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Design, Fabrication, and Test of a 5 kWh Flywheel Energy Storage System Utilizing a High Temperature Superconducting Magnetic Bearing

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ESS Mission and Boeing Flywheel

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Superconducting Flywheel System

The ESS Mission...



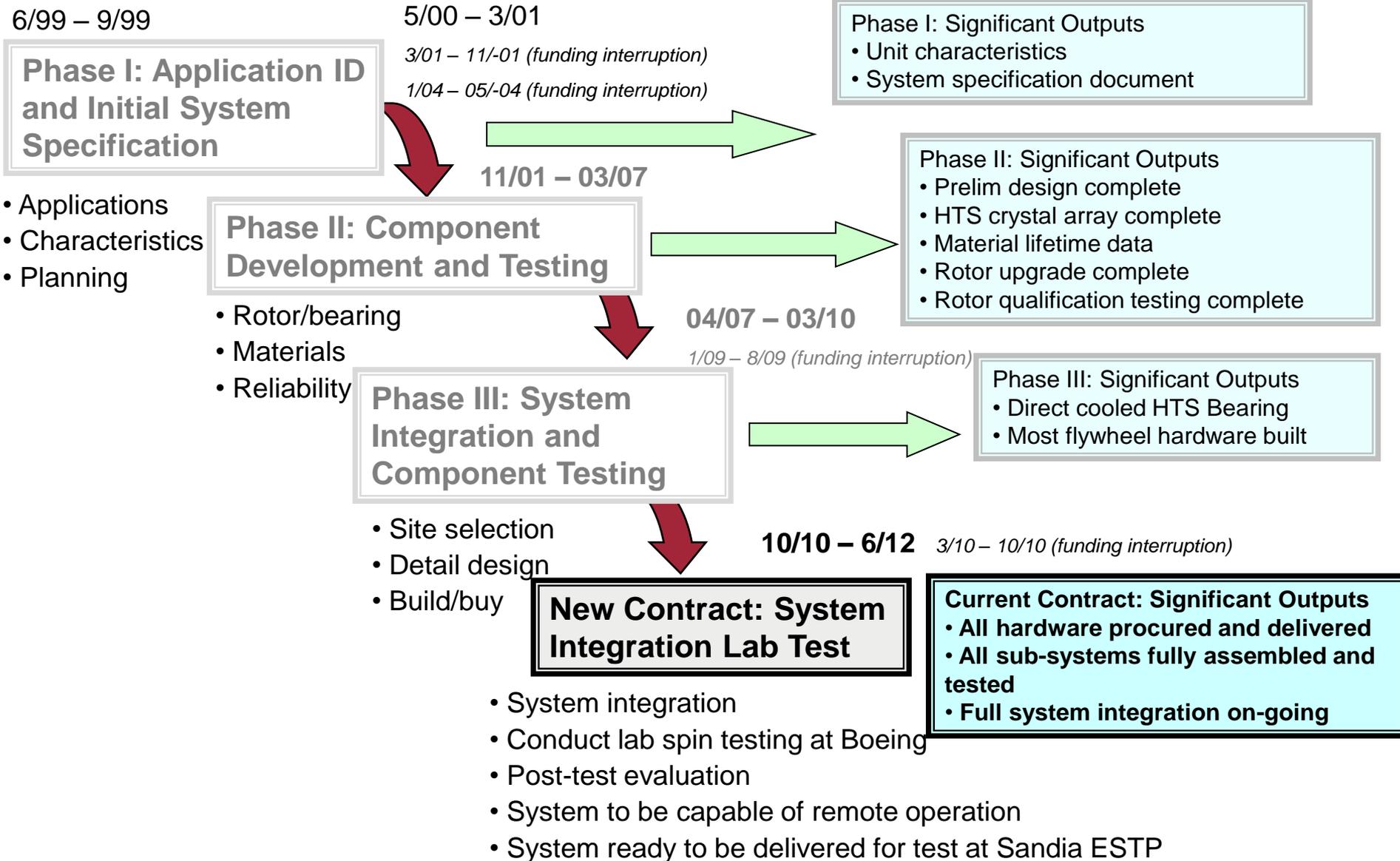
The goal of the ESS program is to develop advanced energy storage technologies and systems, in collaboration with industry, academia, and government institutions that will increase the reliability, performance, and competitiveness of electricity generation and transmission in the electric grid and in standalone systems.

