The NASA Flywheel Battery Project

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presented by
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Presentation Outline

- Background
- Objectives
- Rationale
- Source and Market Assessment
- Approach
- Flywheel Battery Installation Description
- Evaluation and Test Plans
- Initial Flywheel Battery Performance Data
- Future Plans
- Summary

Background

- Sponsors
  - Funded by NASA Headquarters Environmental Management Division (Code OJE)
  - Supported by the GRC Environmental Management Office and the Aerospace Flywheel Technology Program (Code T, was Code R)
- NASA GRC leads the development of flywheel technology for aerospace applications
  - This flywheel battery UPS project is a good fit with our interests and capabilities

NASA Flywheel Technology Program Participation

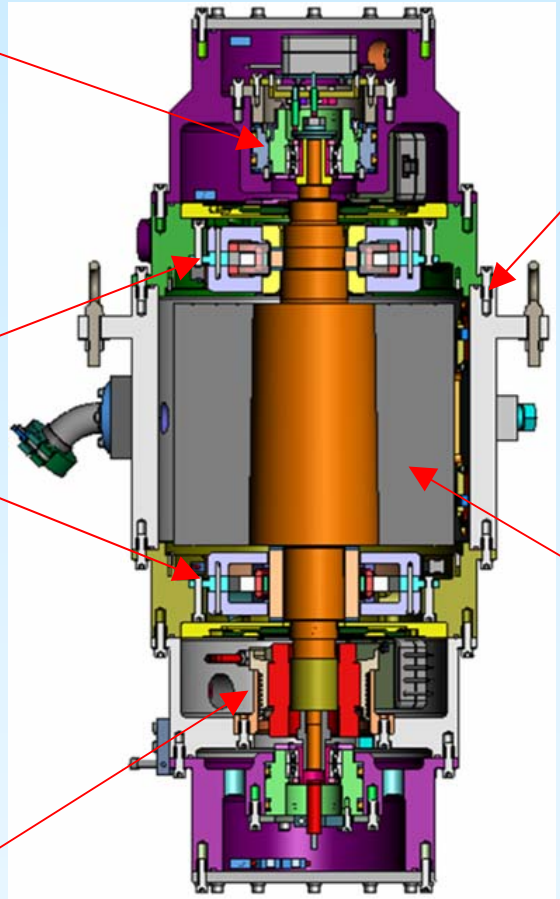
- **Develop advanced aerospace flywheel component and system technologies to meet NASA's long term mission needs for space exploration**
  - **Energy Storage**
  - **Integrated Power and Attitude Control**
  - **Power Peaking**
- **Program Objective is to demonstrate flywheel technology goals**
  - **System Specific Energy (usable) > 50 WHr/Kg (within 5 years), > 200 WHr/Kg long term**
  - **Cycle Life > 75,000**
  - **Round Trip efficiency > 90%**
  - **System Cost Reductions > 25%**
- **The GRC Flywheel Team has strong in-house, academic and industry participation**
- **This experienced in-house GRC Flywheel Team is directly involved in the installation, operation and evaluation of our Flywheel battery.**

Flywheel Technology Challenges

Auxiliary Bearings – touchdown and launch loads, stability, caging

Magnetic Bearings – low losses, higher speeds, sensors, dynamic control

Motor/Generator – low losses, higher speeds, drive controls



Housing – system and component integration, structural/dynamic response

Composite Rotor – long life, safety without containment, light-weight hubs, design and cert. standards

