PROJECT TITLE:	Current Status of the Flywheel Electricity System
ORGANIZATION:	Boeing Phantom Works
PRESENTERS:	Mike Strasik
FY 2006 FUNDING:	$400K

Project Purpose and FY 2006 Objectives: The main purpose of this effort is to develop and test a fully-operational, superconductor-based Uninterruptible Power System (UPS) providing digital quality power for utility or commercial use. The UPS will use a high-speed flywheel for energy storage, and high-temperature superconducting (HTS) bearings for the suspension. Two development units have been built. The first unit had a 3-kW motor/generator (M/G) and proved the suspension concept, while the second unit (still under test) has a 100-kW M/G and a Ballard Power Systems utility interface. Specific objectives for FY 2006 were to: 1) complete full system test of the 100 kW / 5 kWh UPS flywheel system, and 2) design, build, and test a 10 kWh rotor/hub assembly. This project began in FY 1999 in collaboration with Argonne National Laboratory (ANL). Due to funding limitations, ANL did not receive DOE funding for this effort during FY 2006.

FY 2006 Performance and FY 2007 Plans: The program has been focused on testing of the 5 kWh / 100 kW flywheel system, and on preparation for uninterruptible power system (UPS) utility functionality tests to be conducted by Southern California Edison test engineers in the fourth quarter of 2006. The major accomplishment this year was the successful resolution of a hardware over-current fault within the motor controller which was previously causing the controller protection circuit to trip during spin test at around 5,000 revolutions per minute (RPM). **As a result, the complete flywheel UPS system has been successfully tested up to 15,000 RPM**. During the high speed operation, it was discovered that the 100 kW motor stator was experiencing excessive heating during operation. This issue has limited the team's ability to increase the rotational speed of the flywheel system during integration testing past 15,000 RPM. The team's effort focused on understanding the root cause of the stator heating problem, since that issue is preventing the team from completing the full speed system test. After a thorough analysis, it was determined that the stator vendor didn't follow the manufacturing drawings, and included larger fiberglass insulation between coils, which in turn does not allow for the cooling water to reach the hotter parts of the stator, thus limiting the upper speed capability of the generator. By consultation with DOE management, it was decided to complete the testing of the system as is, and not try to replace the faulty stator, since most of the flywheel test performance objectives were already satisfied with the system as is. The team outlined an optimized stator design that would resolve the temperature limitations of the current stator.

During the quotation stage of the purchase orders for the 10 kWh composite rims, Toray Composites America made a managerial decision to no longer fabricate composite rims after Jan 1, 2006. As such, Toray decided to no longer accept rim fabrication orders. This action has caused a 6-month delay in the project due to the time it took to find a new qualified vendor, and as a result, the current contract has been extended through Jan 2007. Boeing has completed a design for the 10 kWh rotor/hub assembly, and the composite rotors are now being manufactured. The design is a scale-up of the 5 kWh UPS flywheel, incorporating some lessons learned but keeping the basic design.

FY 2006 Results: The team accomplished the following key results in its FY 2006 program:

- ✓ Successfully resolved hardware over-current fault within the motor controller which was causing the controller protection circuit to trip during previous spin tests at around 5,000 RPM
- ✓ Improved and optimized the motor/controller software to be able to efficiently spin the flywheel rotor in a non-contact fashion to high speeds
- ✓ **The flywheel system has been successfully tested up to 15,000 RPM**
- ✓ Identified and corrected electrical noise issues obscuring data acquired during spin test activities

- ✓ Identified the major source of the heating in the stator and the reason why the heat is not getting efficiently out of the stator

This project is scheduled to be completed in the first quarter of FY 2007. During this period, the flywheel UPS function will be tested by a Southern California Edison's test engineers, and the 10 kWh composite rotor will be built, and spin tested up to 22,500 RPM.

Research Integration: Boeing and its industrial partners - Praxair, Southern California Edison, Ashman Technologies, and Ballard Power Systems - are actively engaged through frequent phone conferences, on-site visits, and progress reviews. The Boeing Flywheel organization is an active member of the NASA/AFRL Flywheel Rotor Safety and Longevity working group and contributes to drafting the ANSI Flywheel Standard, heading up the rotor NDE section. Boeing hosted the most recent meeting of this group in Seattle

Boeing's working relationship with ANL began in 1988 and has continued since that time. ANL assists with general consultation on this SPI project, and provides additional laboratory and computational support as needed. Boeing has incorporated much of ANL's experience into the design and continuing development of its flywheels. ANL has participated in design reviews and several test series at Boeing. Phone and e-mail exchanges occur on a frequent basis, and several papers with joint authorship have been published.