- **How Does Boeing Flywheel Support the ESS Mission?**
 - Advanced, modular energy storage system
 - Long life >25 years, green technology, no hazardous materials
 - Minimal maintenance (cryocooler ~ 10 yrs MTBF)
 - Superconducting bearings for very high efficiency – enables long term, efficient storage (seconds/minutes/hours/days)
 - Fast response enables UPS/freq regulation applications and long term storage enables storage for renewables (load shifting and GRIDS)

Energy Storage Program 5 kWh / 3 kW Flywheel Energy Storage System Project History and Roadmap

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2010-2011 Current Tasks

Task 1: Complete fabrication of remaining components

- Fabricate or modify mechanical components of the 5 kWh / 3 kW FESS system

Task 2: Continue Integration of 5 kWh / 3 kW FESS

- Continue integration of 5 kWh flywheel system to prepare for spin testing
- Integrate and test new flywheel damper system
- Perform motor encoder test and motor controller hardware integration test
- Integrate flywheel rotor system into one vacuum / containment system which will be mounted into a single external support structure

Task 3: Low speed testing of 5 kWh / 3kW FESS

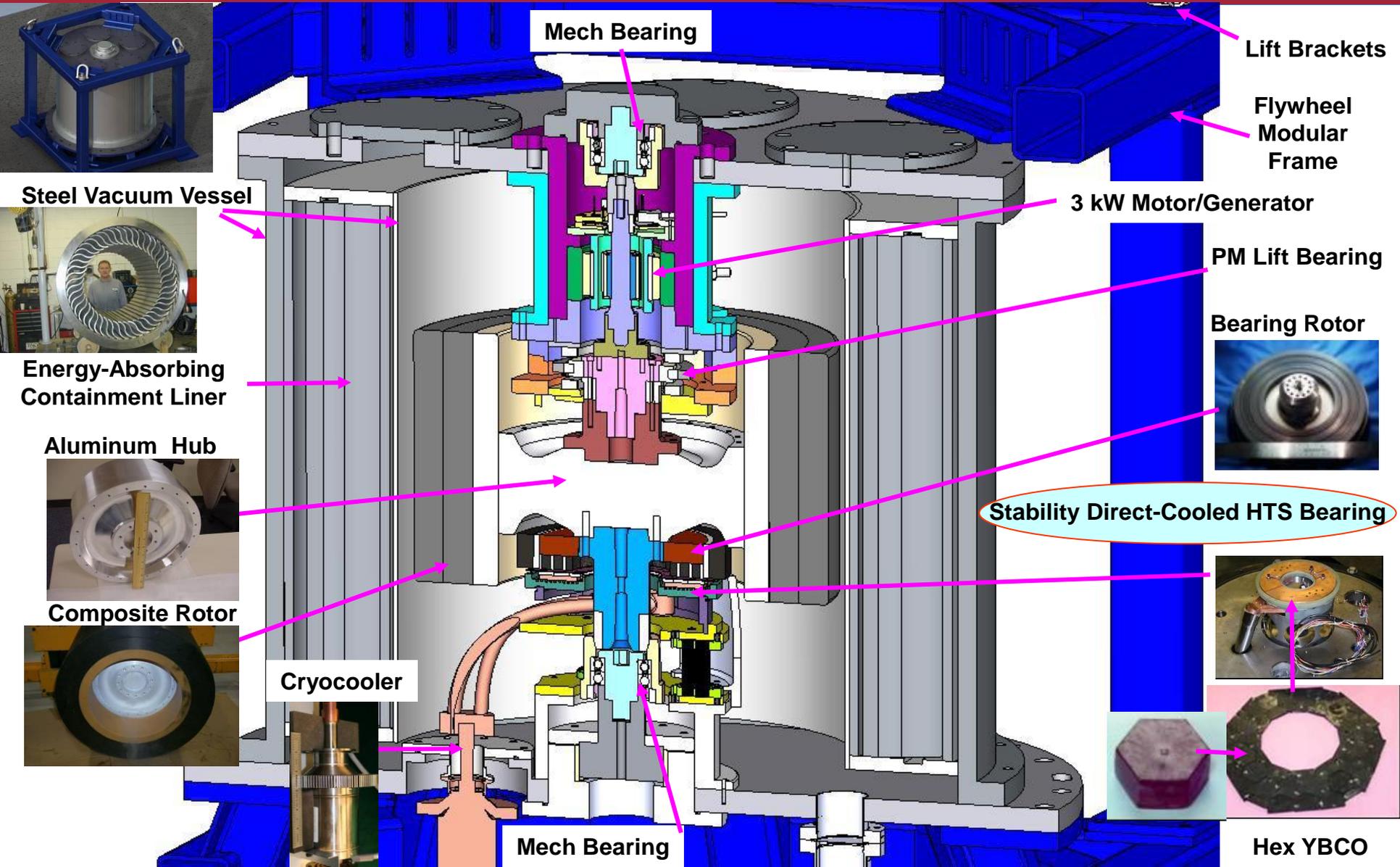
- Conduct and analyze low-speed testing of 5 kWh flywheel system

Task 4: Communicate program results and progress

5 kWh Boeing Modular Flywheel Design (DOE/Sandia)

