2G HTS Wire Status in the USA

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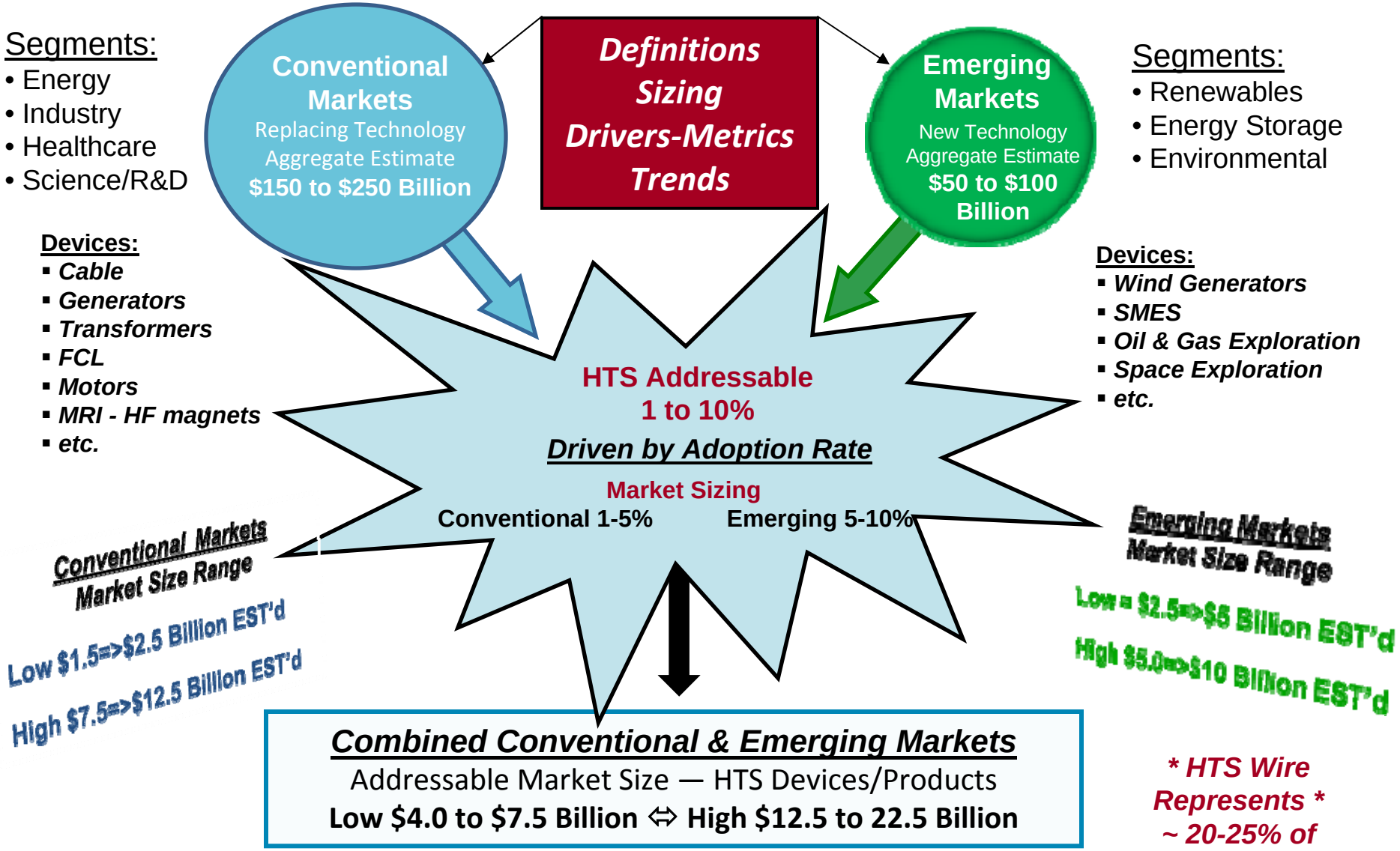
Topics

- HTS market outlook
- Areas of application
- Critical success factors for market adoption
- Status at AMSC
- Status at Superconductor Technologies Inc. (STI)
- Status at SuperPower Inc.
- Summary

HTS market sizing model & analysis

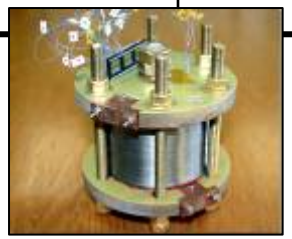


HTS device portfolio - What are the winning devices?

