Our Energy Challenge

27th Illinois Junior Science & Humanities Symposium
April 3, 2005

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Rice University

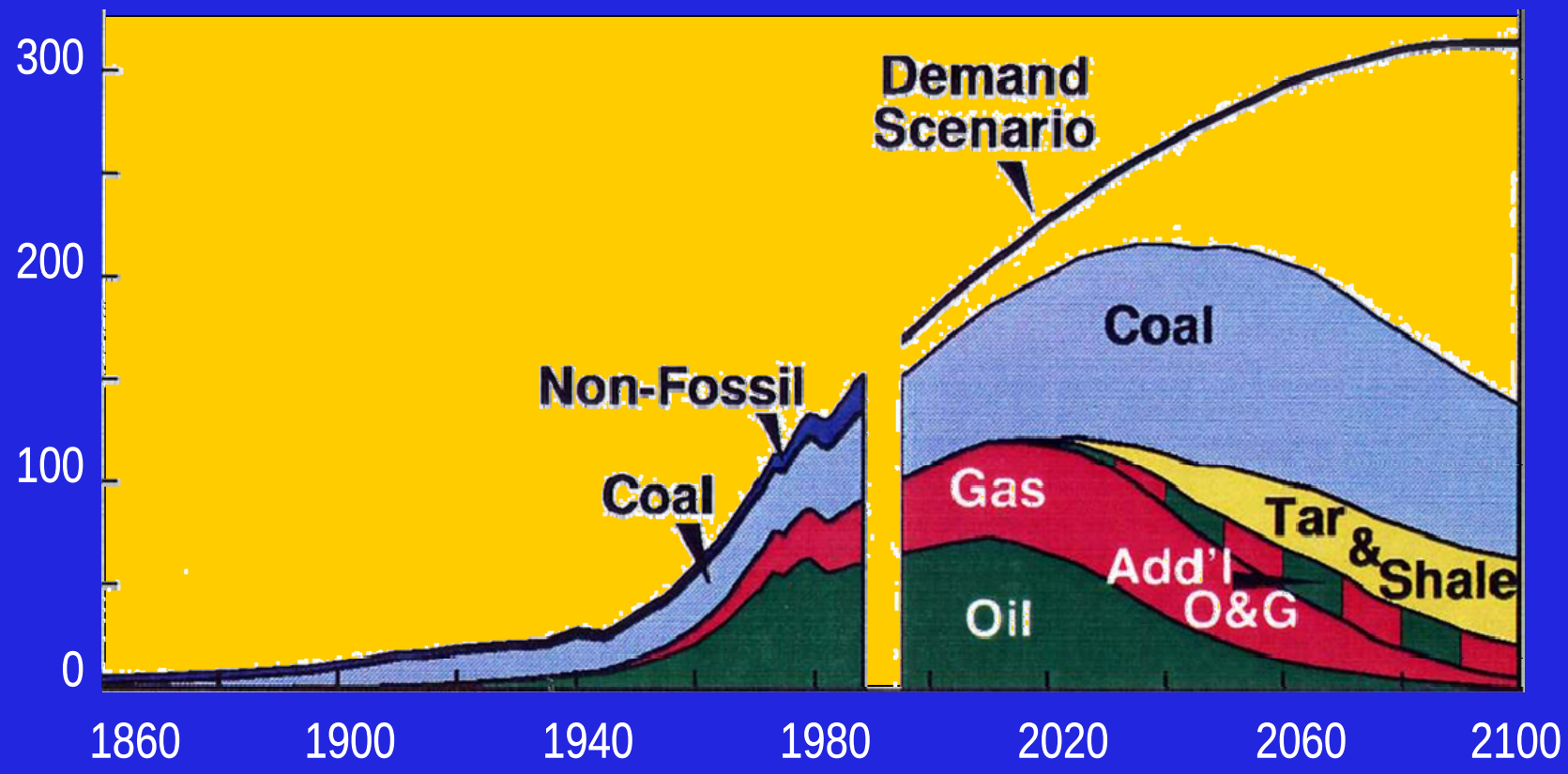
Humanity's Top Ten Problems for next 50 years