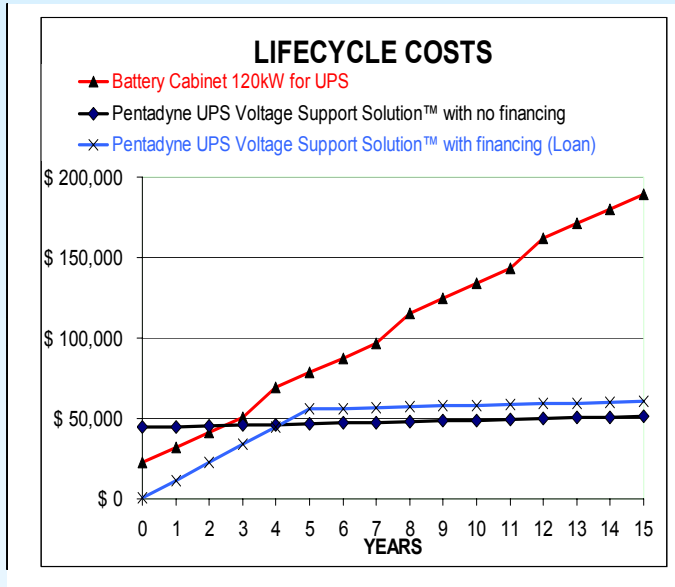
Flywheel Battery Project Objectives

- Demonstrate the viability of flywheel based UPS for NASA GRC UPS applications
- Evaluate the potential advantages and disadvantages of flywheels and batteries for UPS applications at NASA
- Provide an opportunity to obtain for NASA the life cycle advantages of Flywheel UPS

Rationale

- Safety
  - Energized Equipment
    - Batteries cannot be de-energized easily, however the Flywheel can be shut off.
  - Hydrogen
    - Batteries require ventilation, but the flywheel needs none.
  - Acid
    - Special acid containment and controls, but the flywheel needs none.

- Energy Efficient
  - Standby Power Consumption
    - Batteries use an Equalize charge then shift to float charge.
    - The Flywheel uses an adjustable current to maintain charge. It spins up to RPM, then coasts. The flywheel uses almost no power during coasting. The results are a lower standby power consumption.



- Lower Life Cycle Cost
  - At higher upfront cost it appears expensive. However over the life of a normal string of batteries there is a lower cost.

- Better for the Environment
  - Lead disposal costs. Lead is a poisonous and toxic hazard.