Energy	Defense	Transportation	Industrial	Medical	Science/ Research
• **Cable** • **FCL** • **Generators** • **Transformers, incl. FCL** • **Storage** – **SMES** – Flywheels	• **Motors** • **Cables** • Directed energy weapons	• **Maglev** • Motors • Rail engines	• **Induction heaters** • **Motors** • **Generators** • Magnetic separation • Bearings	• **Current leads** • **MRI** • NMR	• **HF magnets** • **Space exploration** • SQUIDS • High energy physics • Electronics • Cell tower base station filters

Courtesy of LS Cable


Courtesy of Waukesha




Courtesy of Oswald

Key:
- **Near-Term addressable: 1-5 years**
- **Mid-Term: 3-7 years**
- **Longer term: 5-10 years**

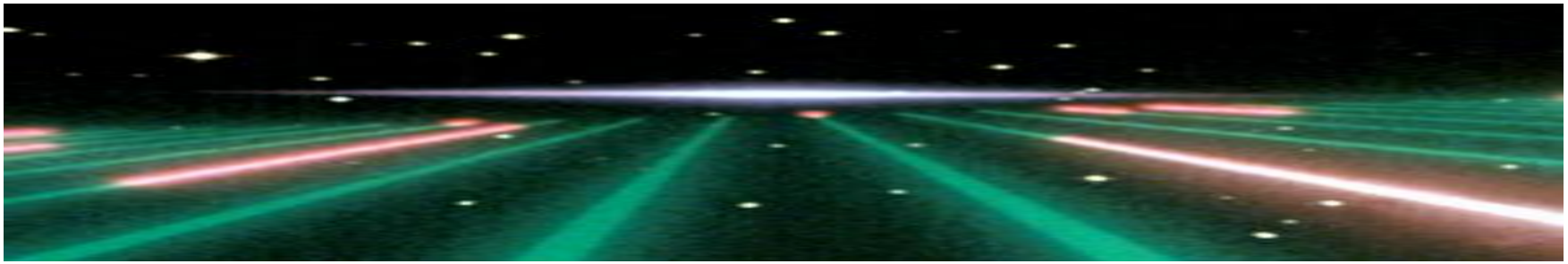
How do we accelerate the HTS adoption rate toward commercialization?

Technology advancement

- Wire
  - Achieve competitive **price**
  - Increase throughput / **supply**
  - Meet **performance** parameters
- Providing a robust product portfolio
  - Market / device-driven
- Continuing device **demonstrations**
  - Government funding
  - Strategic partners

Reduced business risk

- Price must be competitive with alternative technologies
- Meet/exceed customer expectations
  - Supply
  - Quality
  - Performance
- Provide superior customer service and support



Status of 2G HTS Wire Program at AMSC

Acknowledgement: Mr. Rob Rouse

smarter, cleaner
...better energy

AMSC's Commercial 2G Wire Production

- MOD-YBCO/RABiTS manufacturing is operating with a 40 mm web width
- Manufacturing focused on delivery of Amperium™ wire for commercial orders
- New 100 mm manufacturing technology is being installed to meet commercial orders


Production Coating Line


10-m Production Decomposition Furnace

Superconductor Power Cable Installations Powered by AMSC

- American Electric Power energized its superconductor power cable in August 2006
  - 13.2 kV
  - 200 meters (BSCCO)
  - Able to power nearly 9,000 homes and businesses
  - Operating reliably for more than five years

Photo courtesy of Southwire

- Long Island Power Authority energized its superconductor power cable in April 2008
  - 138 kV
  - 600 meters (BSCCO)
  - Able to power 300,000 homes and businesses
  - Operating reliably for more than three years
  - 2G cable to be added and energized early 2012