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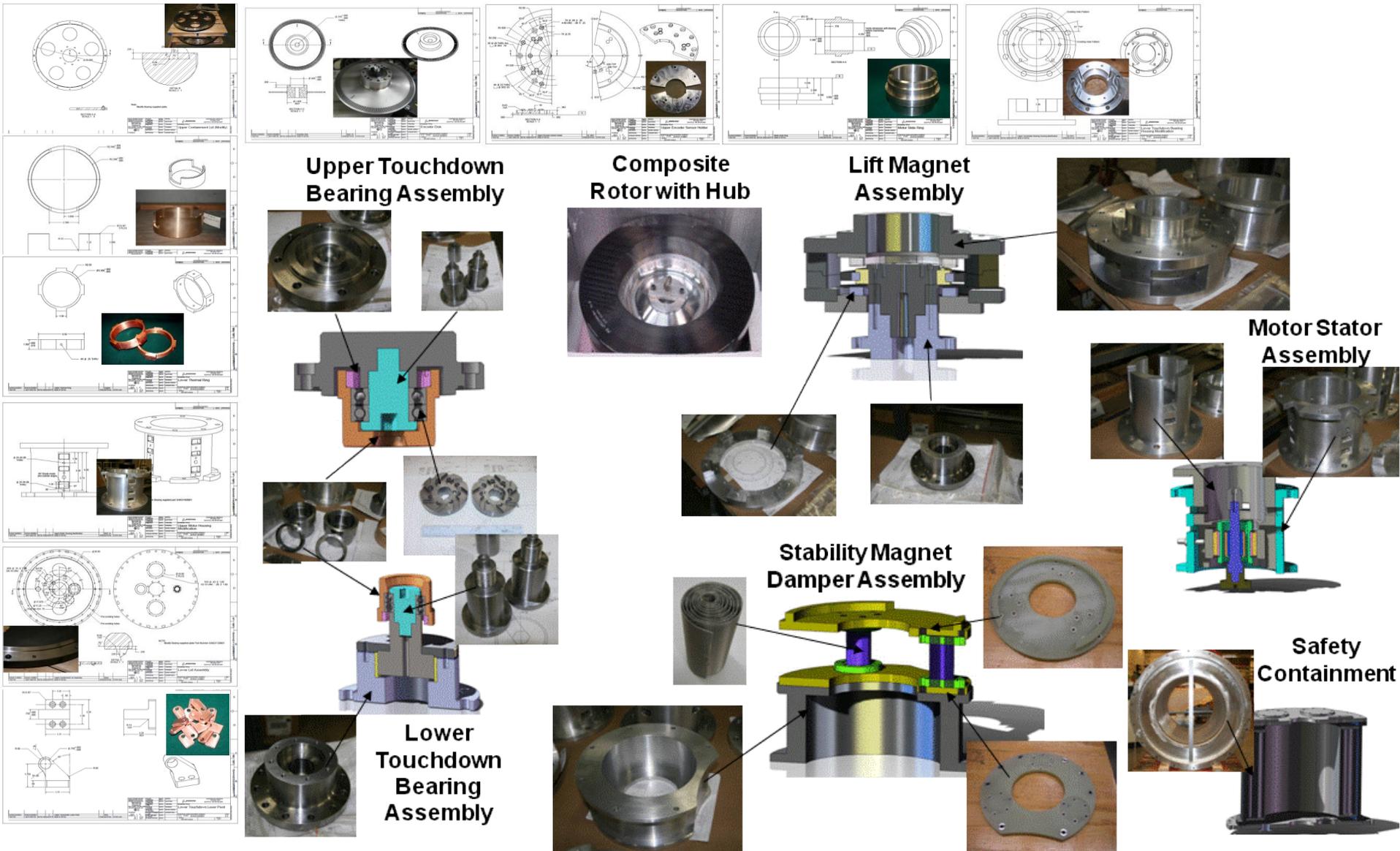
Superconducting Flywheel System