1. **ENERGY**
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

2004	**6.5**	**Billion People**
2050	**~ 10**	**Billion People**

World Energy

Millions of Barrels per Day (Oil Equivalent)



Source: John F. Bookout (President of Shell USA) ,"Two Centuries of Fossil Fuel Energy" International Geological Congress, Washington DC; July 10,1985. Episodes, vol 12, 257-262 (1989).

STUDY

Matthew Simmon's Presentations on Saudi Arabian Oil
(www.simmons-intl.com)
and his new book "Twilight in the Desert"
John Wiley & Sons publishers,
May 2005

Does Greatest Vulnerability Reside In Middle East?

- For decades, all supply/demand models have assumed Middle East oil is "inexhaustible" and cheap.
- Saudi Arabia (with 90 years proven reserves and little exploration) is the inexhaustible Energy King.
- Middle East oil has been the world's most reliable supply (other than geopolitical jitters).

- Everyone has assumed this cornucopia of oil lasts "forever"!
- There is no data to support this belief!

SIMMONS & COMPANY INTERNATIONAL

When Saudi Arabia Peaks
So does the World.

GHAWAR, by far the world's
Largest and most prolific oil field
may have already peaked.

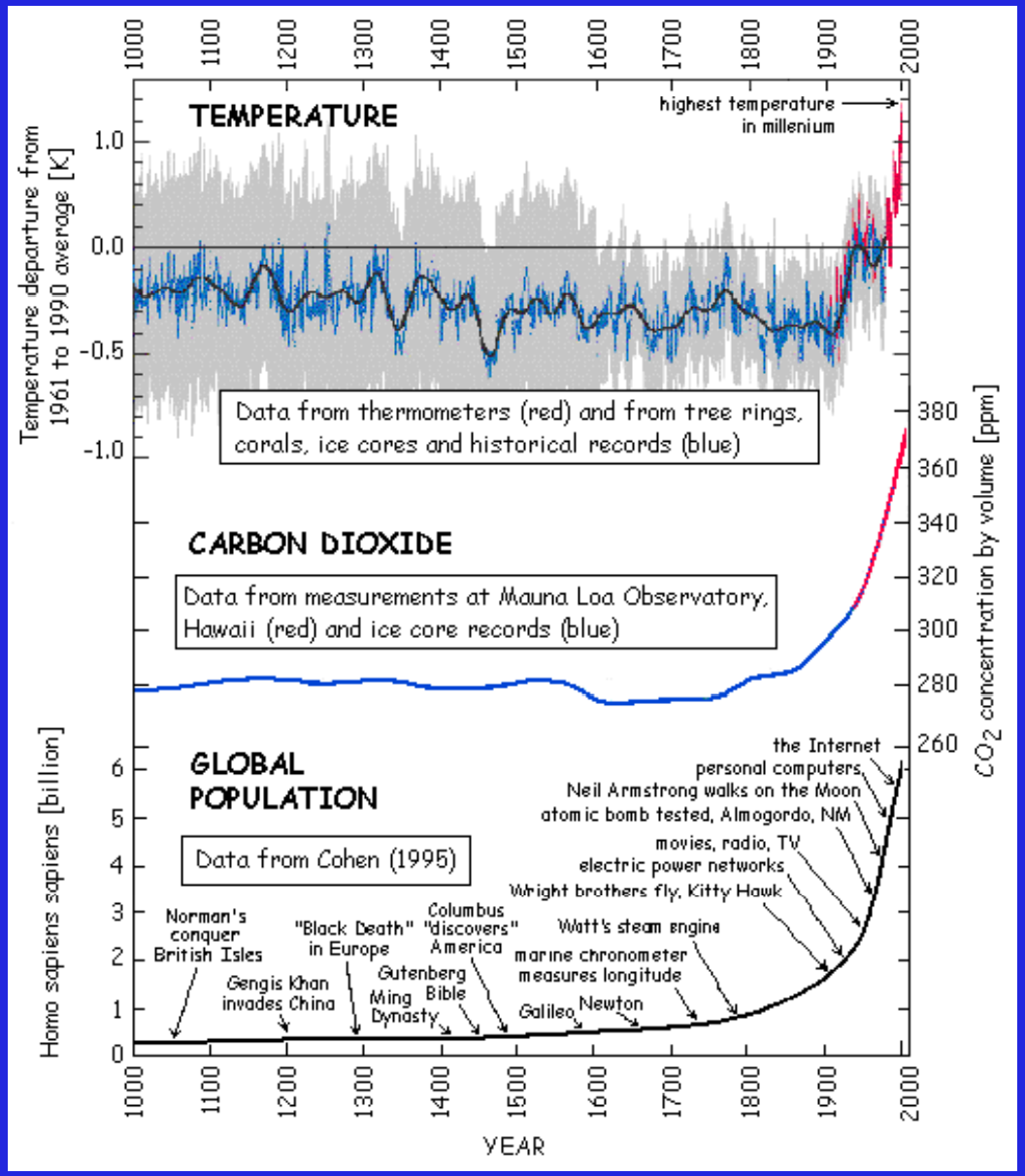
The days of cheap oil are over.