World's First Large-Scale HTS Wire Order

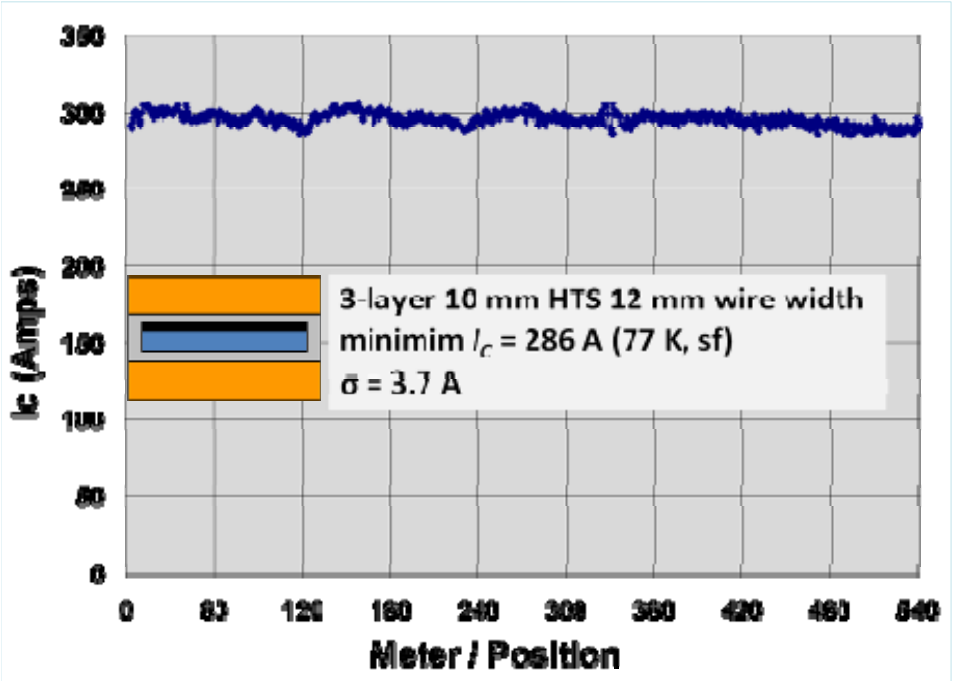
- LS Cable, world's third largest cable manufacturer, placed a multi-year Amperium wire order with AMSC in September 2010
- By far, the world's largest HTS wire order – 3000 km
- Companies entered into a strategic alliance to deploy 50 circuit kilometers of superconductor cable in March 2010

Photo courtesy of LS Cable

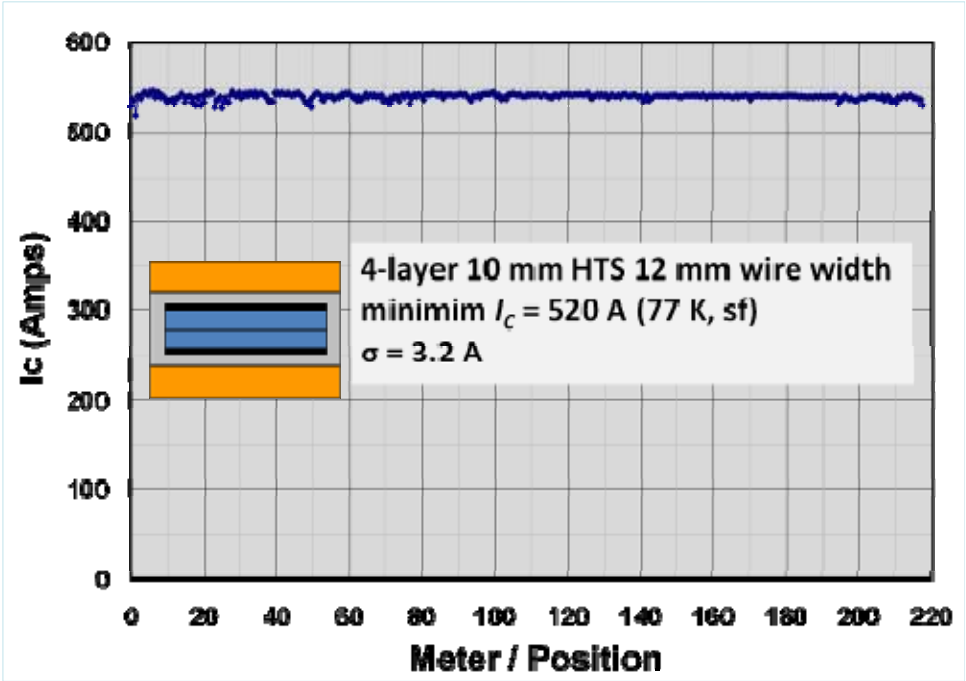
- Korea expected to energize its first superconductor power cable in the grid soon
- LS Cable targeting the global market

Performance of 3- and 4-layer Wires, 12 mm Width

Amperium™ Copper Laminated 12



Beta Wire – Double Insert



Broad range of high amperage options available with 3 and 4 layers, 12 mm wide

SUPERCONDUCTOR TECHNOLOGIES INC.

2G HTS Wire Development Status

20th International Superconductivity Industry Summit

Acknowledgement: Adam Shelton

Overview and History

STI is a world leader in the development and production of High Temperature Superconducting (HTS) materials and associated technologies

Discovery of High Temperature Superconducting (HTS)

Superconductor Technologies Inc. (STI) incorporated in Santa Barbara, California

HTS Thin Films for Electronics

Invents Reactive Co-evaporation – Cyclic Deposition and Reaction (RCE-CDR) HTS deposition technology

