SuperGrid Update

EPRI Superconductivity Working Group
3 April 2003
Milwaukee, WI

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1967 SC Cable !

PROCEEDINGS OF THE IEEE, VOL. 55, NO. 4, APRIL 1967

Superconducting Lines for the Transmission of Large Amounts of Electrical Power over Great Distances

R. L. GARWIN AND J. MATISOO

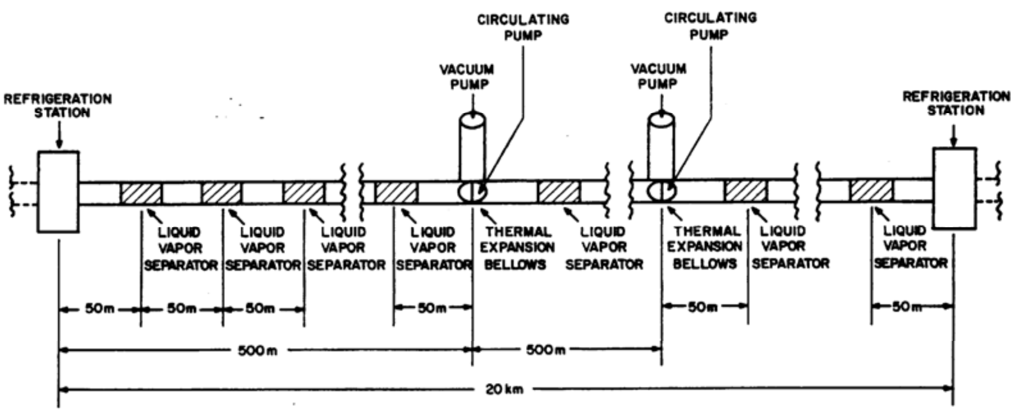


Fig. 2. A 20-km module of the 1000-km, 100-GW line.

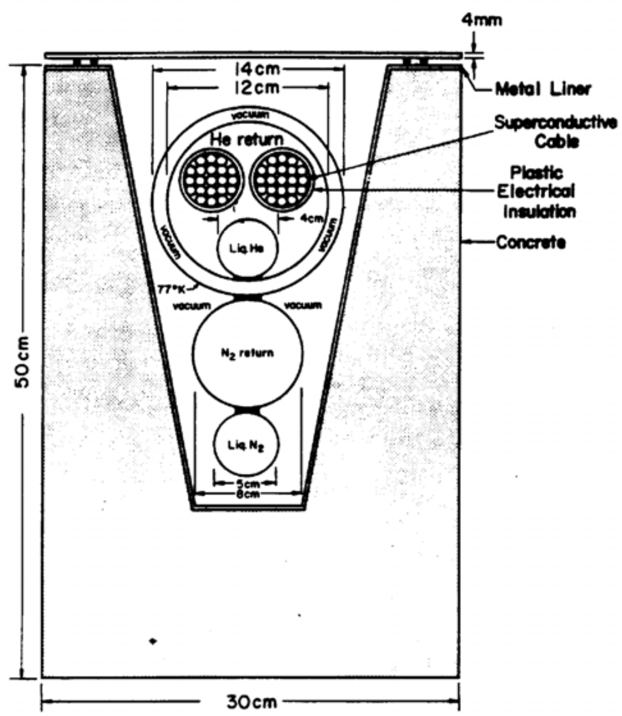
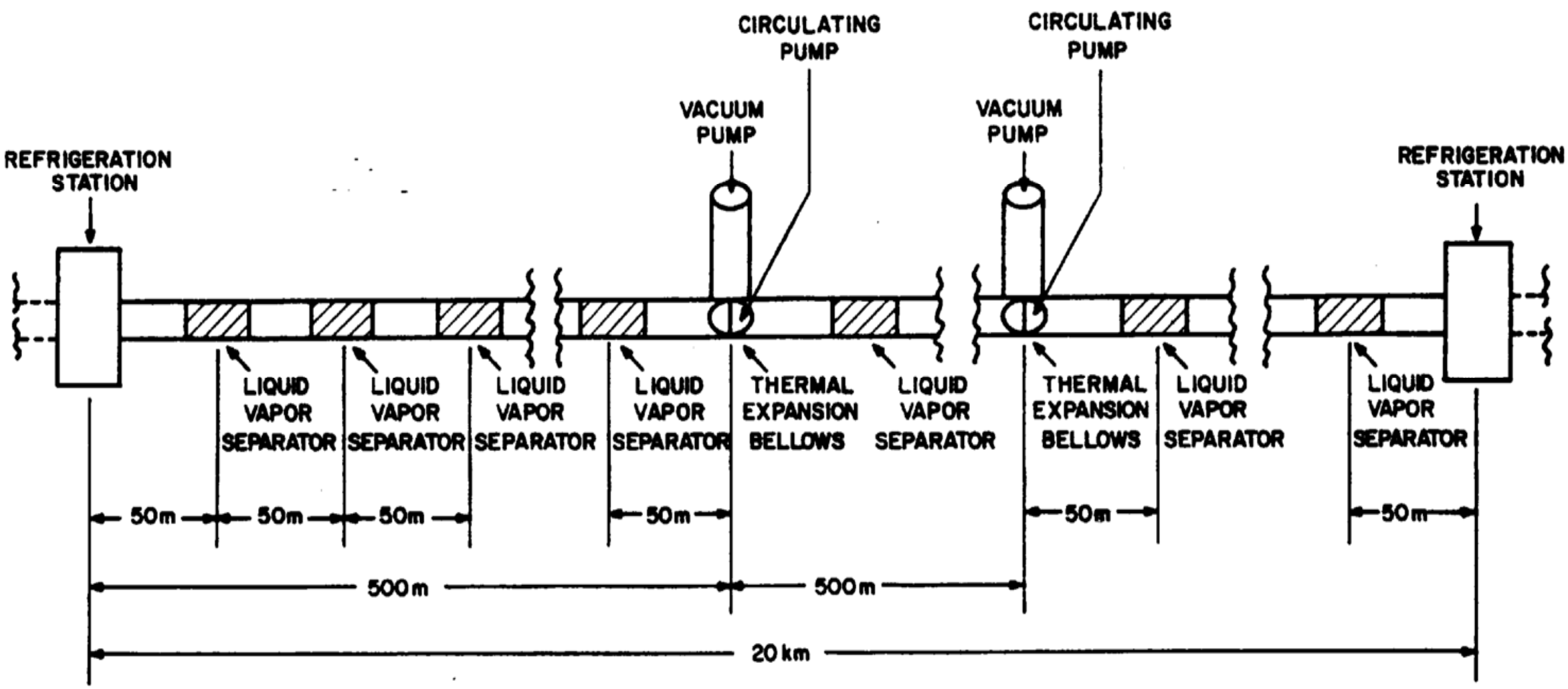