Also Google "peak oil" and look at sites such as "peakoil.com"

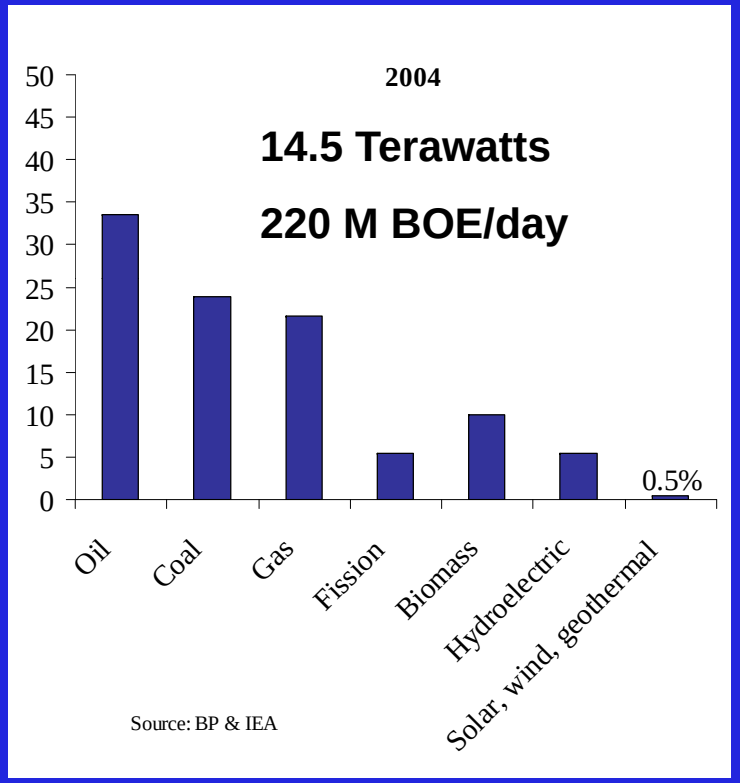
Global warming over the past millennium

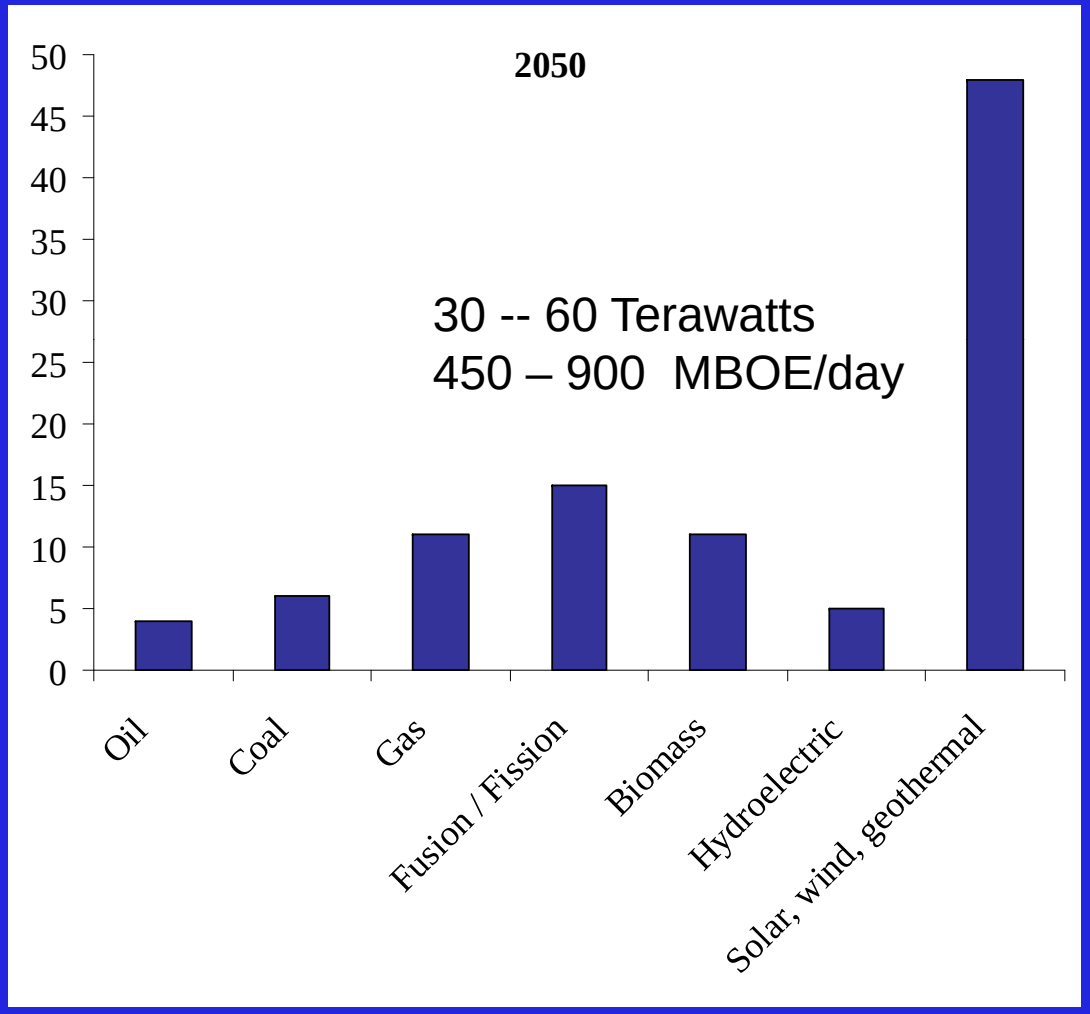
Very rapidly we have entered uncharted territory -– what some call the *anthropocene* climate regime. Over the 20th century, human population quadrupled and energy consumption increased sixteenfold. Near the end of the last century, we crossed a critical threshold, and global warming from the fossil fuel greenhouse became a major, and increasingly dominant, factor in climate change. Global mean surface temperature is higher today than it's been for at least a millennium.

Slide from Marty Hoffert NYU



The ENERGY REVOLUTION (The Terawatt Challenge)





The Basis of Prosperity

20st Century = OIL

21st Century = ??