All Remaining Parts Fabricated and Delivered

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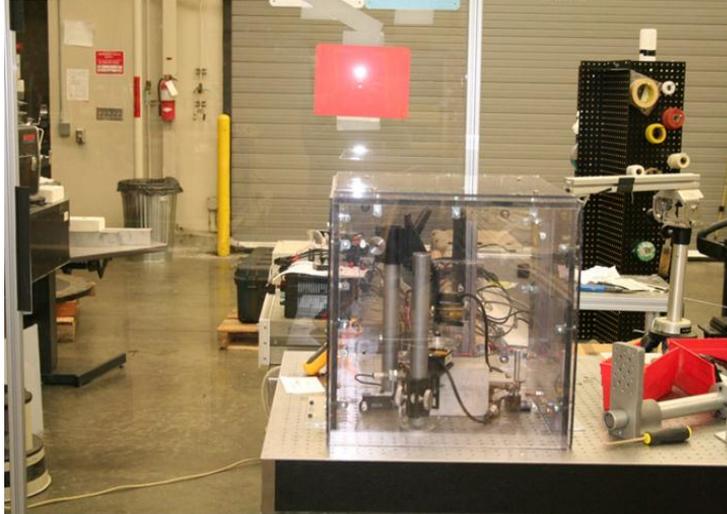
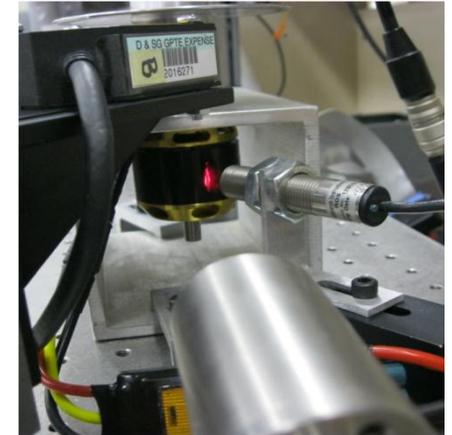
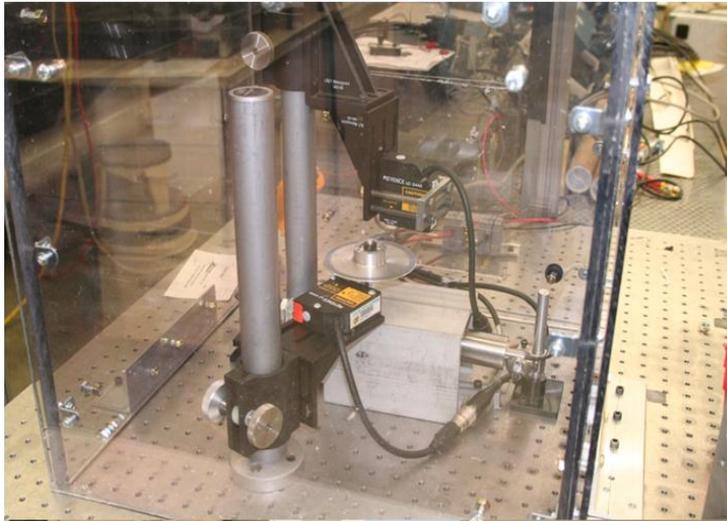
Superconducting Flywheel System