Fig. 1. Cross section of the 100-GW line.

100 GW dc, 1000 km !

Garwin-Matisoo



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Superconducting Lines for the Transmission of Large Amounts of Electric Power over Great Distances, R. L. Garwin and J. Matisoo, Proceedings of the IEEE **55**, 538 (1967)

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Garwin-Matisoo

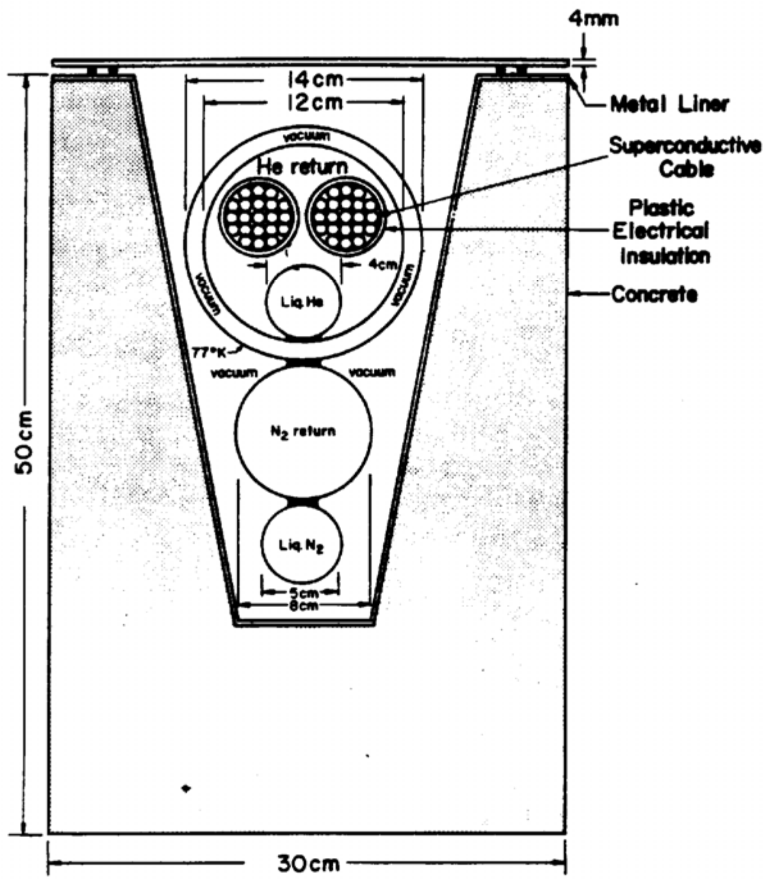
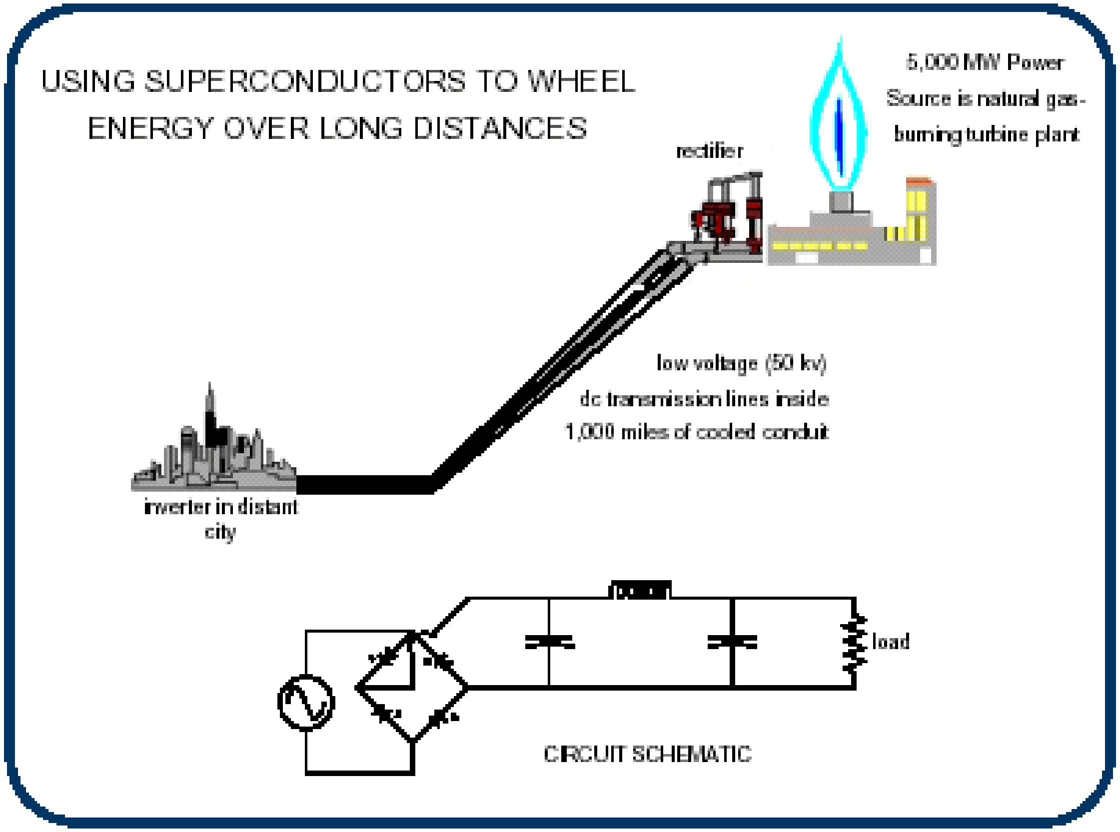


