SUPERCONDUCTIVITY FOR ELECTRIC SYSTEMS

Partnerships For Superconducting Technologies

"An example of the recent technological success that will allow for increased access to all forms of energy, including renewable energy, is the high-temperature superconducting underground power transmission cables that the Department of Energy is developing in partnership with industry."

President's National Energy Plan, May, 2001

What is the DOE Superconductivity Systems Program?

- The leading federal effort for harnessing energy benefits of high temperature superconductivity (HTS). This effort is **enabling an entirely new high technology Industry.**
- An **integrated portfolio of world-class research** by industry/government/university teams.
- The focus for **designing the next generation** of super efficient power equipment for highly competitive electric utilities.

Successes:

- **World's first industrial test of a 3-phase 12.5 kV, 1,250 A** HTS power cable.
- **Built and tested 1,000 horsepower HTS motor**, with design complete for 5,000 hp HTS motor.
- **15kV HTS current controller carried 9,000 A** under fault condition while testing at a utility substation.
- **National laboratories achieve world record** for performance, of 2nd generation HTS wires.

Payoffs of Federal Investment:

- Superconductivity applications and products are expected to generate an **estimated $30 billion product market by 2020.**
- **New jobs, economic growth**, and expanded technologies are being created as the HTS industry evolves.
- HTS will **enable U.S. utilities to replace aged overhead/underground transmission cables** with more reliable, higher capacity transmission networks with minimal environmental impacts.
- **Advancements** in superconducting electric power equipment:

  - **Motors**-HTS motors: 50% smaller, 50% less losses, reduce pollution as compared to today's motors.
  - **Transformers**-oil-free HTS transformers: weigh ~45% less and reduce losses by 30% over conventional units.
  - **Power Surge Protection** - HTS fault current controllers redirect the excess energy into HTS coils where it is safely absorbed without interrupting normal power supply.

CALIFORNIA

Ashman Technologies develops advanced electric motors, generators, and alternators, including several high power-density, high-efficiency, ultra high-speed permanent magnet alternators, starter-generators, alternating-current (AC) and brushless direct-current (DC) motors. Ashman will develop the motor/generator and motor controller for the HTS Flywheel Electricity System project led by Boeing Phantom Works.

The **Electric Power Research Institute** (EPRI) is a research consortium established for the improvement of electric power generation and delivery. EPRI is teamed with Pirelli Cables & Systems in the development of a 77-megavolt ampere (MVA), 3-phase, 2500-foot long, high temperature superconducting cable system for Long Island, NY.

Southern California Edison (SCE), the largest subsidiary of Edison International, has partnered with Boeing Phantom Works to refine system requirements and conduct on-site testing of a 35 kilowatt hour superconducting flywheel energy system. SCE has also been named to provide testing for a transformer component, in collaboration with IGC-SuperPower.

COLORADO

The **National Renewable Energy Laboratory's** (NREL) mission is to develop renewable energy and energy efficiency technologies and practices, advance related science and engineering, and transfer knowledge and innovations to address the nation's energy and environmental goals. NREL will collaborate with Oxford Instruments to develop the conductor for a HTS magnetic resonance imaging system.

Mesoscopic Devices specializes in chemical and cryogenic processes. Working with Boeing Phantom Works on the Flywheel Electricity System project, Mesoscopic Devices will develop the cryocooler through their Boulder Cryogenics subsidiary.

CONNECTICUT

Praxair Inc. of Danbury, will be working with General Electric Corporate Research and Development to develop advanced refrigeration components during the design and development of a 100 MVA HTS Generator project.

DELAWARE

The **DuPont Company** of Wilmington, Delaware will head a team tasked with the development of a high temperature super-conductive reciprocating magnetic separator that will result in more than a 90% improvement in energy efficiency over conventional technology in the minerals and chemicals separation and purification industries.

FLORIDA

The **National High Magnetic Field Laboratory** will conduct special studies for conductor life and integrity measurements in collaboration with General Electric for the design and development of a 100 MVA HTS Generator project.

The **Carpo Division of Outokumpu** is a key member of the DuPont team working to construct a HTS reciprocating magnetic separator.

GEORGIA

The **Southwire Company** of Carrollton, Georgia will construct the superconducting cable and coordinate the activities to install a 1000-foot long, 3-phase, high temperature superconducting cable at the American Electric Power (AEP) substation in Columbus, Ohio. This project will demonstrate the advantage of a long-length HTS power cable that will replace an existing oil-filled, limited current capacity underground power cable.