Mechanical Spin-Test of the M/G Encoder

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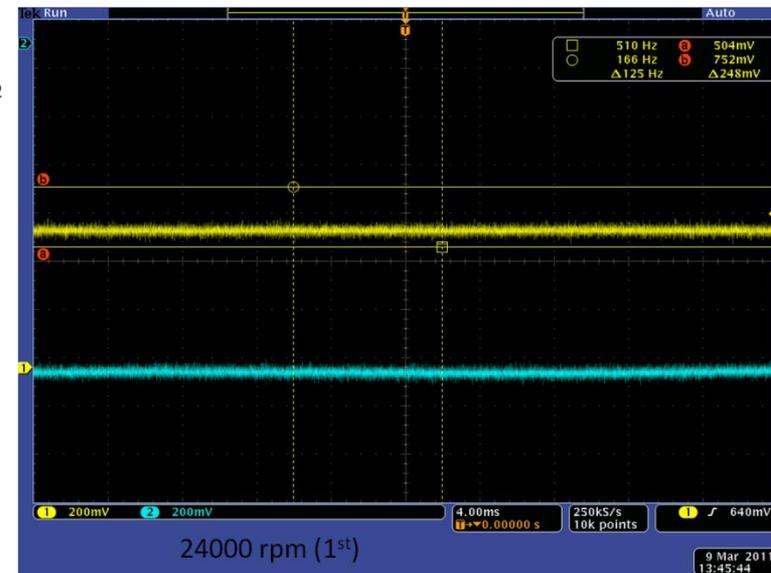
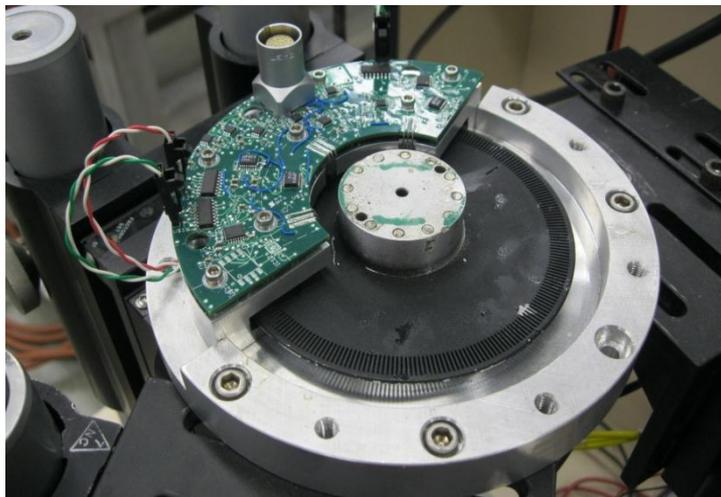
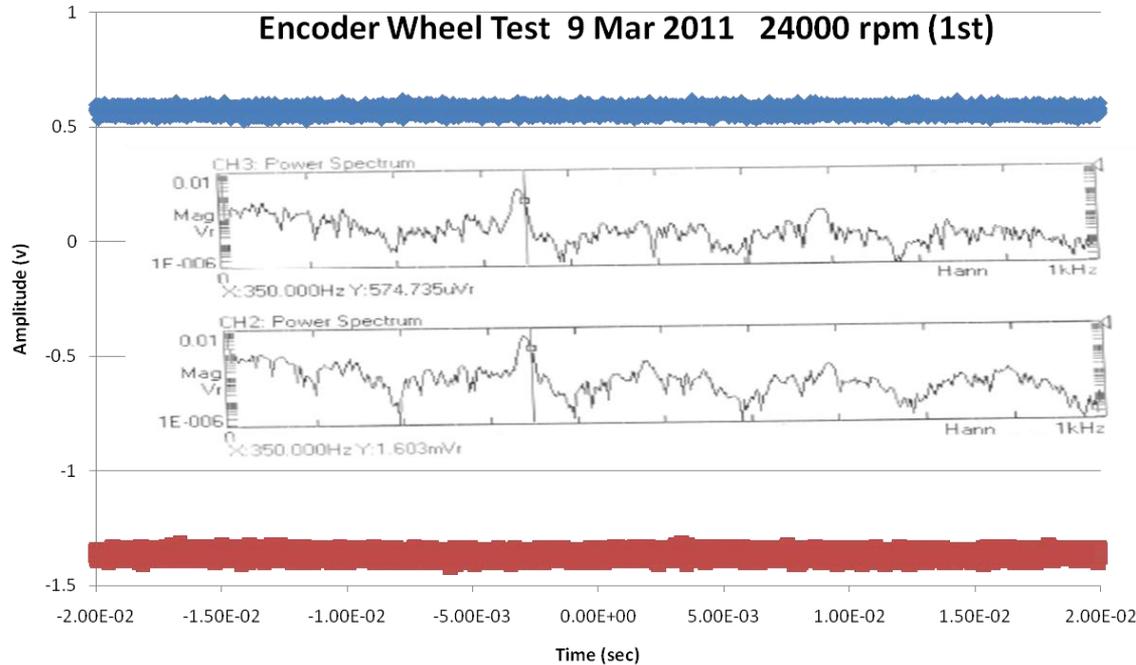