Courtesy of Pentadyne Power Products

Flywheel UPS Markets

Electric Utilities

Commercial Buildings

Electric Rail

Industrial Services

Clean Power Sources

Telecomm

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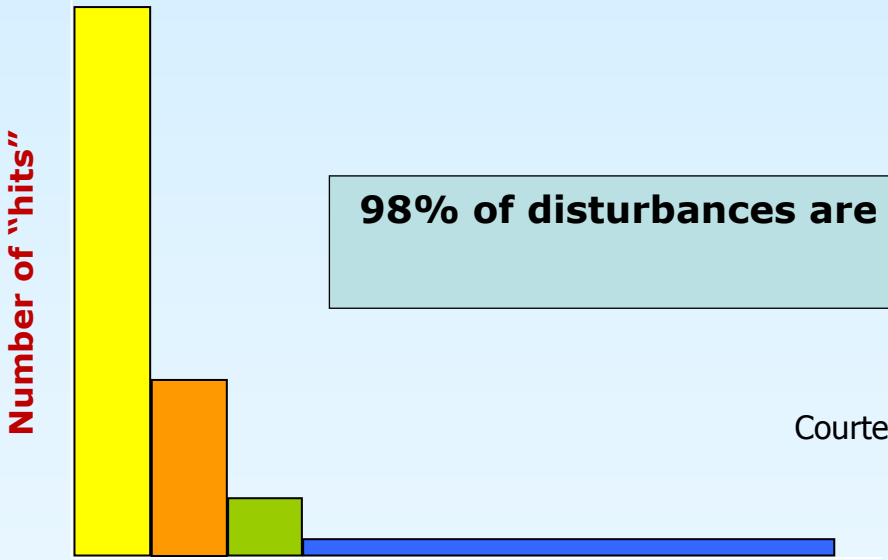
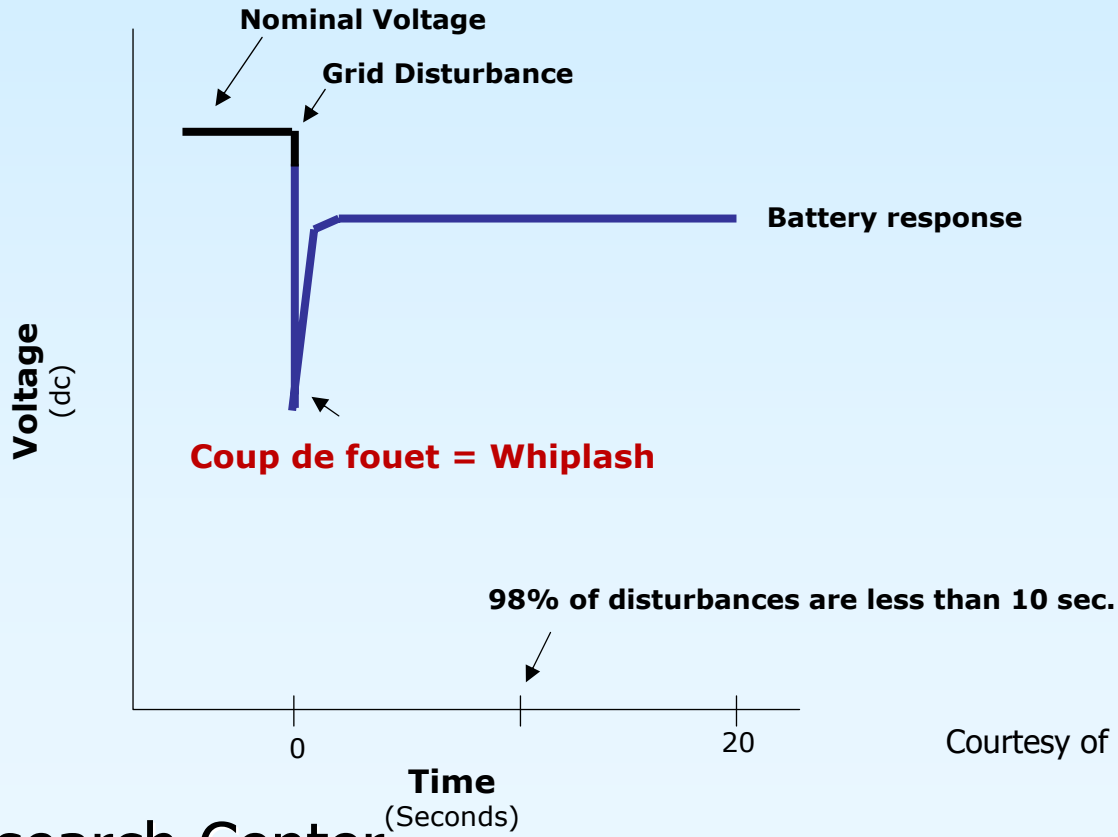
Implementation Options at NASA

- Stand alone for voltage stability during short term power losses or brownouts
- In parallel with batteries
  - absorb the short term voltage instabilities
  - “Save” batteries for longer term outages and significantly increase their life
- Ride thru to a standby generator
  - Provide short term facility power during power loss
  - Provide power to start backup generator and provide a transition period
  - Can support the frequent readiness tests with no life impact

- UPS Battery Use: Discharge Activity Example
  - Many More Short Duration “Hits” than Long Duration