SuperLink® Product Released

High performance Radio Frequency (RF) infrastructure solution

HTS Manufacturing Ecosystem Created

Cost competitive HTS and cryogenics in full scale manufacturing production

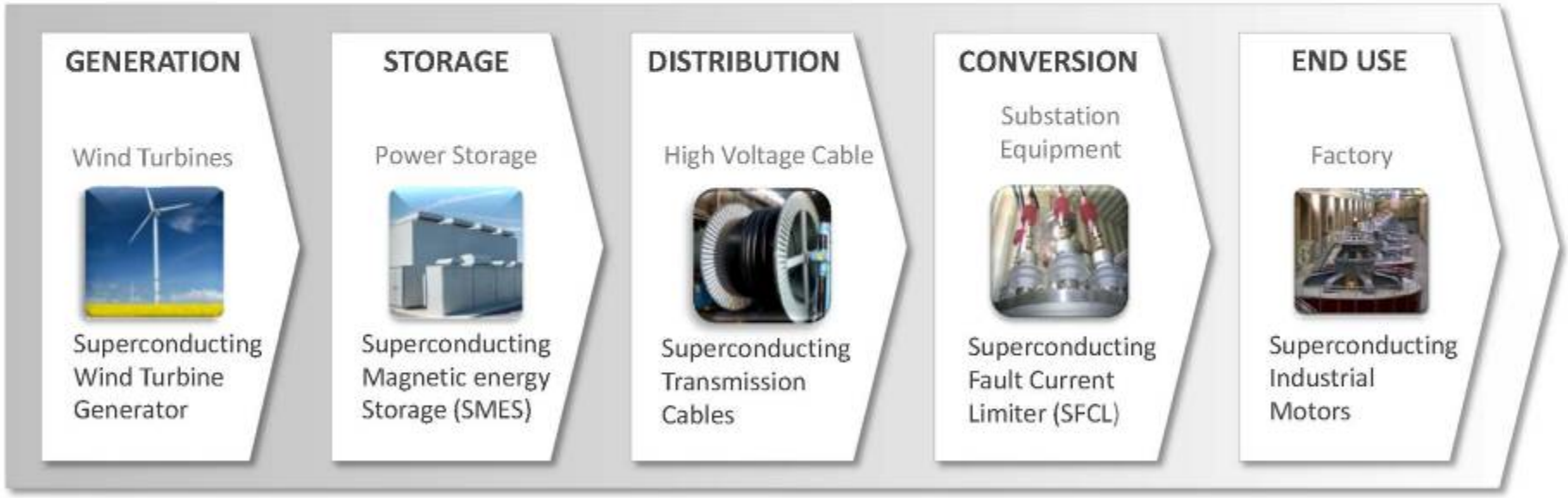
2G HTS Wire for Emerging Power Applications

Developing HTS wire to capture new market opportunities

HTS Technology in the Smart Grid

Increasing investment into Smart Grid infrastructure and alternative power generation

- HTS expected to play a crucial role in new emerging electric power generation, distribution and conversion applications
- HTS power applications expected to improve grid reliability and efficiency at a competitive cost to alternatives
- *"The global market for power generation equipment during the 2010 to 2020 period is estimated at approximately $2.35 trillion"* *(Amadee+Company Superconductivity 2011 – 2020 Analysis and Forecasts).*



2G HTS Wire

SDP → **IBAD/epi MgO** → **RCE-CDR**

Solution Deposition Planarization (SDP)

Ion Beam Assisted Deposition (IBAD)

Reactive Coevaporation – Cyclic Deposition and Reaction (RCE-CDR)

STI's 2G HTS Wire Can Have a Clear Cost and Performance Advantage for the Following Reasons:

- Fewer deposition process steps – reduces runtime and increases yield
- Simple and repeatable template
- Low cost raw materials
  - Start with basic raw compounds vs. more expensive premixed, solution-based compounds
  - Inexpensive substrate material utilized
- High throughput and large HTS growth area
- Lower production equipment cap-ex than alternative manufacturing methods
- Less electricity and production floor space required per kilometer of wire produced