The **J.M. Huber Corporation**, a supplier of engineered materials, natural resources, and technology-based services to customers spanning many industries, is currently partnered with the DuPont Company to provide a field testing facility for the development of a HTS reciprocating magnetic separator.

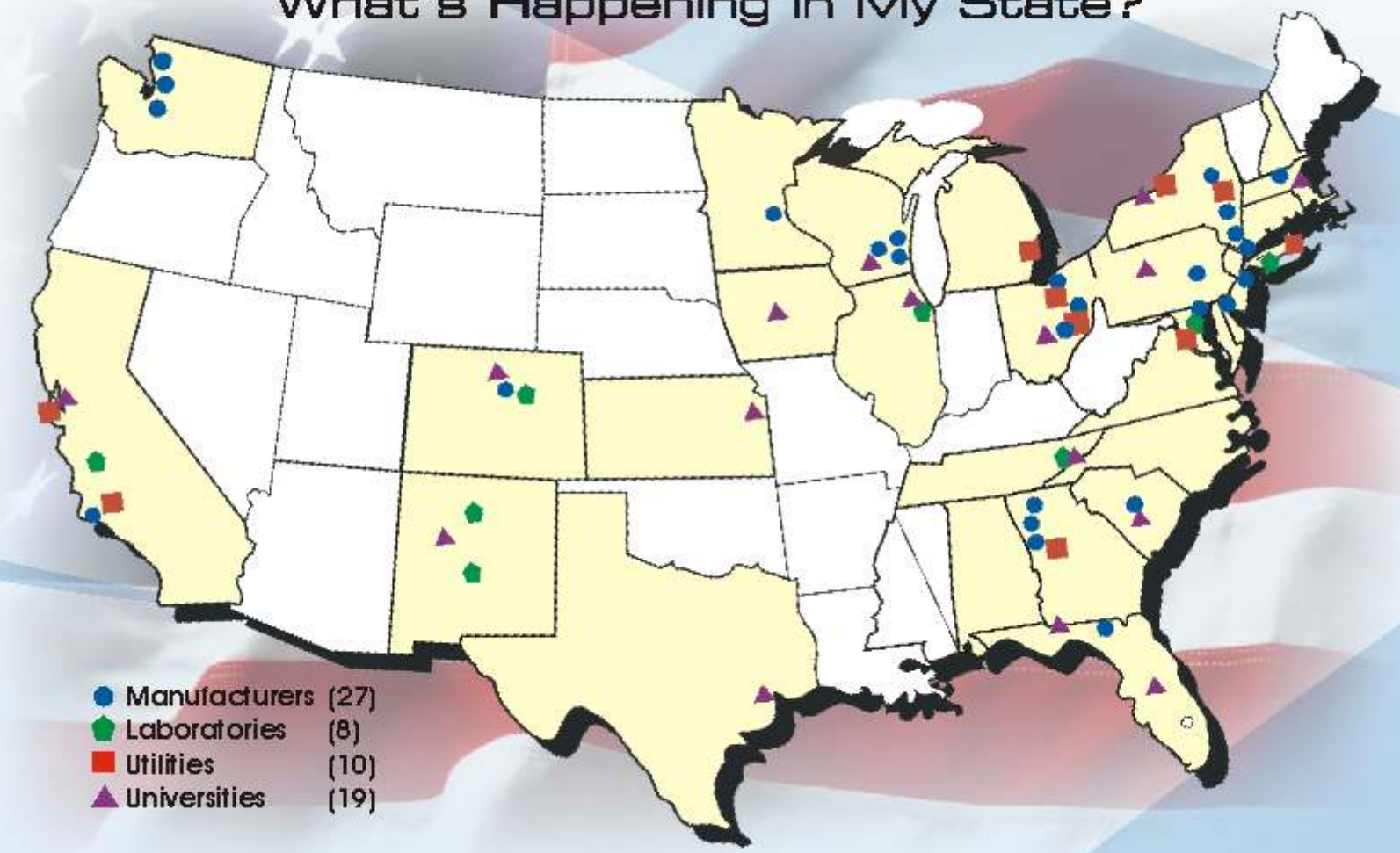
Integrations Concepts Enterprises (ICE) is a software solutions company based in the Atlanta area that will be developing the power controls for the long-length cable demonstration project headed by Southwire.

ILLINOIS

Argonne National Laboratory (ANL), has four major missions: conducting basic scientific research, operating national scientific facilities, enhancing the nation's energy resources, and developing better ways to manage environmental problems. Argonne has developed a process for second generation high temperature super conductors known as inclined substrate deposition or ISD. ISD is a fast robust, and economically attractive process to fabricate biaxially textured templates, is easily reproduced by industry, and critical current density values of >200,000 amperes per square centimeter have been obtained.