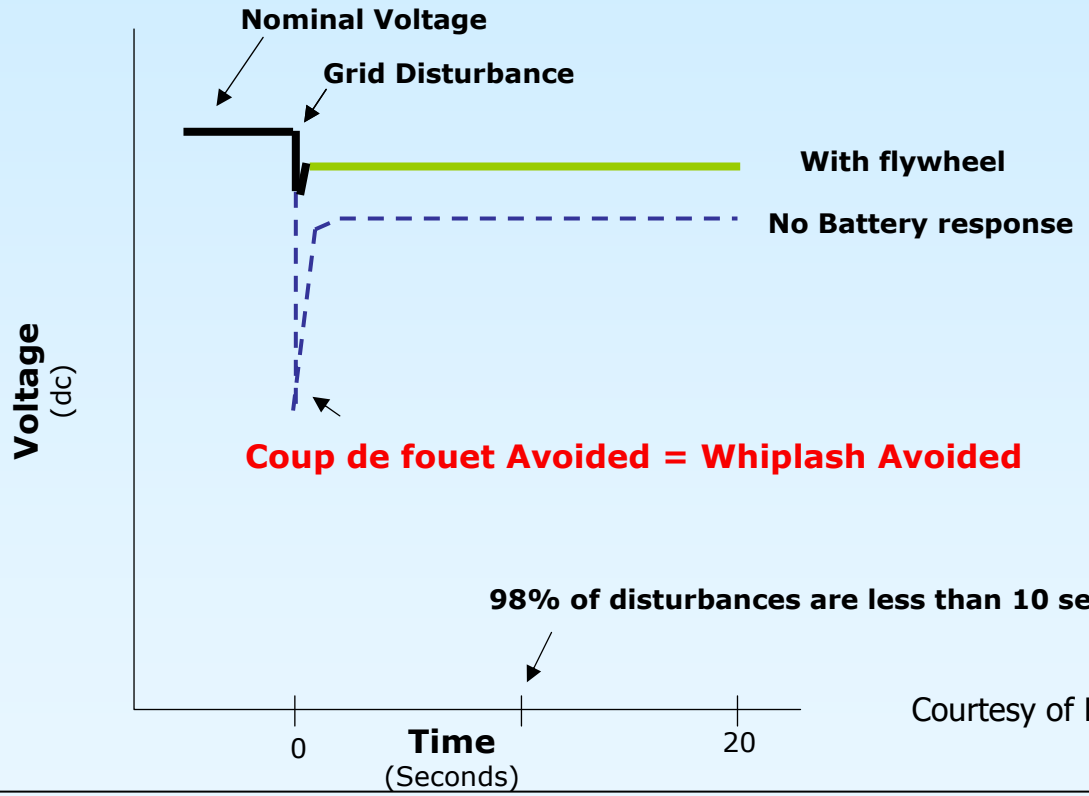


- Every “Hit” Causes Battery Whiplash



Courtesy of Pentadyne Power Products

- Use of a Flywheel UPS Prevents Battery Whiplash



Courtesy of Pentadyne Power Products

Use the Battery Only When You Really Need It for Longer Duration Disturbances

Flywheel UPS Sources

- Several commercial flywheel UPS providers are coming into the UPS market
- Commercial provider maturity ranges from “beta” units in development to production units in the field
- Our source survey identified several potential providers
  - Active Power, http://www.activepower.com/
  - AFS-Trinity, http://www.afstrinity.com/
  - Beacon Power, http://www.beaconpower.com/
  - Pentadyne, http://www.pentadyne.com/
  - URENCO, http://www.urenco.com/flycylinder/

Implementation Approach

- **Key Project Activities**
  - **Define requirements, specifications and interfaces**
  - **Solicit, select and procure the Flywheel UPS**
  - **Install and checkout the Flywheel UPS in PSF for the Flywheel Testbed**
  - **Conduct evaluation testing of the Flywheel UPS both in a stand alone mode and in conjunction with testbed operations**
  - **Conduct comparison study of key UPS characteristics such as life cycle cost, safety, operability, maintainability, energy use, power quality and environmental impacts**
  - **Report progress and results on a regular basis to EMO and NASA HQ**