PRIMARY ENERGY SOURCES
Alternatives to Oil

TOO LITTLE

- **Conservation / Efficiency -- not enough**
- **Hydroelectric -- not enough**
- **Biomass -- not enough**
- **Wind -- not enough**
- **Wave & Tide -- not enough**

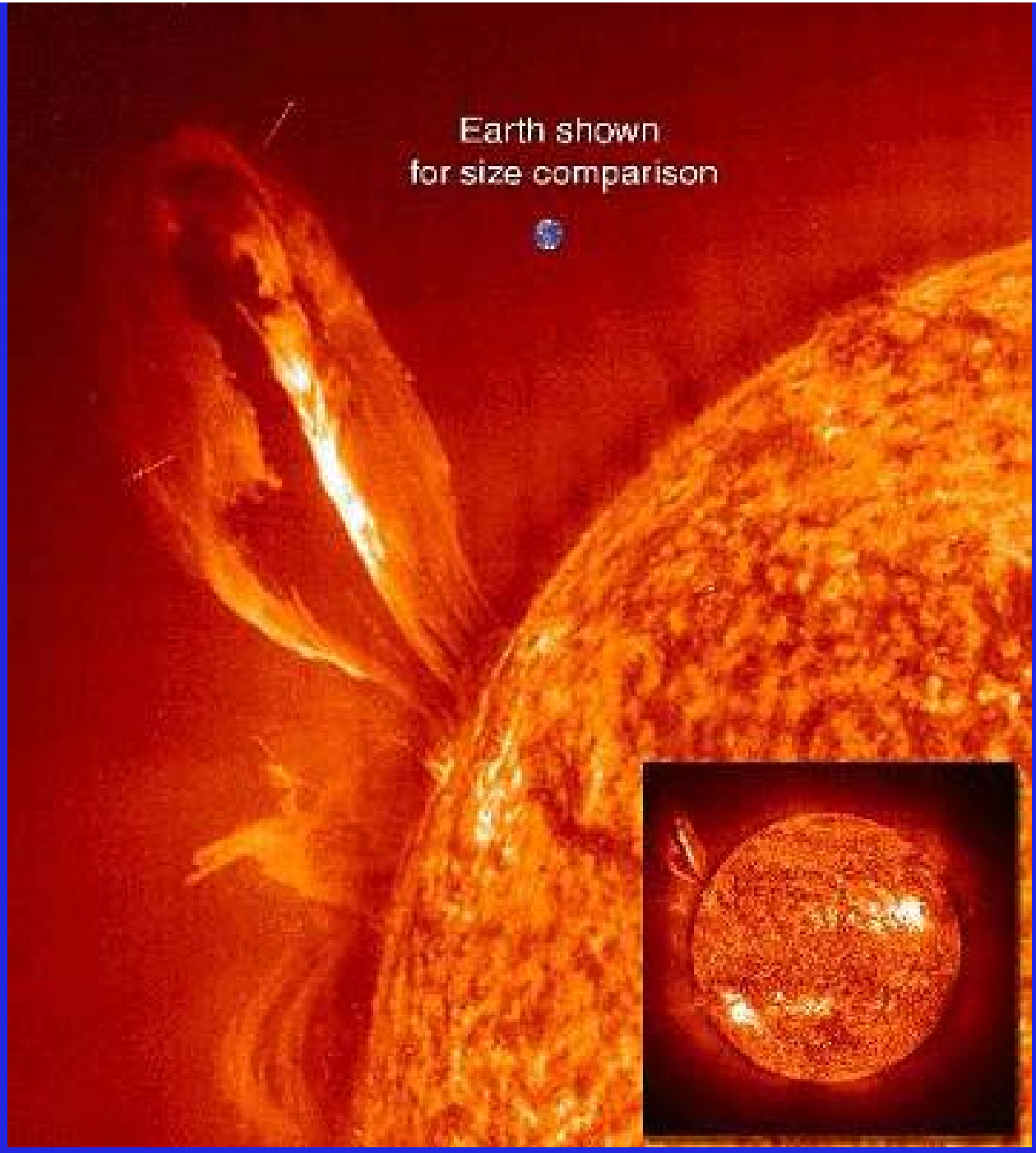
CHEMICAL

- **Natural Gas -- sequestration?, cost?**
- **Clean Coal -- sequestration?, cost?**