Fig. 1. Cross section of the 100-GW line.

- Nb_3Sn Wire
- T_C = 9 K
- LHe liquid-vapor cooled
- LN_2 heat shield

Electricity Pipe



Initial EPRI study on long distance (1000 km) HTSC dc cable cooled by liquid nitrogen
-- 1997 --

P.M. Grant, S. Schoenung, W. Hassenzahl, EPRI Report 8065-12, 1997

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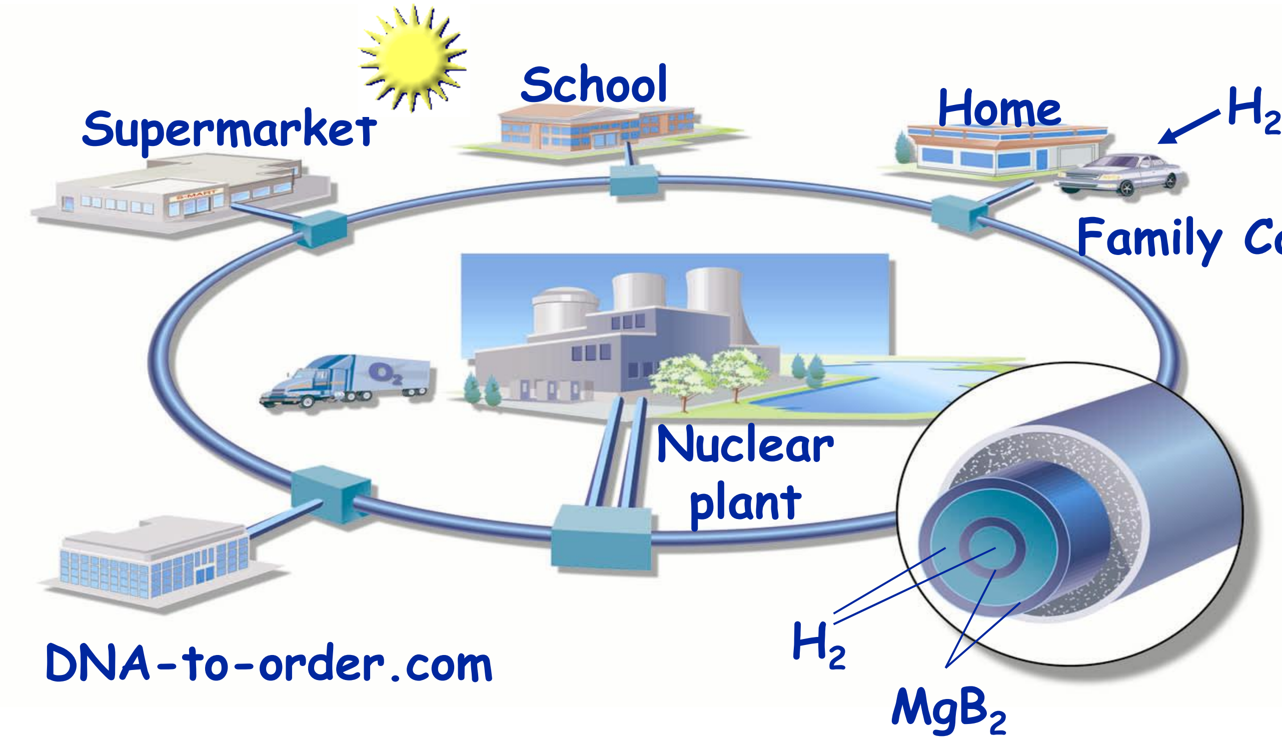
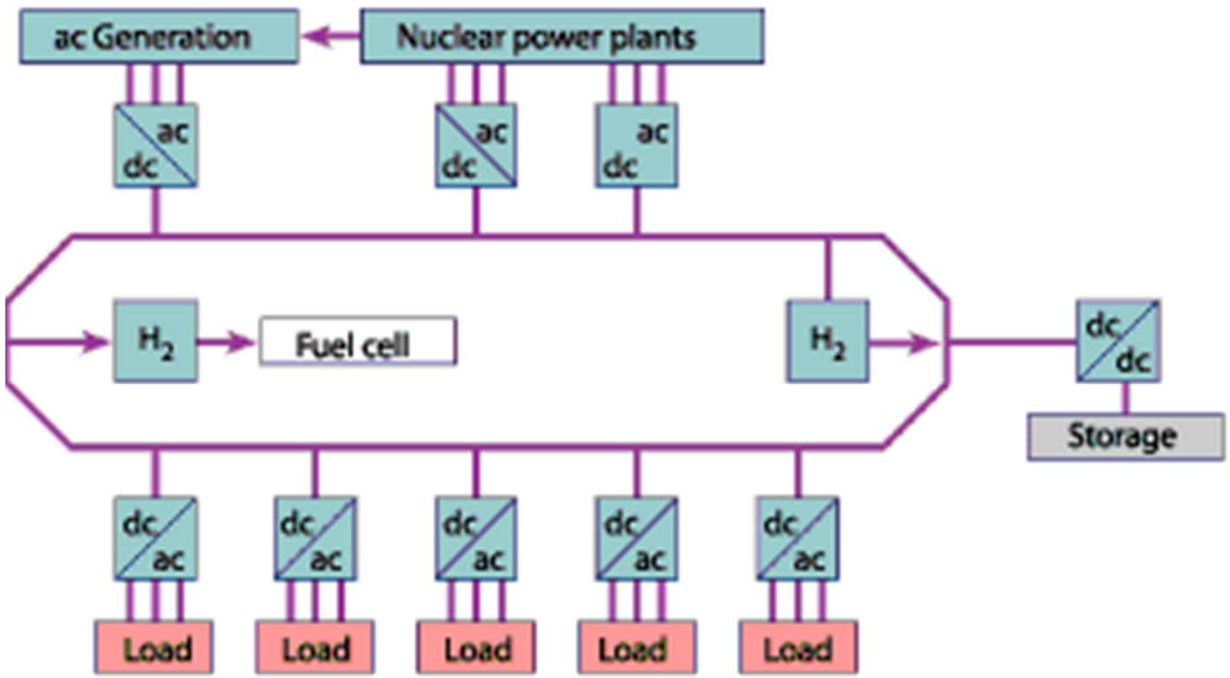
SuperCity