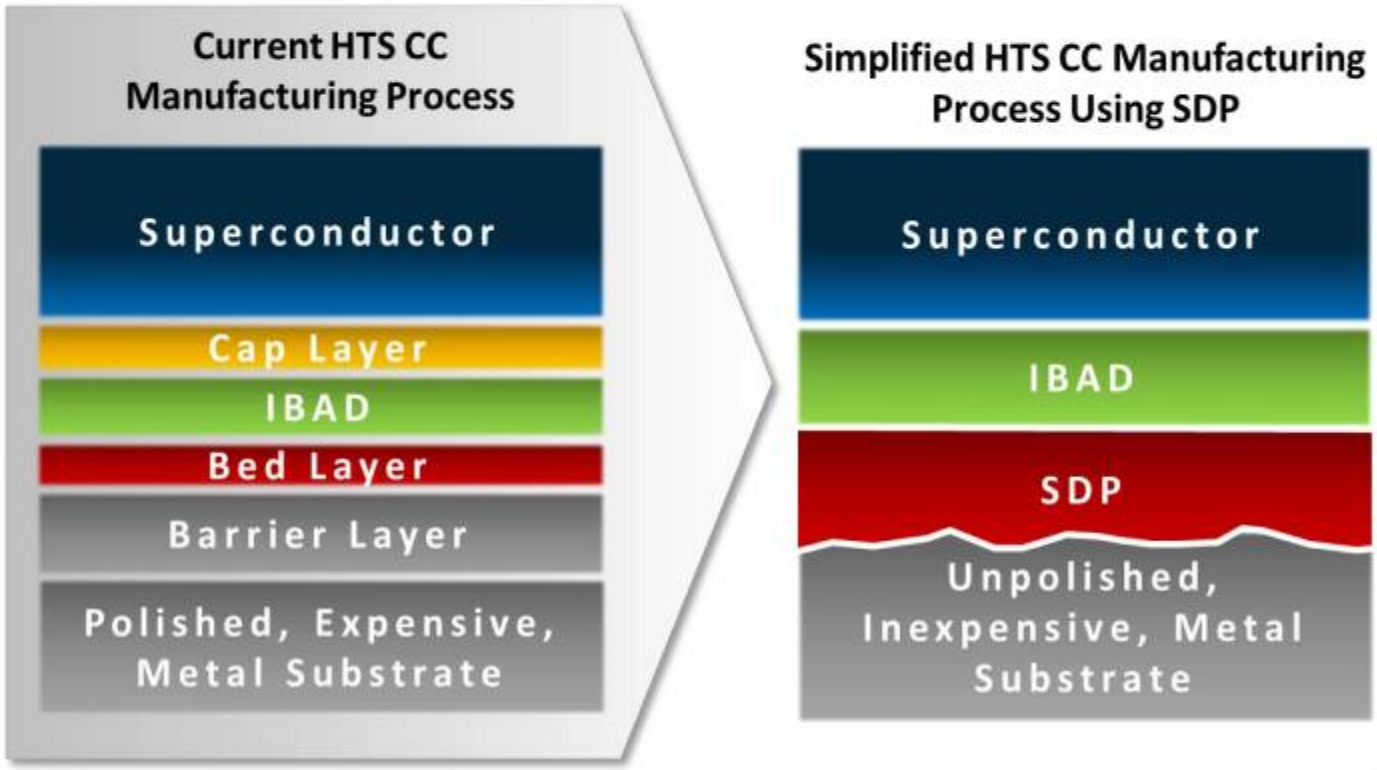
Fewer Layers, Low Cost Process

Existing Processes:

- Substrate processing
- 5 deposited layers

STI Process:

- No substrate processing
- 3 deposited layers



Go to Market Strategy

- **Leverage STI's industry leading expertise in HTS materials and manufacturing to commercialize 2G HTS Wire**
- **Target hyper-growth emerging Smart Grid market**
  - Become a significant supplier to the HTS wire market with our industry leading technology
- **Focus on the customer for development initiatives**
  - Design wins for new emerging products
  - Supply agreements and wire sales to end device companies
- **Build a cost optimized manufacturing process that scales to meet demand**
  - "Copy Exactly" – Intel's manufacturing model
- **Continue to enhance our strong IP portfolio**
  - Protecting STI's unique capabilities

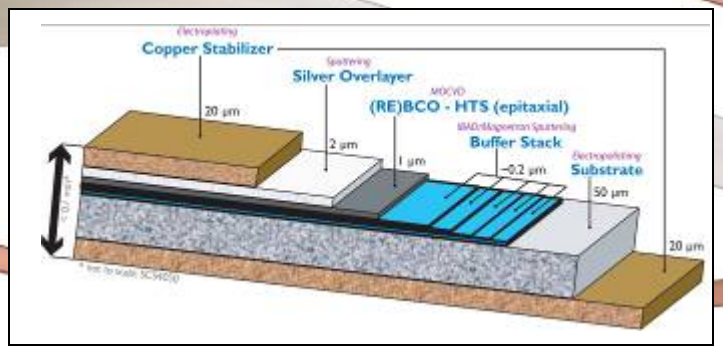
Wire performance results

- **Achieved results on a simplified IBAD template process requiring only Y_2O_3 and MgO layers**
- **STI SF performance demonstrated in Q4/2011**
  - 1015 A/cm at 77 K, SF for a 3.35-μm film on IBAD templates; J_c = 3 MA/cm^2
- **In-field performance**
  - Minimum $I_c(\Theta)$ of 435 A/cm-width at 65 K, 3 T on MgO
  - Minimum $I_c(\Theta)$ of 257 A/cm-width at 65 K, 3 T on MgO/Y_2O_3/Hastelloy
  - Simple RE-BCO compound
  - No artificial pinning centers

SuperPower Inc.

superior performance.
powerful technology.