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Encoder Was Successfully Tested to 24,000 RPM

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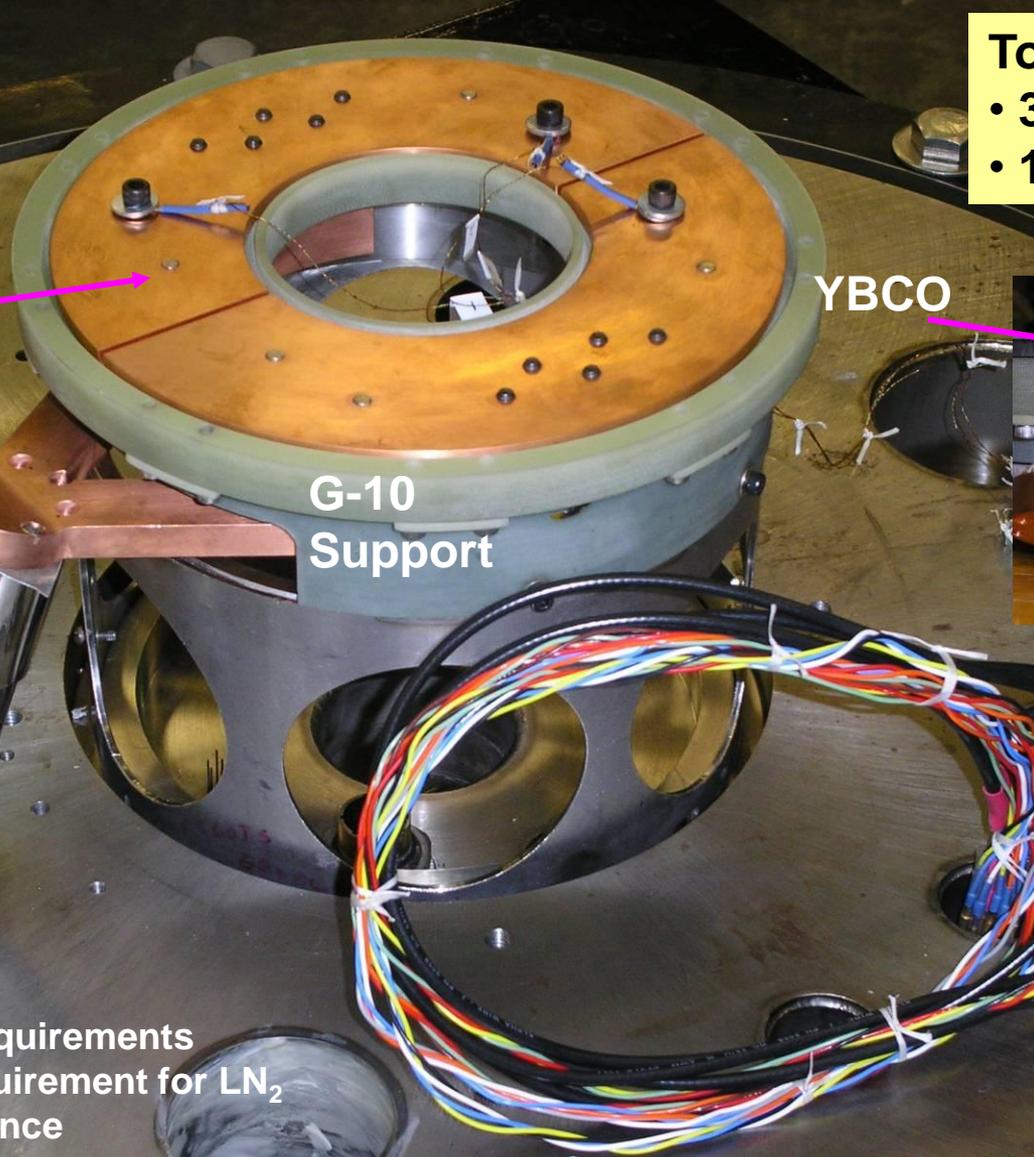
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Direct-Cooled HTS Bearing Design and Tests