P.M. Grant, The Industrial Physicist, Feb/March Issue, 2002

http://www.aip.org/tip/INPHFA/vol-8/iss-1/p22.pdf

SuperGrid

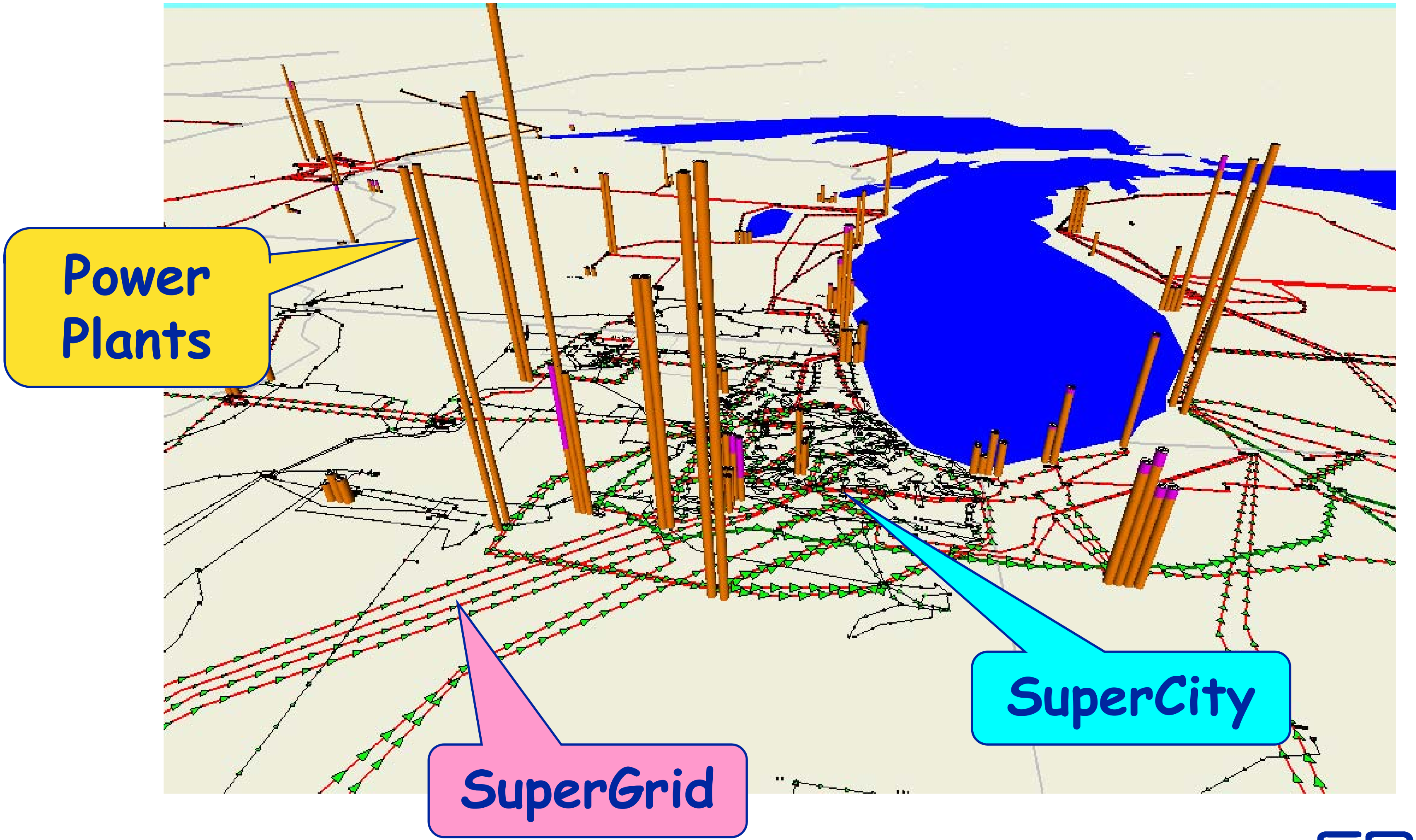


Continental SuperGrid

“Continential SuperGrid Workshop,” UIUC/Rockefeller U., Palo Alto, Nov. 2002

http://www.epri.com/journal/details.asp?doctype=features&id=511

Chicago!