Superconductivity Partnership Initiative

What's Happening in My State?



MARYLAND

The **PG&E National Energy Group** will participate in site integration studies and economic benefit analysis for the design and development of a 100 MVA HTS Generator in conjunction with General Electric Corporate Research and Development

MASSACHUSETTS

Located in Westborough, **American Superconductor** Corporation's (ASC) success in manufacturing superconducting wire was recognized by an R&D 100 award and program prototypes using ASC's wires have set new world benchmarks. ASC has been selected to participate in the "Demonstration of a Pre-Commercial Long-Length HTS Cable System Operating in the Power Transmission Network" project slated for installation in Long Island, New York.

MINNESOTA

The **3M Company** has been chosen to evaluate the potential of coated conductor HTS wire in cable applications in conjunction with the Southwire Company's Long Length HTS Power Cable Project

NEW JERSEY

Oxford Instruments of Carteret, New Jersey, will build and operate a cost-effective, open-geometry, high temperature superconducting magnetic resonance imaging system. The HTS coils will be wound from continuously melt-processed, dip-coated BSCCO 2212 tape. The higher field strength from HTS magnets would expand the accessibility of this crucial, non-invasive, medical diagnostic technology.

NEW MEXICO

Los Alamos National Laboratory (LANL) has performed cutting-edge HTS research, enabling program partners to secure a strong position in the superconductivity marketplace. LANL pioneered the ion-beam-assisted-deposition (IBAD) process to produce the crystalline alignment necessary for high performance in coated conductors of YBCO superconductors. The IBAD process

has achieved current densities of one million amperes per square centimeter of cross section over meter long lengths at liquid nitrogen temperature, and is being scaled up to longer lengths. LANL is also a leader in the development of current controllers and the ac loss characterization of HTS cables.

NEW YORK

General Electric Corporate Research and Development is the lead team member working to design, test, and install a 100 MVA prototype high temperature superconducting generator that will improve efficiency, capacity, and reactive power capability over existing conventional generators.

IGC-SuperPower located in Schenectady, has the team lead for development and installation of a transformer component at a High Temperature Superconducting Substation. This project would demonstrate a prototype utility-sized HTS transformer to convert electricity from 66 kV to 12 kV potential.

The **Long Island Power Authority** (LIPA) will be the site for installation of a 77-MVA, 3-phase, 2500-foot long, high temperature superconducting cable system. LIPA will maintain the site and will also participate in the development of a 1 kilowatt (cold) Pulse Tube Refrigerator for high efficiency cooling.

The **New York State Energy Research and Development Authority** (NYSERDA) was created in 1975 to support certain public benefit programs during the transition to a more competitive electricity market. NYSERDA is a partner with General Electric Corporate Research and Development in the development of a 100 MVA high temperature superconducting prototype generator.

OHIO

American Electric Power (AEP) will participate in site integration studies and benefit analyses in conjunction with General Electric Corporate Research and Development for the design and development of a 100 MVA HTS Generator project. American Electric Power is also involved with the design, installation, testing, and operation of a long-length HTS superconducting power cable project with Southwire Company.

An innovative and state-of-the-art industry leader, **PHPK Technologies** Incorporated will enhance the design and reliability of the cryogenic system for a long length high temperature superconducting power cable project by using closed-cycle refrigeration. PHPK is partnered in this project with the Southwire Company. **Superconductive Components** (SCCI) manufacturers ceramic powders and engineered ceramics for research and commercial applications of superconductors, among other products. SCCI is teamed with Oxford Instruments and will supply the initial HTS powder for the Open Geometry HTS Magnetic Resonance Imaging System project.

SOUTH CAROLINA

Pirelli Cables & Systems, in conjunction with other team members, will develop, test, and evaluate a 77 MVA, 3-phase, 2500-foot long, high temperature superconducting cable system. This particular cable development demonstration project is planned for installation at a site to be named by the Long Island Power Authority, and will provide accurate operating data to be used in network analysis models as well as practical operating experience.

TENNESSEE

Oak Ridge National Laboratory (ORNL) is a DOE multipurpose laboratory conducting energy and environmental R&D, playing a key role in the development of superconducting power cables and transformers. ORNL is also a vital part of research into the fundamental problems of making electrical wire out of the class of ceramic "high temperature" superconducting materials. Oak Ridge researchers have invented a rolling-assisted, biaxially textured substrate (RABiTS) template for high quality HTS tape resulting in critical current density exceeding 3 million amperes per square centimeter.