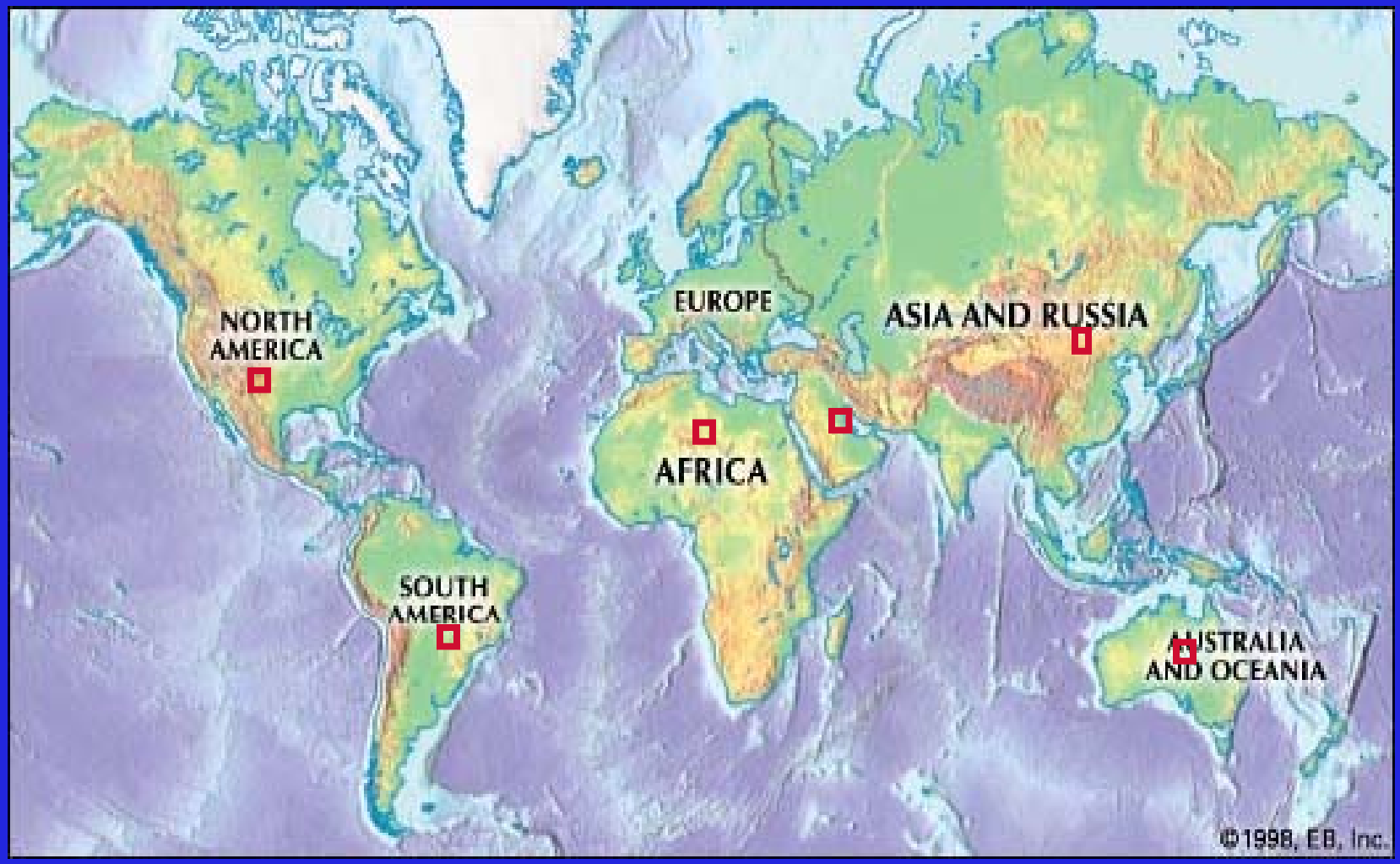
NUCLEAR

- **Nuclear Fission -- radioactive waste?, terrorism?, cost?**
- **Nuclear Fusion -- too difficult?, cost?**
- **Geothermal HDR -- cost ? , enough?**
- **Solar terrestrial -- cost ?**
- **Solar power satellites -- cost ?**
- **Lunar Solar Power -- cost ?**

165,000 TW of sunlight hit the earth



Solar Cell Land Area Requirements



6 Boxes at 3.3 TW Each = 20 TWe

Slide from Nate Lewis @ Cal. Tech

World Energy Scheme for 30-60TW in 2050: The Distributed Store-Gen Grid

- Energy transported as electrical energy over wire, rather than by transport of mass (coal, oil, gas)
- Vast electrical power grid on continental scale interconnecting ~ 100 million asynchronous “local” storage and generation sites, entire system continually innovated by free enterprise
- “Local” = house, block, community, business, town, …
- Local storage = batteries, flywheels, hydrogen, etc.
- Local generation = reverse of local storage + local solar and geo
- Local “buy low, sell high” to electrical power grid
- Local optimization of days of storage capacity, quality of local power