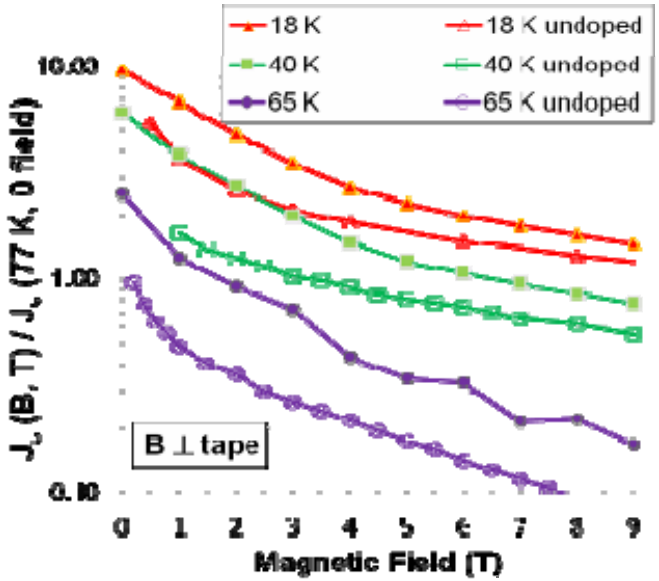
Status of 2G HTS Wire Program at SuperPower



PHILIPS SuperPower Inc. is a subsidiary of Royal Philips Electronics N.V.

Improving price/performance on two fronts: Manufacturing process and in-field performance

Lift Factor of 77 K, zero field I_c	65 K 3 T	40 K 3 T	18 K 3 T
Undoped wire	**0.27**	**1.02**	**2.13**
Zr-doped wire	**0.73**	**1.99**	**3.50**
Lift factor of Zr-doped wire is higher by	**2.7**	**1.9**	**1.6**



Time	Performance at 77K, 0T *	Lift Factor at operating condition	Performance at operating condition	Wire price * ($/m)	Wire price ($/kA-m) at operating condition
Now	100-130 A	2	260 A	$45	$175
2 years	160 A	4	640 A	$35	$ 55
4 years	200 A	6	1200 A	$35	$ 30

At 40K and 3T, the quantity of wire required for the device is **reduced by HALF,** greatly improving the economics of the device

* Average, 4 mm width

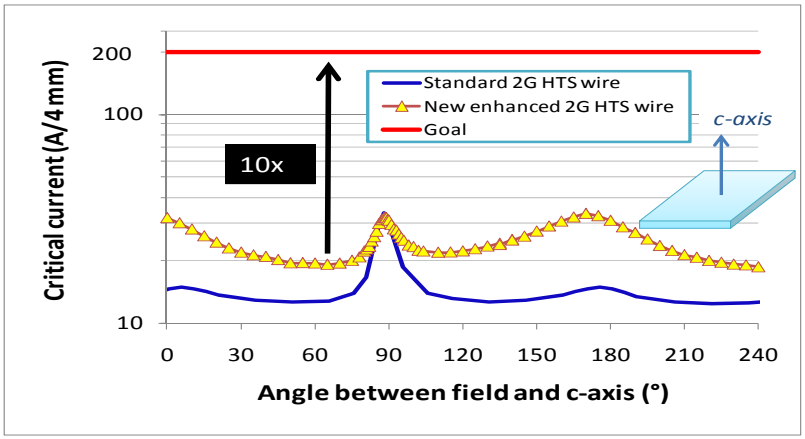
Continuing to drive technology improvements