WASHINGTON

Boeing Phantom Works, located in Seattle, will design, fabricate, and test a 35 kilowatt hour superconducting flywheel energy storage system as a power risk management system that will give power users and utilities a full-scale device to manage both cost and reliability risks.

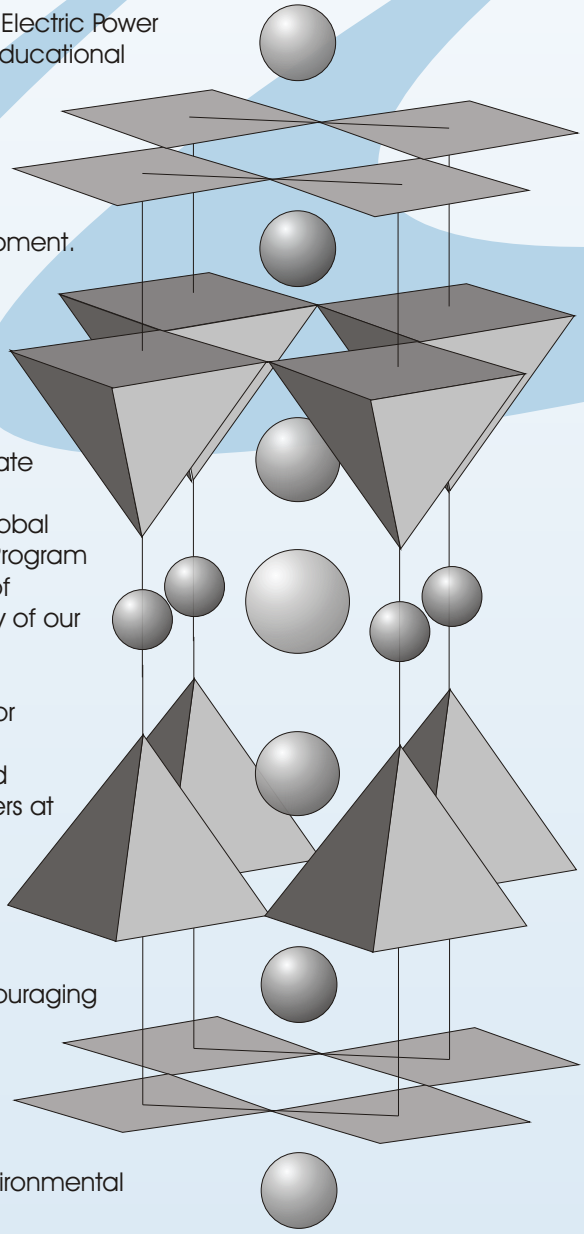
Praxair Specialty Ceramics, a division of Praxair, Inc., will work with Boeing Phantom Works to improve the high temperature superconductor processes for the Superconducting Flywheel Power Risk Management System project.

WISCONSIN

Waukesha Electric Systems, located in Waukesha Wisconsin, is a leading manufacturer of electric utility transformers and has been working with the superconductivity program to develop superconducting transformers which will offer considerable energy and environmental advantages over conventional transformers. Their latest project teams them with IGC-SuperPower to construct a transformer component of a HTS Substation.