2 April 2003: abcNEWS.com

abcNEWS.com


Electric power transmission lines span the downtown Los Angeles skyline. Some say a plan to create an underground power

Powering Up

Researchers: National Power Grid Could Meet Increasing Energy Demands

By Lee Dye
Special to ABCNEWS.com

April 2

— If the United States had been able to do decades ago what a few experts are proposing that we start doing now, nobody would care much about the oil in the Middle East or beneath the Arctic plains.

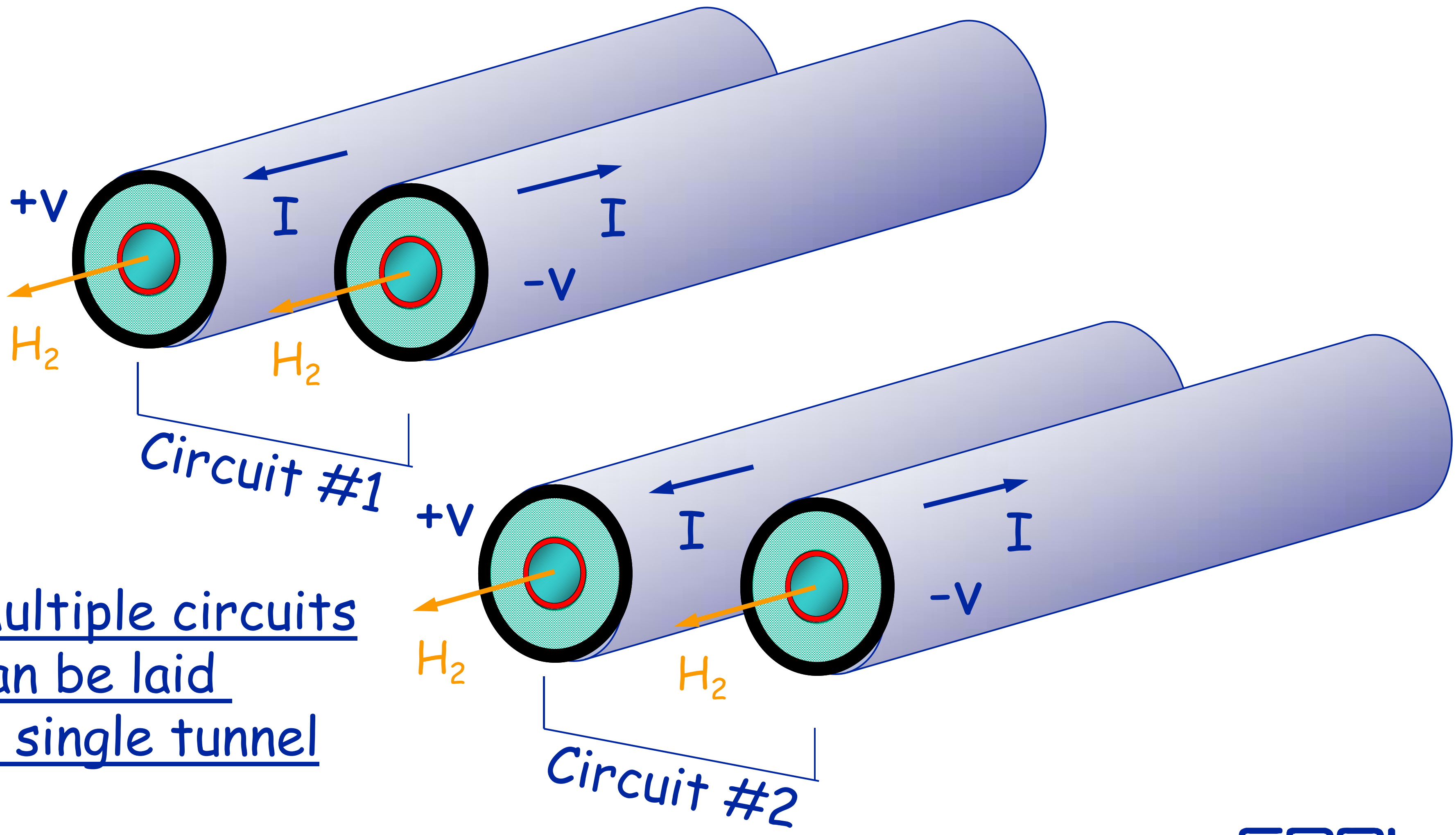
They are proposing something they call a SuperGrid."

…need it.

…omy would be based on hydrogen and electricity, delivered in …us quantities to our urban centers through a vast underground network of …and pipes. Of course, that wasn't possible even a few years ago, but …t breakthroughs in science and technology have convinced a number of key …ers that there is no reason why it couldn't be done in the years ahead.

They are proposing something they call a "SuperGrid," which would carry hydrogen and electricity from distant points to major population centers and shift this country away from its dependence on petroleum.

