Project Title:	Development of Flywheel Energy System
Organization(s):	**Argonne National Laboratory**
Presenters:	J. R. Hull (ANL) and A. Day (Boeing)
FY 2003 Funding:	$300 K

Project Purpose and FY 2003 Objectives: The main purpose of this effort is to support the Boeing Phantom Works in their SPI program 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. Specific ANL objectives for FY 2003 were to (1) provide general consultation on overall design and 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) use a thermal model to predict temperature development in the flywheel under different conditions; and (4) perform small-scale experiments toward developing a lower cost cryogenic system for the HTS bearing.

FY 2003 Performance and FY 2004 Plans: Significant progress was made in all of the FY 2003 objectives. (1) ANL participated in a consulting capacity on all aspects of the system and component design, and provided a safety review of the Boeing experimental facility. ANL participated in the initial assembly and testing of the 3-kW machine. ANL was key in resolving initial issues of rotor stability by specifying a slightly different spacing on the lift bearing components. (2) ANL participated directly in flywheel experiments at Boeing during several lengthy experimental sessions. In addition, results of spindown tests of the HTS bearing component were sent to ANL for interpretation and assistance in understanding. Breakdown of the results into hysteresis, eddy current, air drag, and other losses has been achieved. (3) A thermal model has been developed of the flywheel system. This model has been used to predict the heating of the motor/generator under different operating conditions. The model has also been used to predict the temperature development of the rotor under different chamber pressure conditions. (4) Early in the FY, Boeing identified the cost of the cryogenic system as a potential barrier to commercialization. ANL was tasked with investigating future cryostats and cooling configurations. Experiments were performed on two small-scale rotors to test new cryogenic cooling methods. In the first experiment, the cryochamber housing the HTSs was completely metallic except for the part immediately adjacent to the permanent magnet, which was G-10. In the second experiment, the HTSs were conduction cooled to a cryogenic bath, simulating elimination of liquid nitrogen in the system.

In FY 2004, ANL will continue its general consultation on the SPI flywheel project and plans to further participate in some of the flywheel experimental tests at Boeing. The thermal model will be used to help understand experimental results and make suggestions for advanced designs. The advanced cryogenic system will be further investigated, with tests of a HTS bearing using conduction-cooled HTSs directly mounted to the cold head of a cryocooler.

FY 2003 Results: Key results from the FY 2003 program are summarized below.

1. The 3-kW machine was successfully tested and operated below its maximum specified speed.
2. A thermal model of the flywheel system has been developed. The model has been used to predict temperatures in the M/G region and also to predict the rotor temperature under different pressures.
3. A partially metallic cryochamber was tested, and the results suggest that a liquid-nitrogen filled cryochamber may have more metallic parts than previously believed.
4. A conduction-cooled HTS bearing was tested, and the results suggest that liquid nitrogen can be eliminated from future bearing designs, greatly reducing the cost of this component in future flywheels.

Research Integration: ANL serves in the role of general consultation on the SPI project, in essence,

transferring to the SPI team all of ANL's general knowledge in the area of HTS bearings and flywheel energy storage accumulated over the last fourteen years. This knowledge is expected to augment the existing knowledge of the Boeing SPI team. Boeing has already incorporated much of the ANL experience into their design process in the continuing development of the unique Boeing design. This research integration is expected to continue into the latter testing stages 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 the project.