The Superconductivity Partnership Initiative

Local Efforts Address Global Challenges

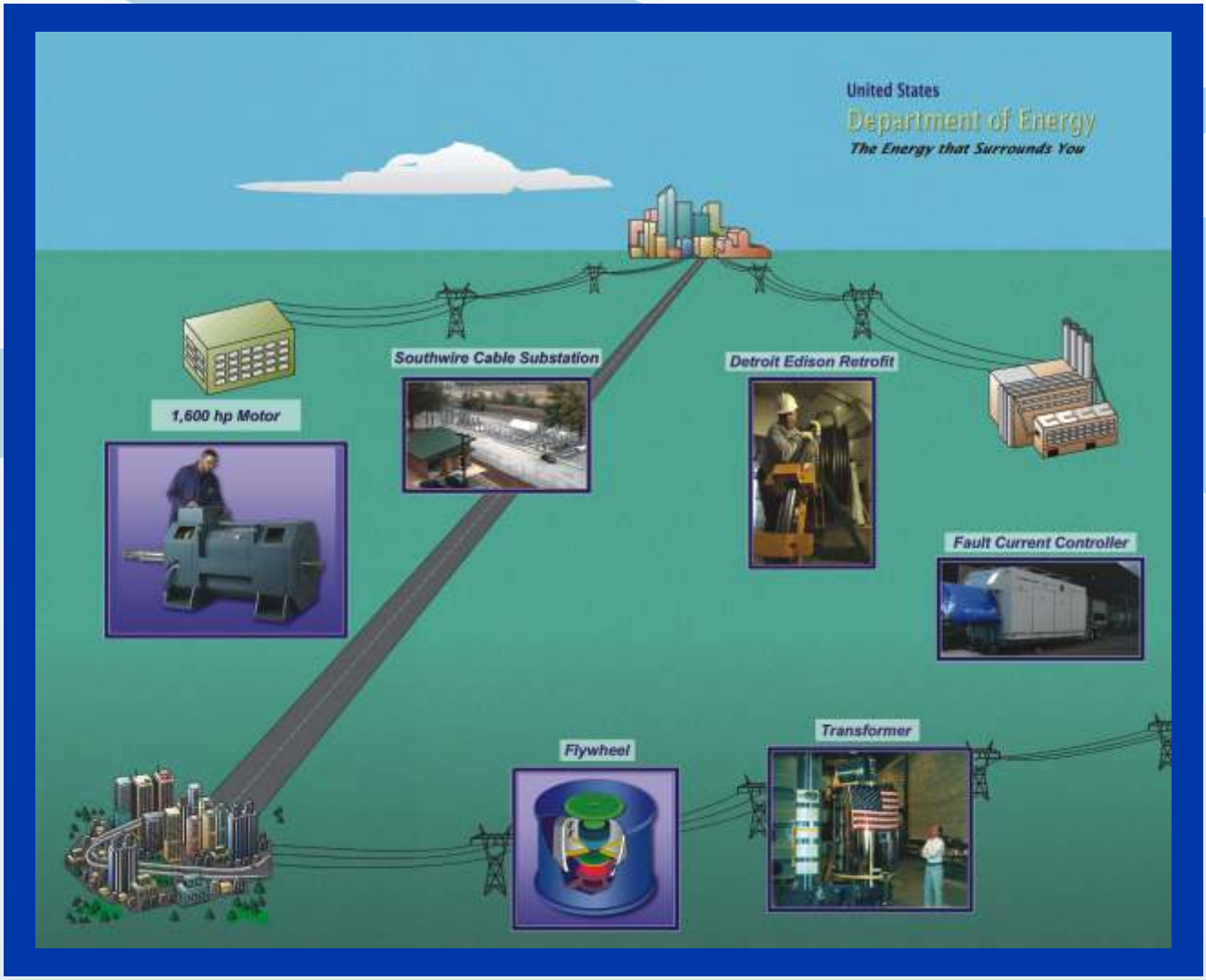


The U.S. Department of Energy (DOE) Superconductivity Program for Electric Power Systems supports national energy, economic, environmental, and educational interests by providing leadership in developing high temperature superconducting (HTS) electric power devices and facilitating their adoption by the utility industry and the private sector. Across the country, the utility infrastructure is aging. There is an unprecedented opportunity in the coming years for rapid market penetration of HTS power equipment to replace existing aged equipment. With this opportunity also comes the need for increased awareness and education of HTS technologies, issues, and benefits in order to achieve the general acceptance of HTS power equipment and the resulting modernization of our national electric system.

The DOE has created an innovative partnership structure to accelerate this technology development. Known as the Superconductivity Partnership Initiative (SPI), it is designed to meet the challenges of global competitiveness and is an integral part of DOE's Superconductivity Program for Electric Systems focusing on the development and field testing of technologies that will improve the efficiency, capacity, and reliability of our electricity infrastructure.

The Department of Energy expects to continue cost share funding for additional SPI projects in order to maintain a strong portfolio that will capitalize on continuing improvements in HTS wire, component, and systems characteristics. DOE typically cost shares with the SPI partners at 50% of the proposed budget, spread over the life of the project. This funding leverage creates a program that strongly benefits from interaction among industry, universities, and the national laboratories.

Additionally, the Superconductivity Program is also interested in encouraging activities to broaden the national effort and deliver the accomplishments of the program to the state and local level. State organizations include, but are not limited to: state energy offices; public utility commissions; departments of environmental protection, natural resources, consumer advocates, and community and economic development; legislators; state environmental and economic commissions; and business roundtables.



Super-Efficient Technologies Modernize the National Electric System

High temperature superconducting technologies promise to improve almost every aspect of how electricity is generated, delivered, and used. HTS, when commercialized on a large scale, should provide significant environmental and economic benefits. Prototype HTS power equipment is currently being designed and tested in key applications and these HTS SPI prototype demonstrations are teaming utilities with HTS industry stakeholders in an effort to prove the technology under real-world conditions. Further, the SPI projects will begin to educate utilities, industry stakeholders, federal and state agencies, legislators, and regulators on the potential of HTS technology.

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