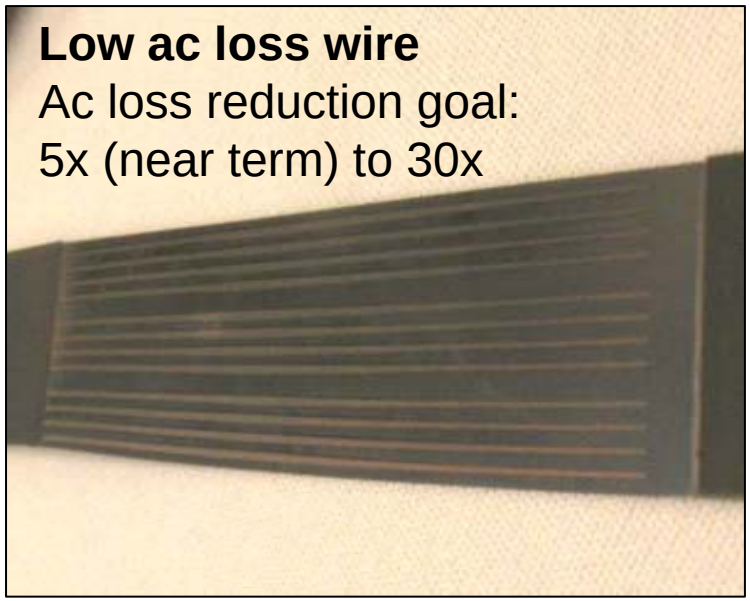
Achieve higher amperage

	Today	2 yrs	5 yrs
Ic at 77 K *	100-130 A	200 A	300 A

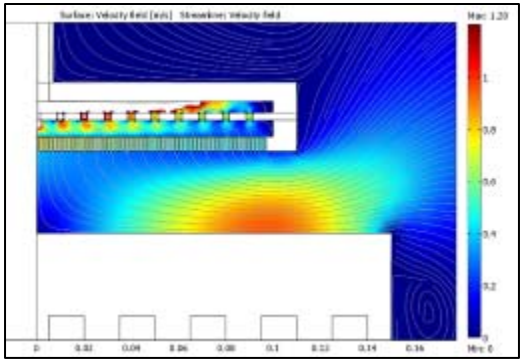
* 4 mm width

Improved in-field performance





Increased production and reduced cost

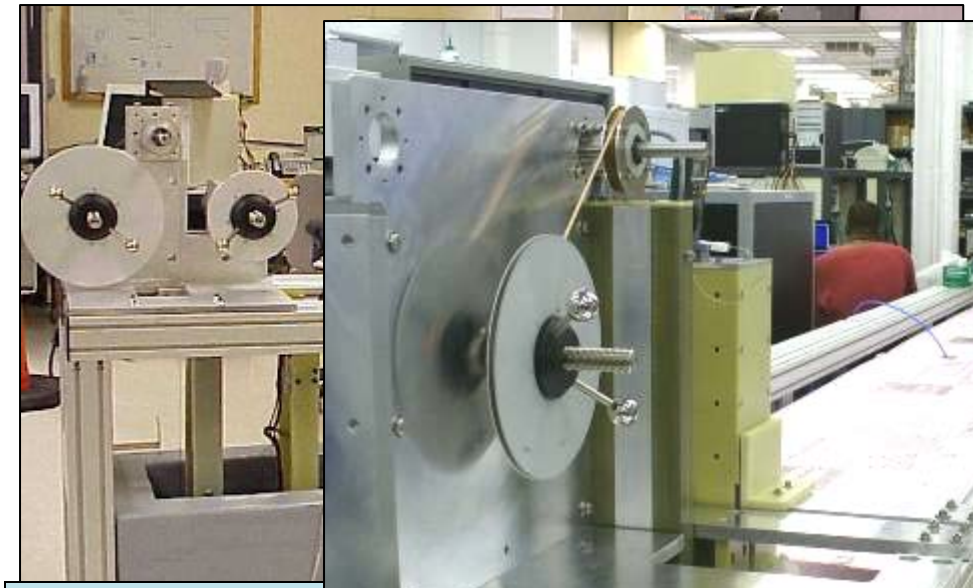


New MOCVD Reactor Design

Silver electrodeposition

Manufacturing improvements: Engineering equipment to quickly test kilometer lengths of coated conductor

- LTS wire is tested only at two ends
- Coated conductor is tested for I_c and n-values **100% over entire length**