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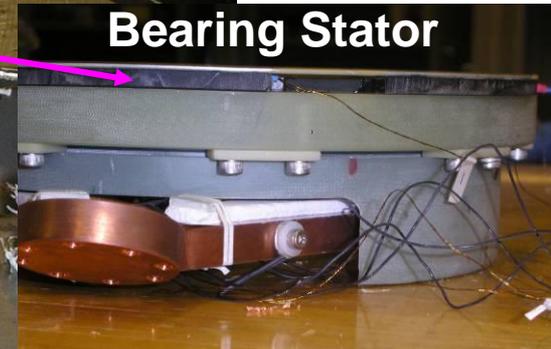
Superconducting Flywheel System



Total Loss

- 3.3 W at 2.1 mm gap
- 1.6 W at 3.9 mm gap

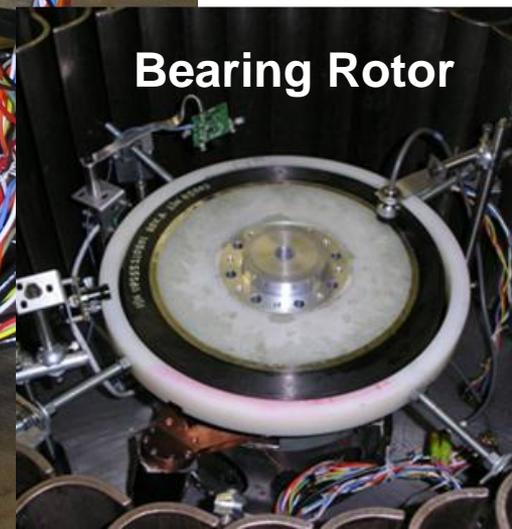
YBCO



Bearing Stator

Cold Head

G-10 Support



Bearing Rotor

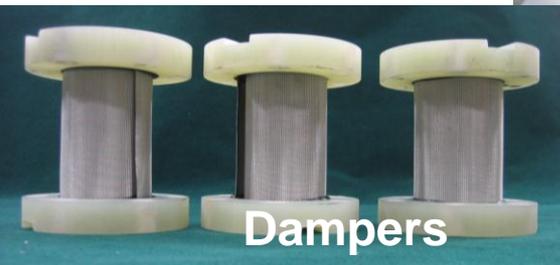
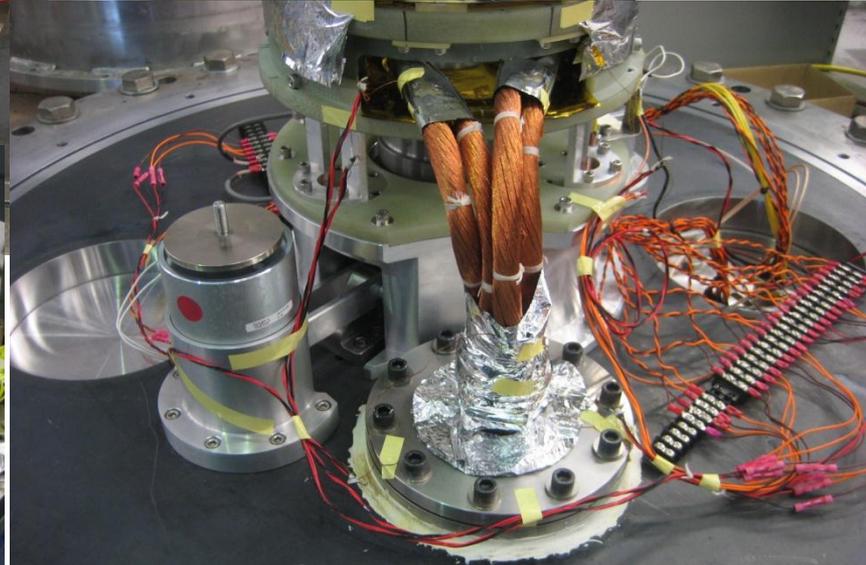
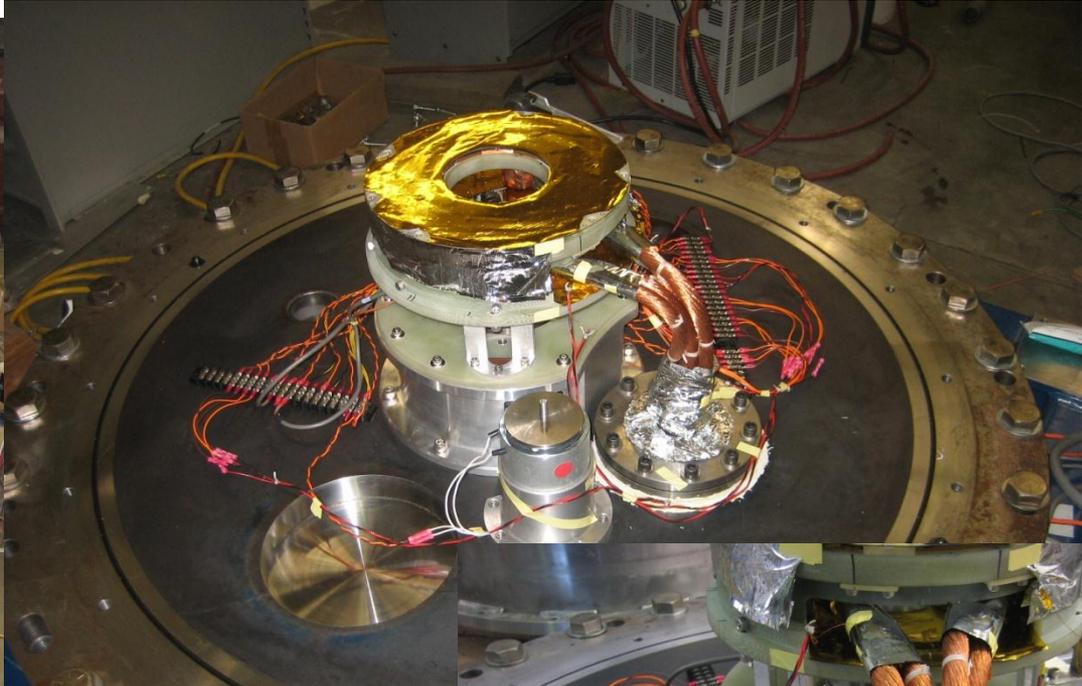
- Benefits:
- ~60% fewer parts
 - Reduced power requirements
 - Eliminates the requirement for LN₂
 - Reduces maintenance