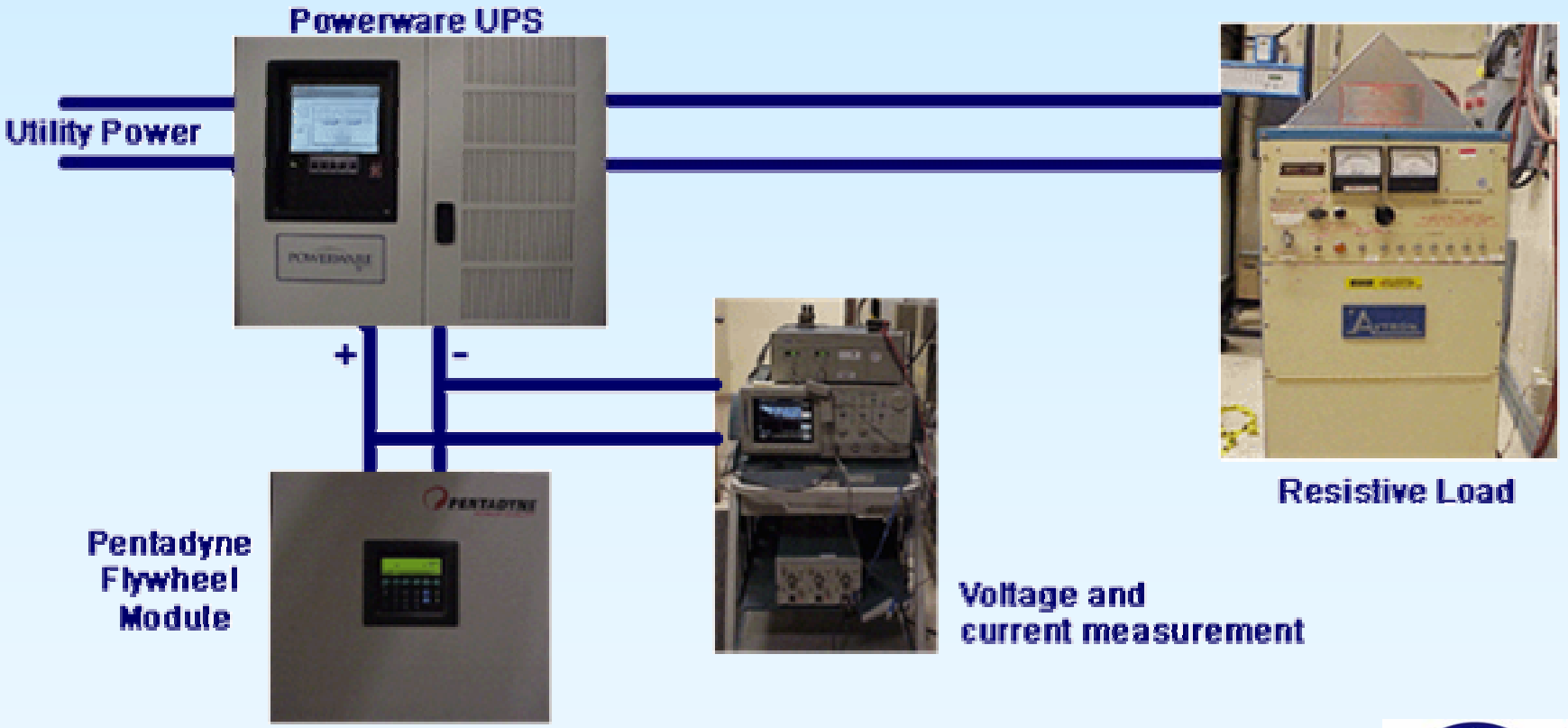
Implementation Approach

- Participants
  - GRC Environmental Management Office
  - Call Henry, Inc.
  - Flywheel Technology Program Team
  - Pentadyne Power Products (Flywheel Unit)
  - Powerware, Inc. (UPS Front-end)
- Procurement
  - Market study indicated several potential sources
  - Competitive procurement of the flywheel battery unit by CHI, Inc.
- Location
  - NASA GRC Power Systems Facility, Building 333
  - Integrated into the flywheel technology test-bed
- Installation
  - Lead by NASA contractor CHI, Inc
  - Powerware and Pentadyne directly participated in the installation and checkout
  - Support from GRC flywheel team

Evaluation Criteria and Test Plans

- **The study effort will address key questions and concerns about Flywheel vs Battery UPS**
  - **Life Cycle Cost Evaluation**
  - **Safety Assessment**
  - **Reliability, Availability, Maintainability**
  - **Operability and Ambient Requirements**
  - **Energy Use**
  - **Power Quality**
  - **Environmental Impacts**

