High Performance Flywheels - A New Spin On Space Based Energy Storage

Nanotechnology and Energy: Storage and the Grid
Rice University
November 16, 2005

Raymond F. Beach
NASA Glenn Research Center
Spacecraft Flywheel System
And Our Team

Auxiliary Bearings – carry launch and touchdown loads
University of Toledo

Magnetic Bearings – provide non-contact suspension of the rotor
Texas A&M

Housing – Lightweight aluminum housing provides spacecraft mechanical and thermal interface
NASA Glenn/University of Toledo

Composite Rotor – stores energy. Designed for long life, safety without containment, light-weight hubs, design and cert. standards
University of Texas - CEM

Motor/Generator – efficiently transforms electrical energy to mechanical energy and back to electrical energy
NASA Glenn Research Center
Why Flywheels - Integrated System Solutions

Modular Power Systems

- IPAC: Integrated Power and Attitude Control
- IP²AC: Integrated Power, Propulsion and Attitude Control
- MFS: Multi-Functional Structure

Spacecraft Structure

Energy Storage

Momentum Storage

Hi V Bus + IPAC

IP²AC

MFS

Tethers/ Electric Propulsion

Modular Assemblies

Modular Components

Modular ORU’s
Integrated Power and Attitude Control System

Sources
Provide Energy

GRC Solar Array Field

Loads
Consume Energy

Flywheel Avionics
Transform Electrical to Mechanical Energy

Flywheel Modules
Store Energy and Momentum
Progress on Performance

Flywheel Performance Metrics

Flight Prototype Modules
- EM Fidelity
- Based on Flight Requirements for ISS and Commercial S/C

Flywheel System Testbeds
- Laboratory H/W Fidelity
- Based on System and Lab Test Requirements
- IPAC
Surface Planetary Power Study

• Objective
  – Requirements Included Environmental And Science Power During Insolation And Eclipse (354 Hour Night)
  – 25 kW Baseline Utilized PV And Fuel Cell Power System
  – Power System Mass Constrained Based On Lander Capability

• Flywheel System Parametric Study
  – Study Data And Projections From NASA And Boeing Company
  – Carbon Nano-tube Composite Rotor
  – Superconducting Magnetic Bearings
  – Iron-less Permanent Magnet M/G
  – Micrometeorite Shield Based On JSC Transhab
Surface Planetary Power

### System Mass Breakdown

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor and M/B</td>
<td>5368 kg</td>
</tr>
<tr>
<td>Motor/Generator</td>
<td>84 kg</td>
</tr>
<tr>
<td>PMAD</td>
<td>122 kg</td>
</tr>
<tr>
<td>Cryocooler</td>
<td>120 kg</td>
</tr>
<tr>
<td>Meteor Shield</td>
<td>1112 kg</td>
</tr>
<tr>
<td>Strut Mass</td>
<td>1260 kg</td>
</tr>
</tbody>
</table>

### Flywheel System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Storage</td>
<td>10,600 kW-hr usable</td>
</tr>
<tr>
<td>Power</td>
<td>30 kW for 14.75 days</td>
</tr>
<tr>
<td>Mass</td>
<td>8066 kg</td>
</tr>
<tr>
<td>Specific Energy</td>
<td>1315 W-hr/kg</td>
</tr>
<tr>
<td>Number of Units</td>
<td>20</td>
</tr>
<tr>
<td>Operating Speed Range</td>
<td>83k to 250k rpm</td>
</tr>
</tbody>
</table>
Concluding Remarks

• Study Results For Solar Power System (Both Fuel Cell And Flywheel Storage) Indicate Potential For Non-nuclear Lunar Power
• Flywheel Storage With Advanced Carbon Nano-tube Rotors Has Potential To Double Power System Capacity On Single Lander
• NASA Glenn Research Center In Conjunction With UT-CEM, TAMU, UT, CSU, Boeing Pursuing Development Of Advanced Testbed To Demonstrate Advanced Flywheel Technologies For Space Applications