System Integration Under Way

- Lower Touchdown and Superconducting Bearing Assembly

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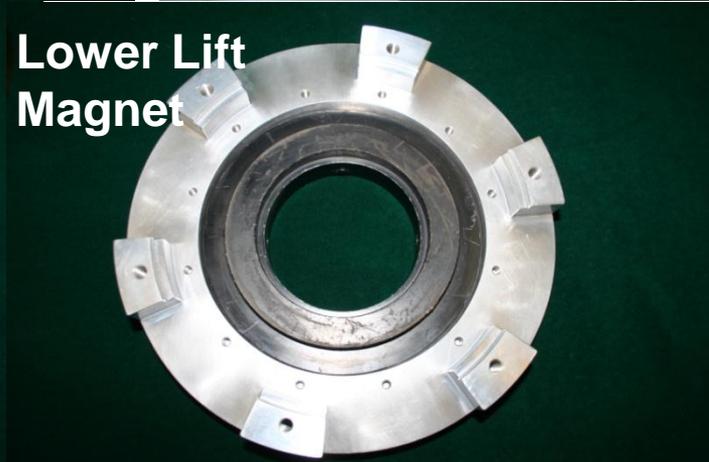
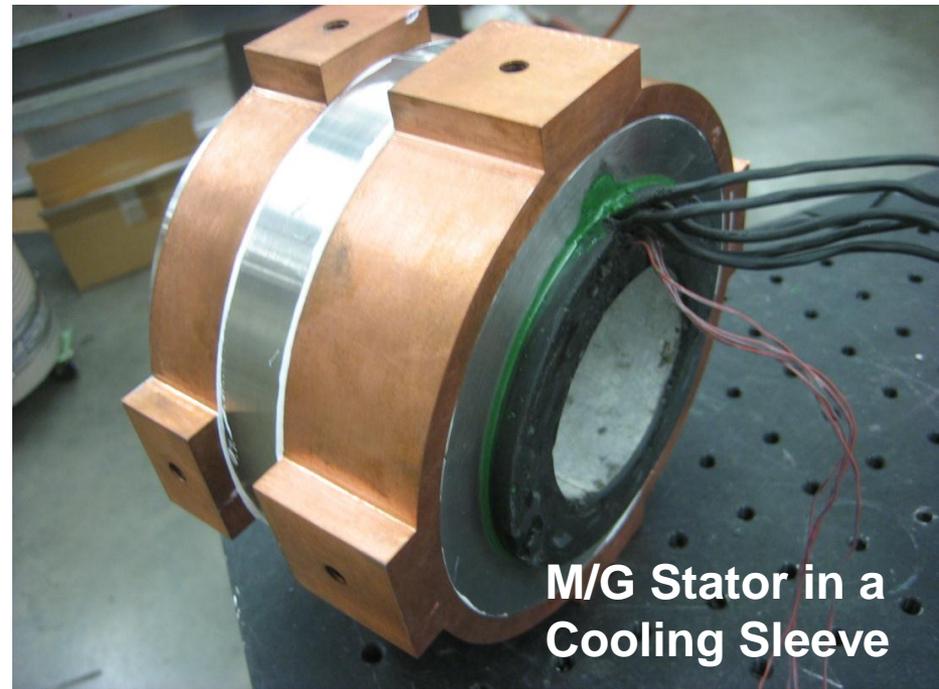


Dampers

System Integration Under Way - Motor-Generator and Lift Magnet Assembly

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Vacuum System and Outgassing Tests

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Collaborations and Leverages

- Boeing is working with ARPA-E on low-cost flywheel project utilizing development of alternative low-cost composite material to reduce overall flywheel system cost
- Boeing forms Strategic Alliance with Siemens
- Continued investment by Boeing in flywheel test and manufacturing facilities
- Boeing continues funding high temperature superconductor work at the University of Cambridge
- Boeing is purchasing two superconductor materials and processing patents from University of Cambridge to increase Boeing flywheel portfolio strength (currently > 35 patents, and 15+ pending)
- Boeing is holding various discussions with potential flywheel manufacturing and commercialization partners

Boeing Energy and Siemens Form Strategic Alliance

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Media

Boeing, Siemens Form Strategic Alliance for DOD Energy Modernization

Alliance will provide secure microgrid management solutions that lower costs and increase efficiency

WASHINGTON, Aug. 8, 2011 – Boeing [NYSE: BA] and Siemens [NYSE: SI] today announced a strategic alliance for the joint development and marketing of "smart grid" technologies to improve energy access and security for the U.S. Department of Defense (DOD), the largest energy consumer in the federal government.

The collaboration centers on providing U.S. military installations with secure microgrid management solutions that lower operational costs and increase energy efficiency.

"This collaboration will make a real difference in how the DOD uses energy," said Tim Noonan, vice president of Boeing Energy. "For years, Boeing has developed secure, networked systems vital to the nation's defense, and bringing this capability to the development of energy security and efficiency is vital for the military's future. Boeing and Siemens' combined approach will help provide energy independence and critical infrastructure protection to ensure mission success for the U.S. military, at home and abroad."

The alliance draws on Boeing's expertise in providing the DOD with complex systems and technologies, and Siemens' industry-leading global energy management capabilities.

"Siemens is the only company worldwide that provides its customers with energy-efficient technologies that enable 'smart' production, transmission and consumption," said Judy Marks, head of Siemens U.S. Federal Business. "The Siemens and Boeing team has a vision for the United States' energy future, and we're committed to helping the DOD achieve unprecedented levels of power reliability, quality, efficiency and energy independence."

New 2011-2012 Tasks Under Negotiations

Further modify the 5 kWh / 3 kW flywheel energy storage system (FESS) to provide a fully integrated self contained FESS ready for shipment to Sandia National Laboratories Energy Storage Test Pad (ESTP) that is ready and capable for grid connected and/ or micro-grid testing.



FES System

Summary

- All sub-systems fully tested and passed QA
- Started system integration for low-speed testing
- Strong leverage from other projects and partnerships benefits this project
- Planned wrap up of multi-year development with FESS to be exercised at SNL ESTP