SuperCables



Multiple circuits can be laid in single tunnel

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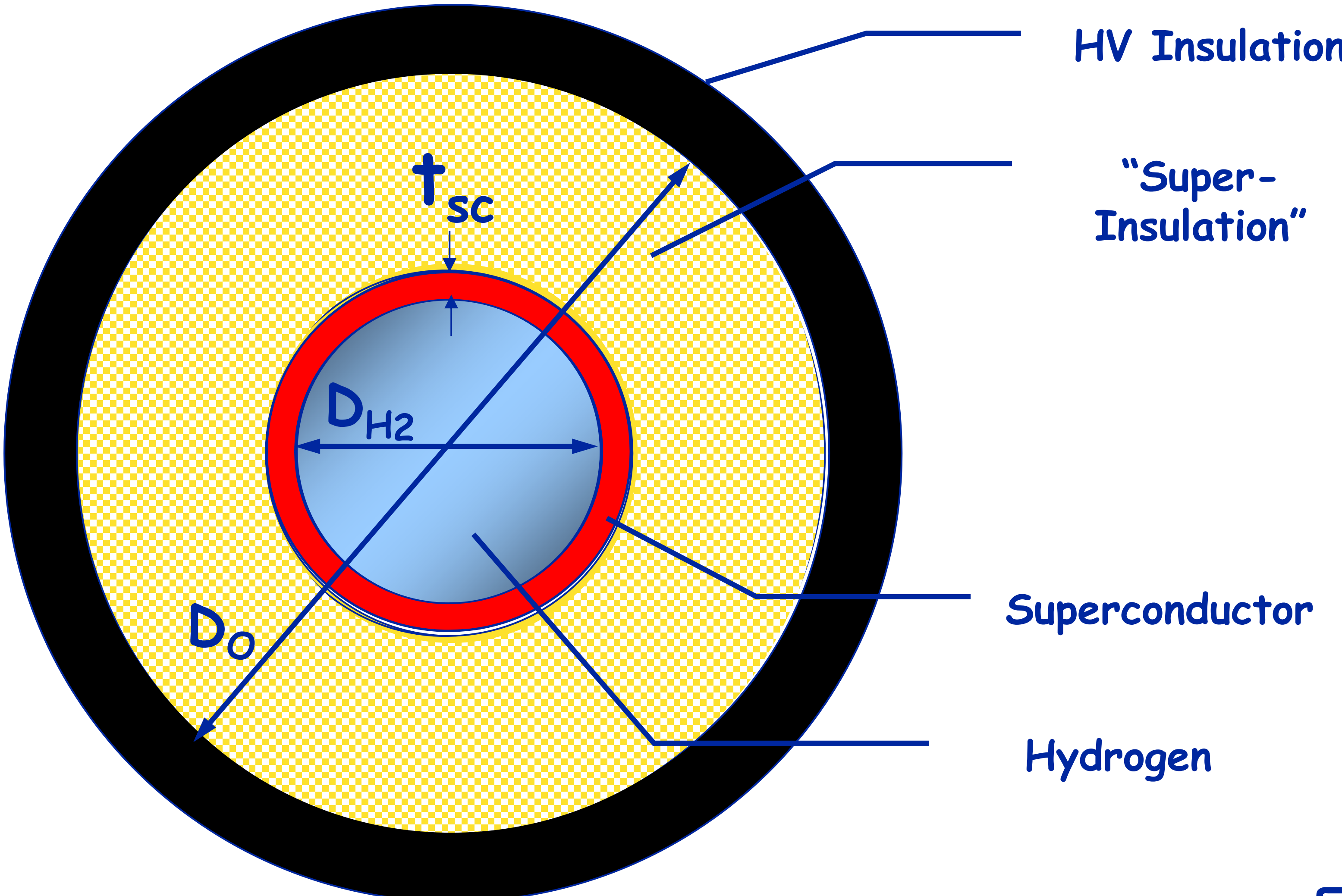
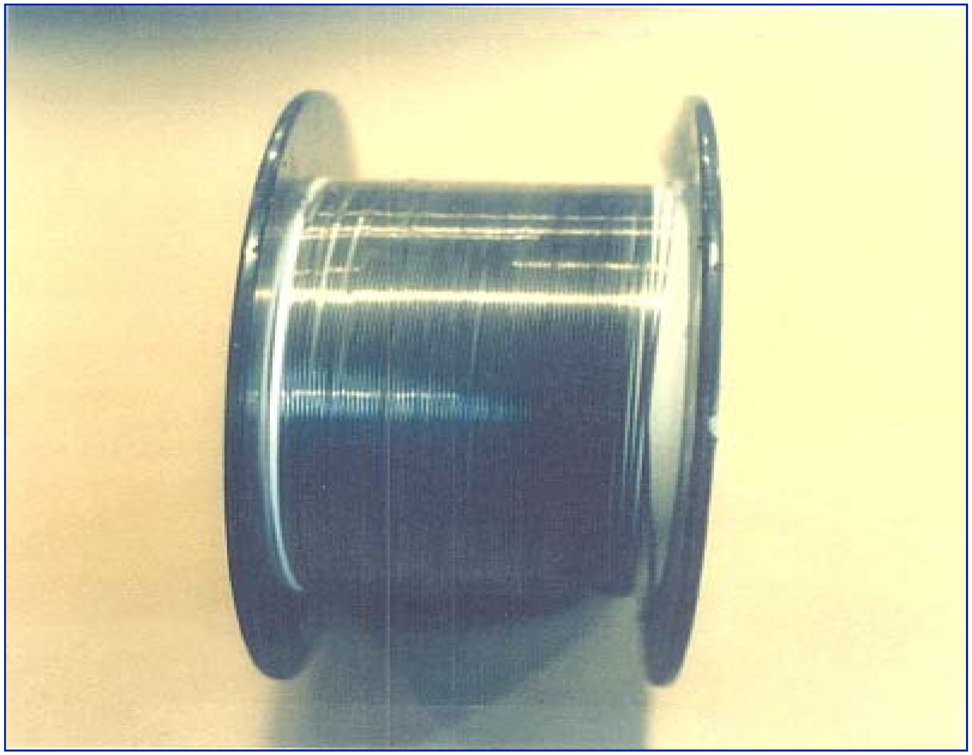
SuperCable