Flywheel Battery Installation



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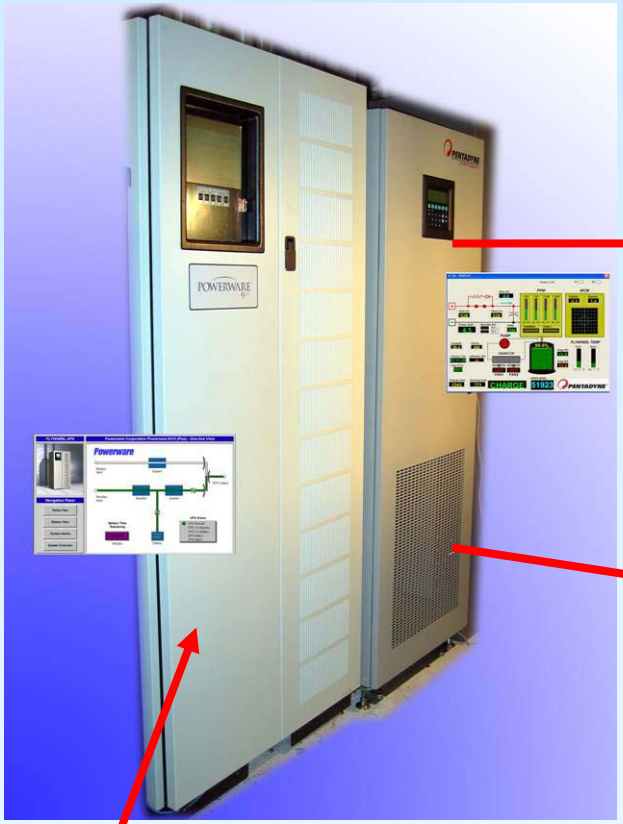
NASA Flywheel UPS Test Bed



Remote Status via Laptop and Internet

Pentadyne Flywheel Energy Storage Unit

Flywheel Rotating Unit Vacuum and Containment Housing

Powerware UPS Unit

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Approach

- **The approach we took was to provide a low maintenance, low cost solution to improving a typical practice that is has been “the norm” for many years!**
- **We took a typical 120/208 volt, 100 amp, 3 phase power panel. Paired it with a Automatic Transfer Switch, and Generator. Then made it an Uninterruptible reliable source that can be used in many applications.**
- **Hi Speed, Composite rotor running in a vacuum, with magnetic bearings provided a Hi-Tech solution to an old technology.**