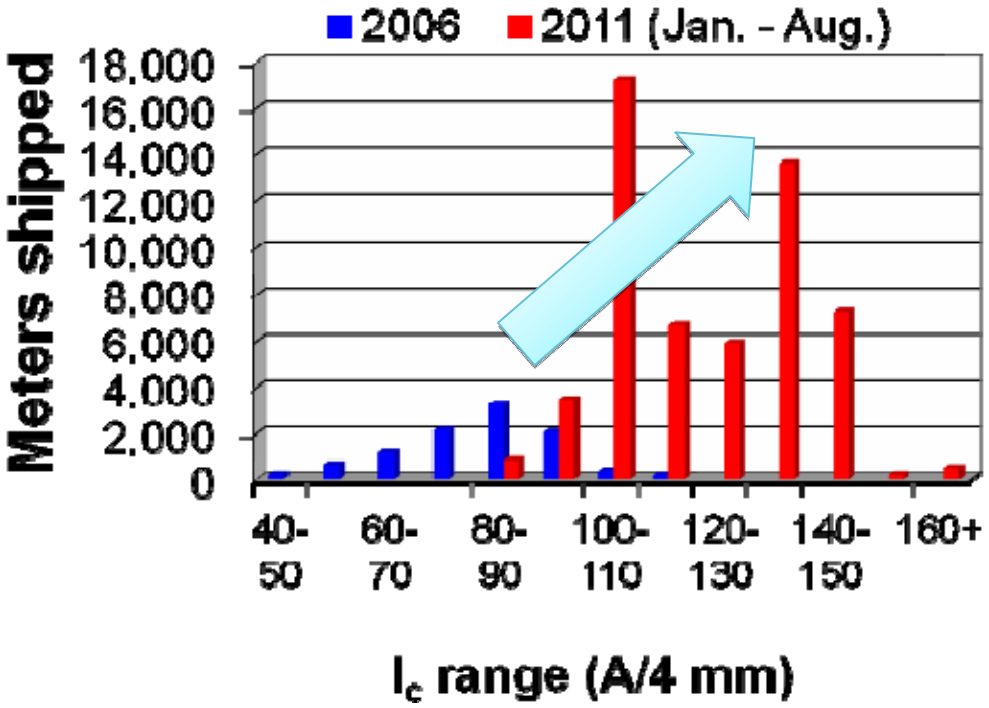


2003: *Ic, n-va*
1 m *intervals*

2006: *Ic, n-value, thickness, wid*
measurement in ***5 m*** *intervals*

2011: *Ic, n-value, thickness, width measurement in* ***10 m*** *intervals*

Five years of pilot manufacturing results in significant increases in 2G HTS wire shipments and performance



Metric	2006	2011
Average I_c (A/4 mm)	**80 A**	**122 A**
I_c range (A/4 mm)	**40 – 118 A**	**80 – 165 A**

50% increase in average I_c
100% increase in minimum I_c
40% increase in maximum I_c

Significant advances in manufacture of coated conductors in the last five years

Courtesy of Nexans/KIT

- Long lengths routinely manufactured
  - 1,000 m demonstrated with minimum Ic of ~ 300 A/cm (2009)
  - 100 – 300 m typical shipped lengths
- High critical currents in production wires
  - Critical currents of wires shipped in 2011 range from 80 to 165 A/4 mm with an average of 122 A/4mm
- Excellent in-field performance in high fields at intermediate and low temperatures
  - 800 A/cm (Je = 800 A/mm2) at 4.2 K,10 T, field perpendicular to wire
  - 600 A/cm at 40 K, 3 T, field perpendicular to wire
- Customized to meet unique requirements of multiple applications
  - Excellent 2D uniformity of critical current across width for ROEBEL cables
  - Tight bandwidth of critical current for FCL
  - Multiple prototypes of cables, FCL, coils demonstrated
- Superior mechanical properties
  - Yield strength >700 MPa with superalloy-based coated conductors

Courtesy of NHMFL

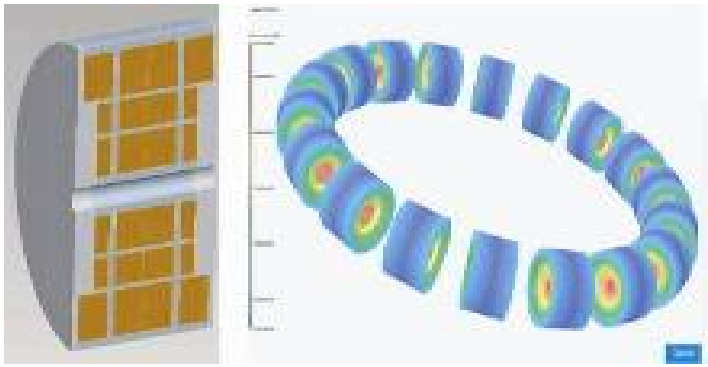
Courtesy of IRL/General Cable Superconductor

Current SuperPower demonstration projects – vehicles for continuing wire development efforts

DOE Smart Grid

Demonstration Program – **2G Superconducting FCL Transformer**

Waukesha – SuperPower – UH - Oak Ridge National Laboratory – Southern California Edison



ARPA-E GRIDS Program – **2G SMES Project**

ABB – SuperPower – Brookhaven – UH

New Program – October 2011!

ARPA-E REACT Program – **Low-cost wire for HTS wind turbine generators**

SuperPower – UH – NREL – Tai Yang - TECO Westinghouse

Summary

- U.S. is scaling up manufacturing operations to ensure supply
- Working to meeting the price / performance challenge
- Continuing to advance the technology
- Collaborating to ensure success
- Finding new sources of funding to continue device demonstrations

Thank you for your interest!