Project Title:	Development Status of Flywheel Electricity System
Organization(s):	**Boeing/Argonne National Laboratory**
Presenters:	Mike Strasik (Boeing)
FY 2004 Funding:	$367 K (Boeing)/($0 K) ANL

Project Purpose and FY 2004 Objectives: The main purpose of this effort is to develop a 10-kWh flywheel energy system based on high-temperature superconducting (HTS) bearings. The first unit developed had a 3-kW motor/generator (M/G). The second unit developed has a 100-kW M/G. This effort started in FY1999. Due to DOE's funding limitations this year, the Boeing project received significantly lower funding than planned, and ANL didn't get any DOE funding at all. Specific objectives for FY 2004 were to complete the manufacturing of all components for the 100 kW/5 kWh UPS flywheel system, test all individual components at full speed, assemble the system, and fully test the UPS flywheel system at Boeing site with technical assistance from Southern California Edison's test personnel.

FY 2004 Performance and FY 2005 Plans: Due to funding limitations, limited progress was made in the FY 2004 objectives. All components of the 100 kW / 5 kWh flywheel UPS system were manufactured and also successfully tested up to 102% of the operating speed. The major accomplishment of this year was the successful spin-test verification of the redesigned aluminum hub/composite flywheel rotor. This fully verified the new Boeing hub/rotor design and modeling tools for predicting static and dynamic performance of the system. In addition, the Boeing flywheel test facility has undergone a major upgrade with the addition of two new larger air turbines to allow spin-testing of heavier components at higher speed. A larger air compressor became necessary to run the larger air turbines and was also acquired. The Boeing South Park Facility has been upgraded with dedicated 480 VAC, 200 Amp, 3-Phase power system for Flywheel testing, as well as a separate 480 VAC 30 Amp, 3-phase power system for voltage sag testing. The designs of the 480 VAC systems were in accordance with Southern California Edison recommendations for power quality testing of the 5 kWh / 100 kW flywheel UPS system. All modifications were inspected by the Sate of Washington and were certified for spin testing. All the facility modifications and upgrades (> $400K) were paid for by the Boeing Company. This additional capability at Boeing will result in substantial economical and logistical benefits to the program since we don't have to send hardware and personnel for spin testing at various facilities. Additionally, the Boeing flywheel spin-test facility will be one of the largest of this type in the U.S.

FY 2004 Results: Key results from the FY 2004 program are summarized below.

1) All components of the 100 kW / 5 kWh Flywheel UPS systems were manufactured.
2) All flywheel components were spin tested up to 102% of the operating speed (22,900 rpm).
3) The redesigned metal Hub/Composite Rim assembly was balanced and quill tested to 22,900 RPM (102% MEOS) and soaked for 15 minutes and thus met acceptance testing criteria per ANSI Space Flywheel Standard ANSI/AIAA S-096-200X.
4) Stainless steel cryostat for HTS stability bearing was manufactured, sealed, and tested at liquid nitrogen temperatures with no leaks on first seal attempt.
5) The cryogenic system including thermosyphon, GM cryocooler, and bearing cryostat was assembled and tested.
6) All control and monitoring systems for the flywheel system were assembled and successfully tested.
7) Electrical systems from Ballard Power Systems (BPS) and Ashman Technologies have been installed. These include the Motor Controller unit and the Utility Interface Unit.
8) The emergency dump load required to spin the system down in the event of an inverter system failure has been delivered.
9) The load bank required to support Southern California Edison utility testing has been selected and ordered.
10) The SAG generator electrical interface to the facilities electrical system was completed.

11) A separate test cell for spin test qualification was built within the Boeing test pit to provide in-house balancing and spin-testing of components

FY 2005 Plans: FY 2005 is the last year of the present SPI project. The 100 kW / 5 kWh UPS flywheel system will be assembled and fully tested by Boeing. Operational characteristics of the UPS system such as critical frequencies, vibration, rotational losses, power output, power quality, peak power capabilities, charge and discharge time, cryocooler performance, and vacuum level will be monitored and analyzed. Flywheel system will also be tested by Southern California Edison's Test personnel to verify power quality, sag, and performance characteristics required by a UPS system. A new task to design, build, and spin test 10 kWh composite wheel with the redesigned metal hub will be added to the FY 2005 project.

In FY 2005, ANL will (1) provide general consultation on overall testing of the system and components, based on ANL's previous experience with these types of devices; (2) participate in experimental tests of flywheel systems at Boeing; (3) provide thermal analysis to predict temperature development in the flywheel under different conditions; and (4) perform small-scale experiments toward developing a lower-cost, direct cooling system for the HTS bearing.

Research Integration: Boeing and its industrial partners, Praxair, Southern California Edison, Ashman Technologies, and Ballard Power Systems are very actively engaged in frequent phone teleconferences, on-site visits for testing, test planning, design, and progress reviews. Boeing Flywheel Organization is an active member of the Flywheel Rotor Safety and Longevity working group and is continuing to contribute to the ANSI Flywheel Standard, heading up the rotor NDE section. Boeing recently hosted this group's meeting at Boeing Flywheel Facility. Our successful working relationship with ANL has started in 1988 and has continued since. ANL serves in the role of general consultation on this SPI project. Boeing has already incorporated much of the ANL experience into the design process in the continuing development of the unique Boeing design. This research integration is expected to continue and will be useful in the design phase of the next generation flywheel as well. ANL has participated in design reviews and several lengthy experimental series at Boeing. Phone and Email exchanges have been made on a frequent basis on various features of the flywheel design. Boeing-made HTS samples have been sent to ANL for evaluation. Several papers with joint authorship have been published. It is expected that this level of exchange will continue throughout this project and the Phase-3 SPI.