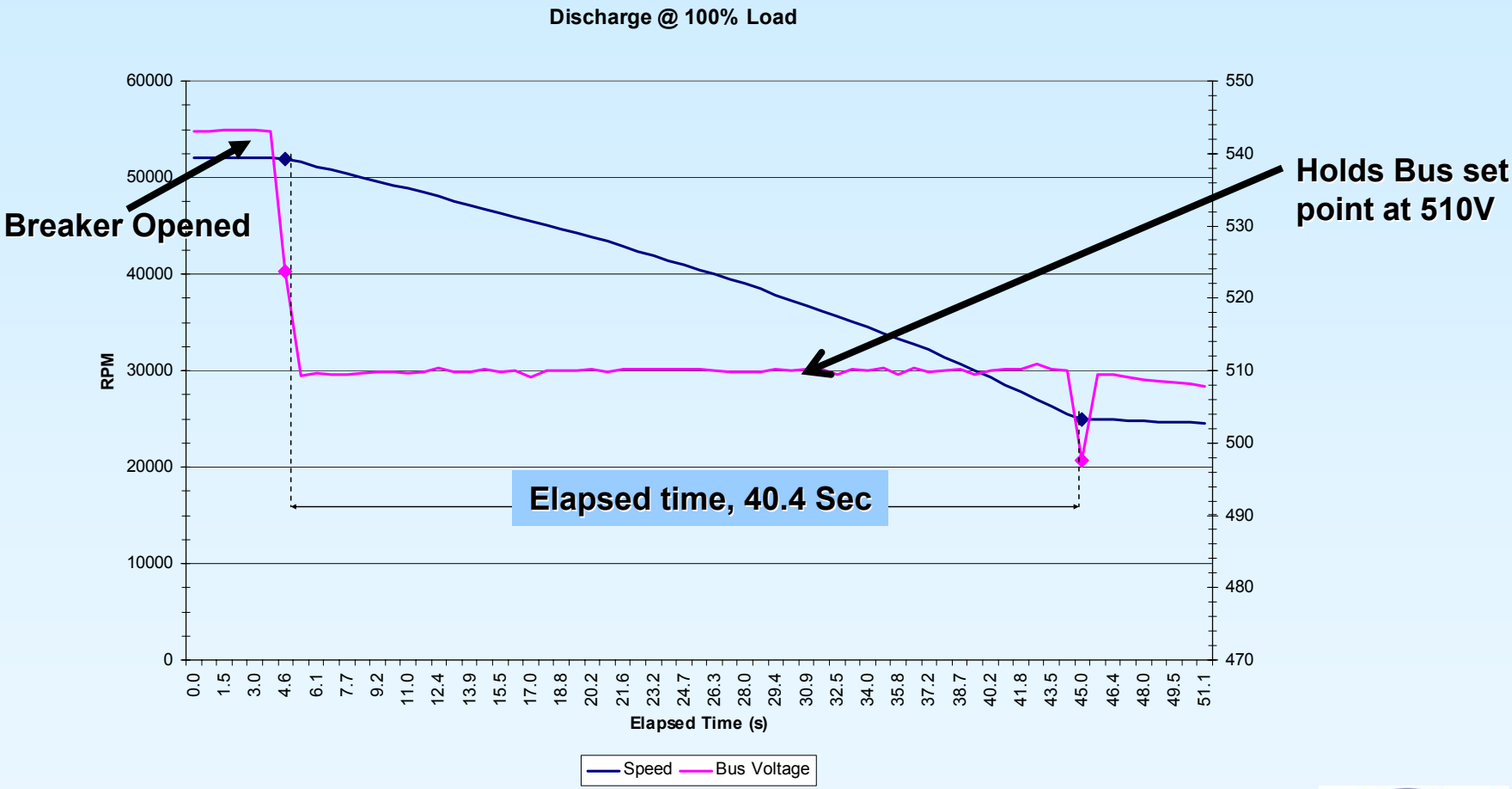
Flywheel Battery Installation Description

- UPS: Powerware 9315-50 (50 kVA, 40 kW)
- Flywheel Battery: Pentadyne VSS 120 (2400 kW-seconds)
- Load Bank: Avtron K595 Resistive Load (208 Vac, 3 Phase, 40 kW)
- Instrumentation: Tektronix TDS 754D Oscilloscope, Agilent 34401A Multimeter