HV Insulation
"Super-
Insulation"
t_{sc}
D_{H2}
D_O
Superconductor
Hydrogen

HyperTech MgB_2 Wire

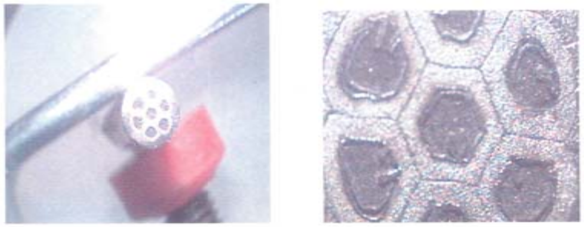
60 meters, 1.2 mm Mono



MgB_2 CTFF Iron in Monel

Multi-filament

MgB_2 , 7 filament multifilament, iron CTFF in Monel



J_e = 25,000 A/cm^2 @ 20 K

Power Flows

Hydrogen

$P_{H2} = 2(Q\rho vA)_{H2}$, where

P_{H2} = Chemical power flow
Q = Gibbs H_2 oxidation energy (2.46 eV per mol H_2)
ρ = H_2 Density
v = H_2 Flow Rate
A = Cross-sectional area of H_2 cryotube

Electric & H_2 Power

Hydrogen (LH_2, 20 K)

Power (MW)	Inner Pipe Diameter, D_{H2} (cm)	H_2 Flow Rate (m/sec)	"Equivalent" Current Density (A/cm^2)
500	10	3.81	318

Electricity

Power (MW)	Voltage (V)	Current (A)	Critical Current Density (A/cm^2)	Annular Wall Thickness (cm)
1000	+/- 5000	100,000	25,000	0.125

Thermal Losses

$W_R = 0.5\varepsilon\sigma\,(T^4_{amb} - T^4_{SC})$, where

W_R = Power radiated in as watts/unit area
$\sigma = 5.67\times10^{-12}$ W/cm^{2}K^4
T_{amb} = 300 K
T_{SC} = 20 K
ε = 0.05 per inner and outer tube surface
D_{SC} = 10 cm

W_R = 3.6 W/m

Radiation Losses

Heat Removal

$dT/dx = W_T/(\rho v C_P A)_{H2}$, where

dT/dx = Temp rise along cable, K/m
W_T = Thermal in-leak per unit Length
ρ = H_2 Density
v = H_2 Flow Rate
C_P = H_2 Heat Capacity
A = Cross-sectional area of H_2 cryotube

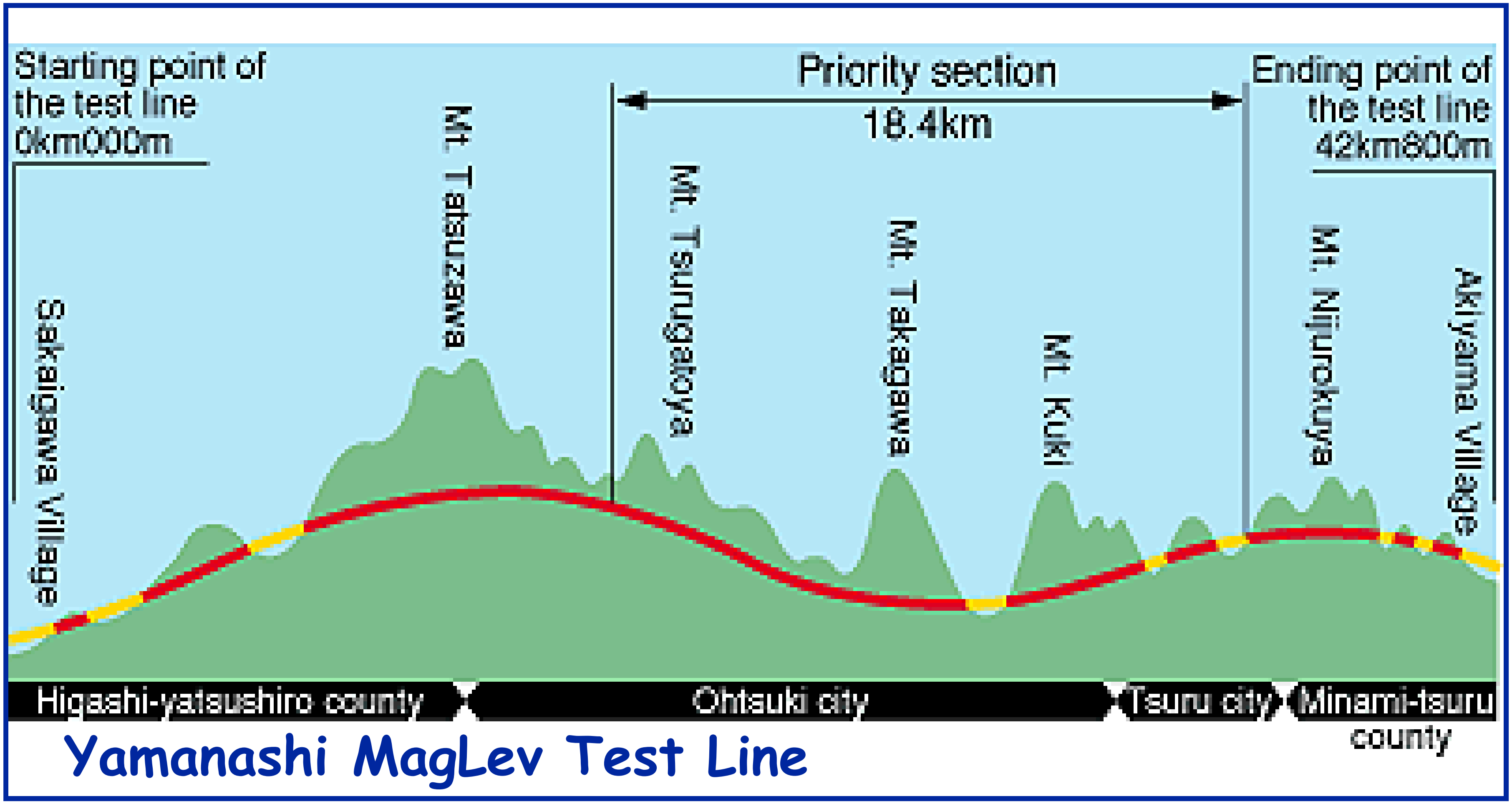
Take W_T = 1.0 W/m, then $dT/dx = 1.89 \times 10^{-5}$ K/m,
Or, 0.2 K over a 10 km distance

Remaining Issues

- Current stabilization via voltage control
- Magnetic forces
- Hydrogen gas cooling and transport
- Pumping losses
- Hydrogen storage
- Costs !!

