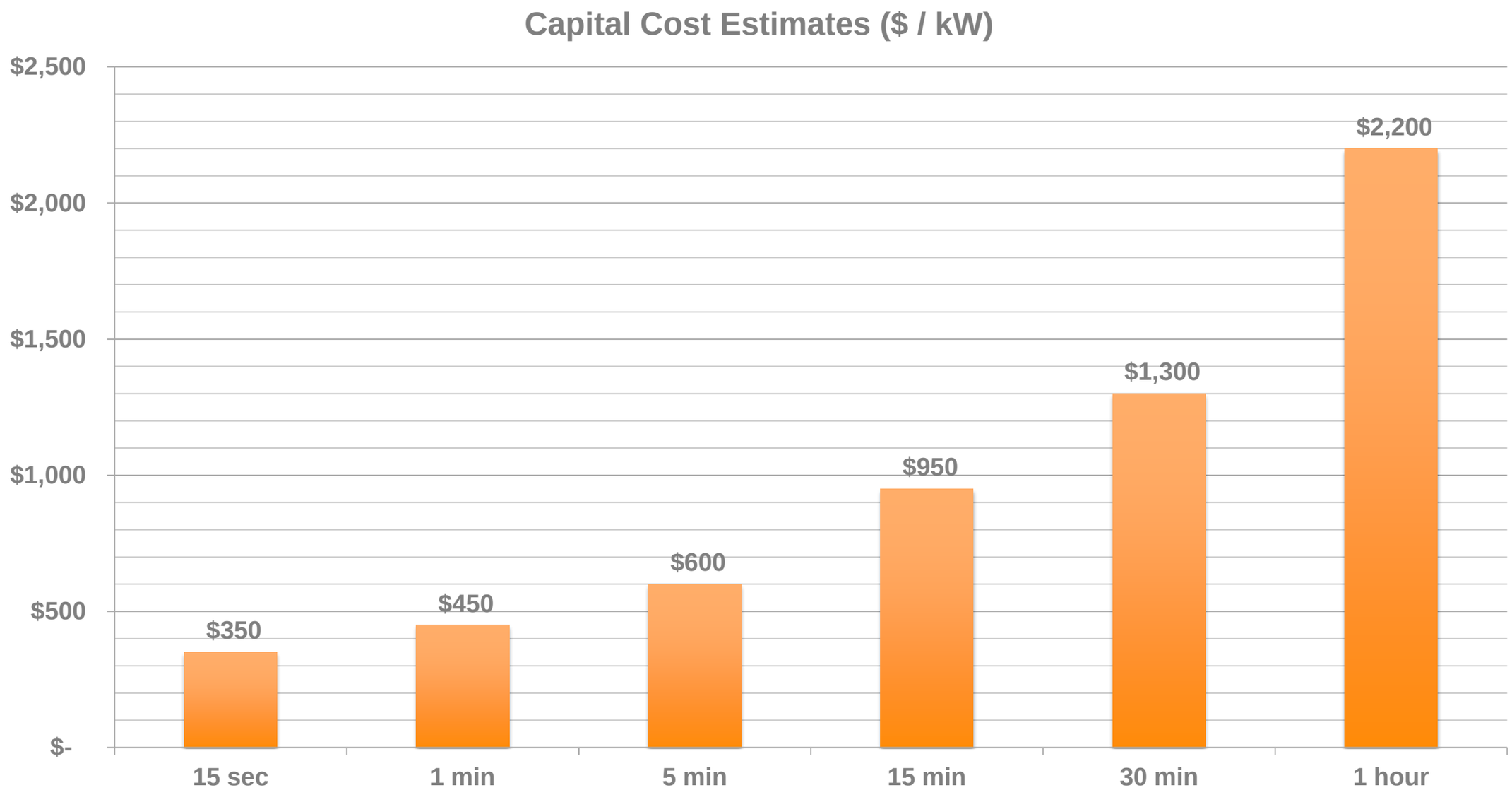
Capital Cost Estimates (AC-to-AC)



Cost estimates based on point designs for a 125 kWh flywheel system

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Conclusions:

< 1/2 Capital Cost ($ / KW)

vs. traditional flywheels

- Flywheel rotor costs represent a cost breakthrough

- Balance of System costs dominate flywheels

- Project partners have helped Amber Kinetics evaluate aggressive BOS cost reduction

- Preliminary cost estimates for long-duration storage systems are higher than anticipated

- Project requires identification of a clear application for which flywheels can prove to be economically competitive

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thank_you

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