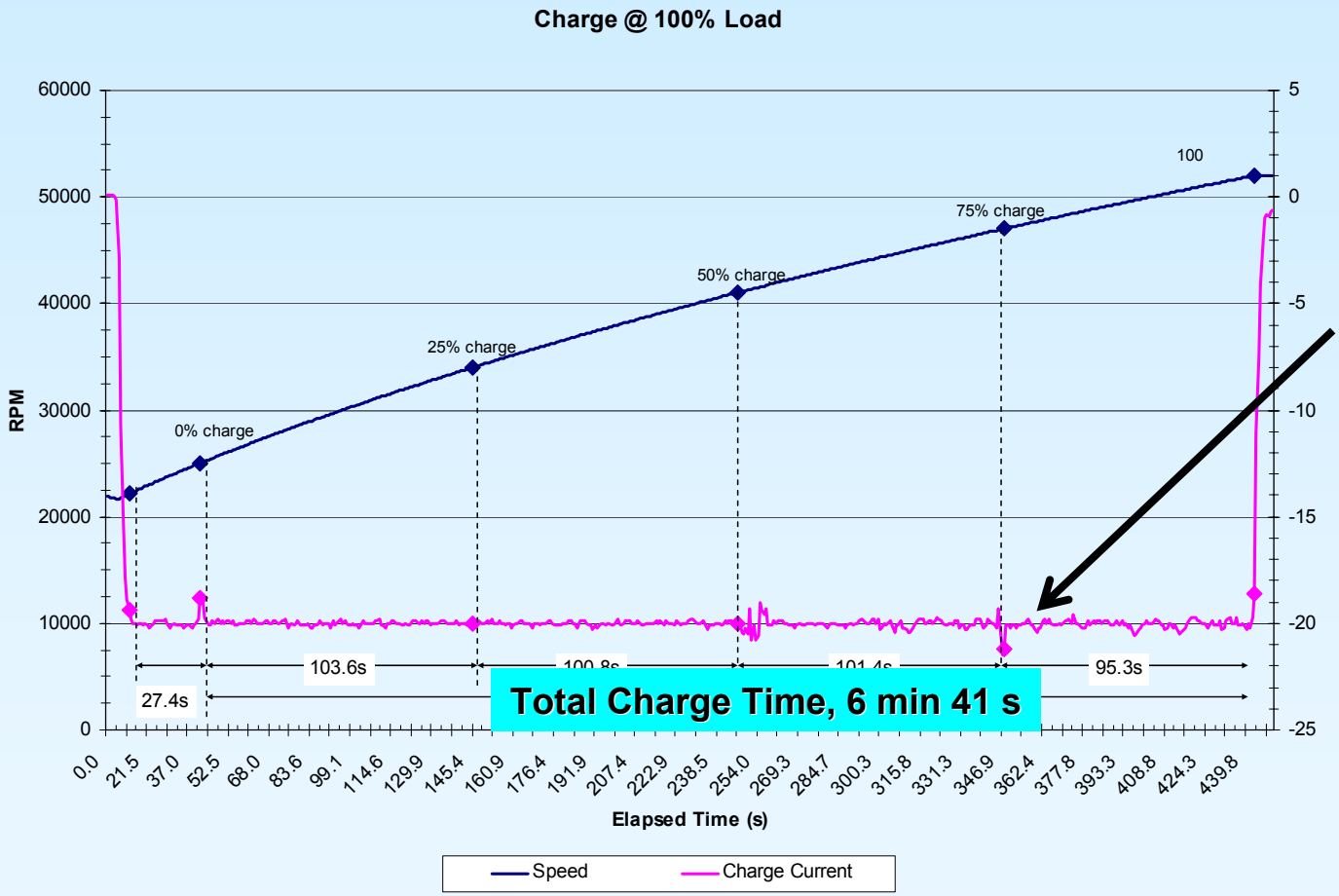
Preliminary Flywheel Battery Performance Data

- Power Quality
  - Open circuit output voltage ripple was .76V, 0.2% of total output voltage
  - Ok for Powerware UPS front end
- Standby Losses
  - Average standby losses were 228 watts
  - Periodic charges to maintain full speed not yet measured

Discharge Characteristics at Full Load, 40KW



Charge Characteristics at Full Current



Charge at Max Current, 20 Amps

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Future Plans

- Continue tests of flywheel UPS to evaluate its operation, capabilities and performance characteristics and limitations for our facility
- Conduct our comparative study of flywheel and battery based UPS
- Deliver our final report this FY
- Retrofit our ‘Beta” Unit with a production unit as soon as its available from Pentadyne

Summary

- NASA HQ and GRC Environmental management Offices are funding the evaluation of a flywheel based UPS
- Objective is to demonstrate a new clean, reliable, cost effect and safe technology for NASA UPS needs
- New commercial markets and sources are growing for flywheel applications
- The GRC flywheel team has installed and is operating a flywheel UPS to support our flywheel technology testbed
- The flywheel UPS installation and checkout went well with excellent operability, and tech support
- The flywheel UPS study will be completed this FY and can support future UPS purchase plans