Hindenburg Hysteria

Tunnels



Starting point of the test line 0km000m
Priority section
18.4km
Ending point of the test line 42km800m
Mt. Tatsuzawa
Mt. Tsurugatoya
Mt. Takagawa
Mt. Kuki
Mt. Nijurokuya
Sakaigawa Village
Akiyama Village
Higashi-yatsushiro county
Ohtsuki city
Tsuru city
Minami-tsuru county
Yamanashi MagLev Test Line

Tunnels for the SuperGrid

What's Needed:

- Joint efforts with research groups, engineering firms, contractors, and machine manufactures to develop and demonstrate appropriate excavation and tunneling systems
- Link directional drilling, micro-tunneling and larger tunnel boring machine technologies
- Support demonstration projects using advanced technologies for driving tunnels (e.g., VLHC @ Fermilab)

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Rock Group

Transformer Form Factors

Waukasha Transformer Sizes

	Weight	Width	Length
300 MVA			
lbs, in	500,000	80	200
tons, ft	250	6.67	16.67
30 MVA Conventional			
lbs, in	96,000	108	108
tons, ft	48	9.00	9.00
30 MVA Superconducting			
lbs, in	32,000	36	72
tons, ft	16	3	6

"Heavy Movers"

<u>CalTrans/CHP</u>

"18" Wheelers:	20,000	lbs/axle
=	80,000	lbs gross
=	40	tons

“Heavy Lifters”

Helicopters

Boeing Chinook CH-47F

Max Gross Weight:	50,000	lbs =	25	tons
Empty:	23,401	lbs =	11.70	tons
"Freight"	26,599	lbs =	13.30	tons

Planes

Lockheed C-5A Galaxy

4000 Mile Range:	250,000	lbs =	125	tons
8000 Mile Range:	125,000	lbs =	63	tons

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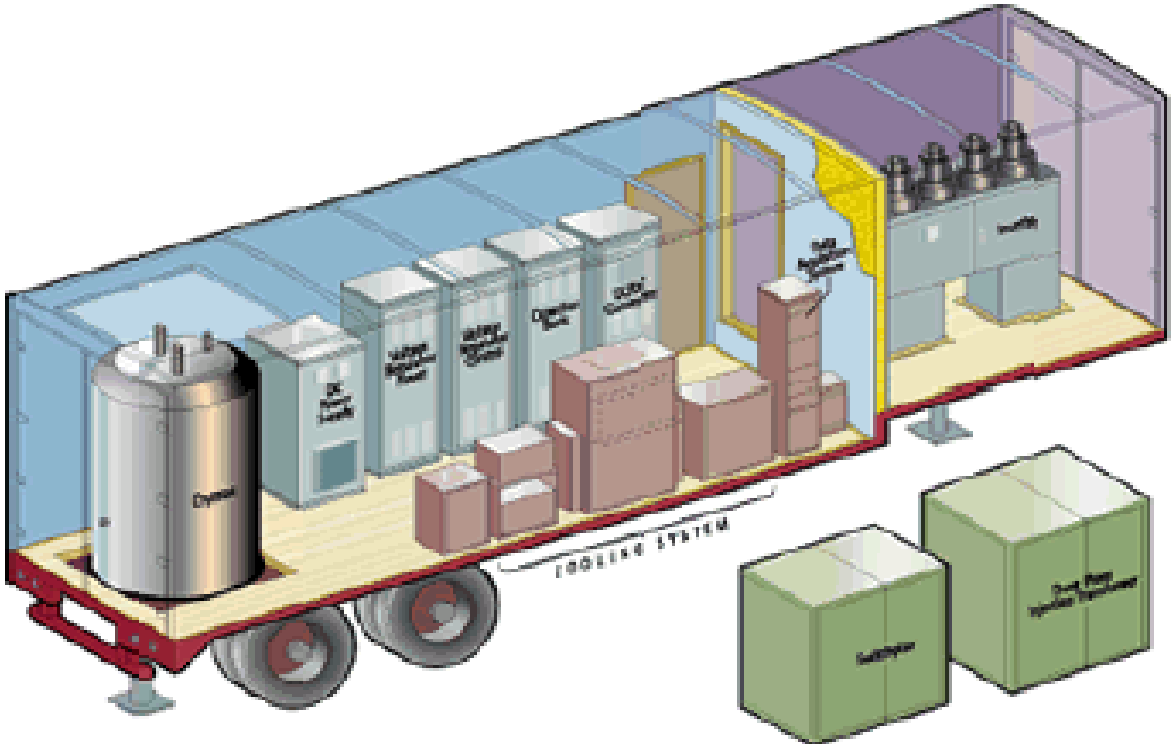
A Moveable Substation



Supergrid Opportunities

- Long-term project
- Large capital costs for installation
- Special requirements for installing the grid: tunnel size, lengths of runs, ranges of ground conditions to be encountered.
- Trend with time: less space and more difficult access for installing utlities. Less public tolerance for disturbance
- Increasing use of tunneling and trenchless technologies rather than trenching and open excavation.
- Focus for improving tunneling technology for supergrid:
  - *Contracting practices: mitigation and assignment of risk*
  - *Joint efforts with research groups, engineering firms, contractors, and machine manufactures to develop and demonstrate excavation and tunneling systems that will fit the requirements of the project*
  - *Link directional drilling, micro-tunneling and larger tunnel boring machine technologies.*
  - *Support demonstration projects using advanced technologies for driving tunnels.*

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