Project Title:	**HTS Coated Conductor Characterization and Analysis**
Organization:	Oak Ridge National Laboratory
Presenters:	David Christen and James Thompson
FY 2010 Funding:	$700 K (DOE to ORNL)

Overall Project Purpose and Objectives:

The purpose of this research is to provide measurement and analysis of superconducting properties of emerging and prototype coated conductor materials, in order to establish the practical limits of performance that are attainable. The project provides guidance for the ongoing work in CRADAs with US HTS wire manufacturers, and points the way to further improve the HTS superconducting properties. The work focuses on HTS performance characteristics in substantial magnetic fields, where the nature of vortex interactions with themselves and material inhomogeneities determine the loss-free current-conduction capability needed for specific applications. Of particular interest are the characteristics and understanding of anisotropic flux pinning provided by self-assembled extended defects, when coupled with additional pinning morphologies and the intrinsic electronic anisotropy of HTS cuprates. The program devises and implements novel experimental methods to ascertain properties previously inaccessible at the lab scale, for understanding the materials in regimes relevant to technological scale.

Principal objectives of the program include:

- Supplement and extend measurements of the field-orientation dependent J_c of state-of-the-art materials to lower temperatures and practical electric and magnetic field levels using novel contactless magnetization techniques

- Through direct, high-field measurements of the orientation-dependent irreversibility fields, further evaluate the unique competition between the anisotropic extended pinning and the intrinsic electronic anisotropy that can yield isotropic critical currents.

- Document the effects of different dominant pinning structures on prototype 2G wire short-segment performance, for various regimes of operational parameters (temperature, field, orientation)

2010 Approach and Results:

Very high-performance HTS coatings are emerging from both base program research in developing ideal nanostructures for pinning enhancement (e.g., the ORNL project “Engineered Columnar Defects for Coated Conductors”) and from newly improved commercial prototypes. This project conducts a combination of electrical transport and contactless magnetic-based techniques to broadly characterize and analyze the relevant superconductive properties as a function of temperature, magnetic field, orientation in field, and effective electric field level. We have implemented new methodology in characterizing orientation-dependent critical currents, extended to parameter regimes that are otherwise highly problematic for laboratory scale techniques.

In this period, specific accomplishments include:

- A comparative assessment of the orientation dependent irreversibility field of materials with and without extended defects. This work involves collaboration with the NHMFL at Florida State University, and elucidates the competing effects of thermal activation vs. pinning in the high-field regime. A systematic tilt of second-phase columnar defects in RBCO on IBAD substrates provides angular asymmetry as a signature of pinning effects.

- A generalized vector-current model was developed to determine critical current densities both within superconducting grains and crossing the grain boundaries in coated conductors. The generalization becomes essential when the grain boundaries transmit a large fraction of the current, as in RABiTS-templated materials with significant meandering of the grain boundaries. Comparison of intragrain J_c values for such materials with those measured on companion single crystal films supported the essential correctness of the model.

- Analysis of transport current measurements to reveal effects of high-field matching of the equilibrium vortex density with the array of columnar defects. The results have been correlated with microstructural characteristics of the density and order of the columnar array. Dependence on orientation of the matching phenomenon has been qualitatively described with a simple, intuitive model.

- Studies showing the effects of temperature, field, orientation, and electric field levels on the superconducting properties of RBCO materials with different pinning nanostructure. The systems explored were doped to contain either columnar pinning structures, or rare-earth oxide precipitates, or a mixture of these. In general, the variation of J_c with orientation of the magnetic field was most extreme at elevated temperatures and fields; decreasing the temperature progressively reduced the dependence on field orientation, leading to a more isotropic response.

2011 Plans and Expectations:

- Develop a more complete experimental scope of the observed flux-pinning phenomena in systems that exhibit the combined effects of self-assembled extended and additional pinning structures
- Employ new experimental techniques to document details of the vortex pinning energy in different systems with controlled nanostructure
- Further advance the level of fundamental understanding for future guidance in materials design: e.g., mechanisms that underlie the observed regimes of field- and orientation-dependent critical currents
- Further apply new methodologies to establish properties of supercurrent conduction in coated conductors at the lower temperatures, high magnetic fields, and low electric field regimes where 2G-wire based equipment and devices may be operated.

Technology Transfer, Collaboration, Partnerships:

The project involved interactions with and contributions from collaborators at external institutions and industrial partners, as well as within ORNL. Prototype state-of-the-art short 2G segments and control samples were used for magnetic field orientation-dependent and extended-range properties measurements. Materials were acquired through other ORNL base programs, from SuperPower Inc, from AMSC, and through collaborations with the University of Dayton. Close interaction with the University of Tennessee, Florida State University, and North Carolina A&T University has provided complementary techniques and broad-based expertise.