- Electrical grid does not need to be very reliable
- Mass Primary Power input to grid via HV DC transmission lines from existing plants plus remote (up to 2000 mile) sources on TW scale, including vast solar farms in deserts, wind, NIMBY nuclear, clean coal, stranded gas, wave, hydro, space-based solar…”EVERYBODY PLAYS”
- Hydrogen and methanol are the transportation fuels

Enabling Nanotech Revolutions

1. Photovoltaics -- drop cost by 10 fold.
2. Photocatalytic reduction of CO_2 to methanol.
3. Direct photoconversion of light + water to produce H_2.

4. Batteries, supercapacitors, flywheels -- improve by 10-100x for the distributed Store/Gen Grid, and automotive applications
   (especially plug-in hybrid vehicles).

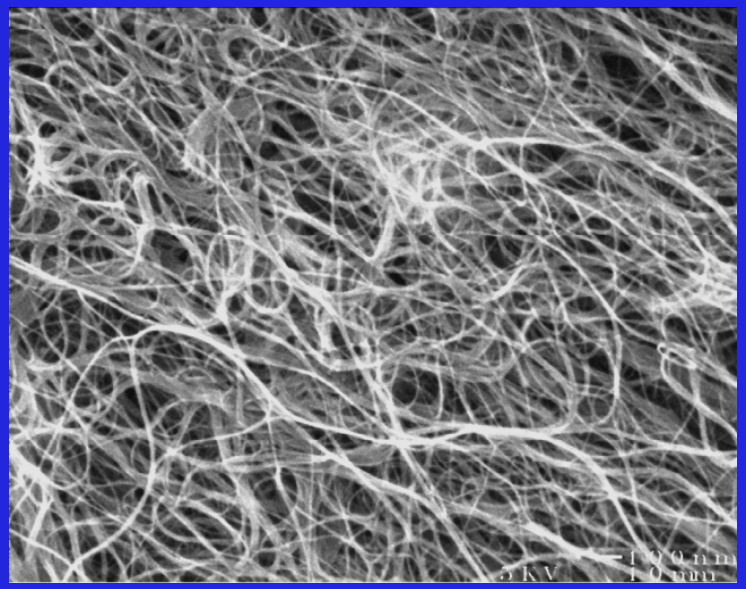
1. Power cables (superconductors, or quantum conductors) with which to rewire the electrical transmission grid, and enable continental, and even worldwide electrical energy transport; and also to replace aluminum and copper wires -- particularly in the windings of electric motors and generators.

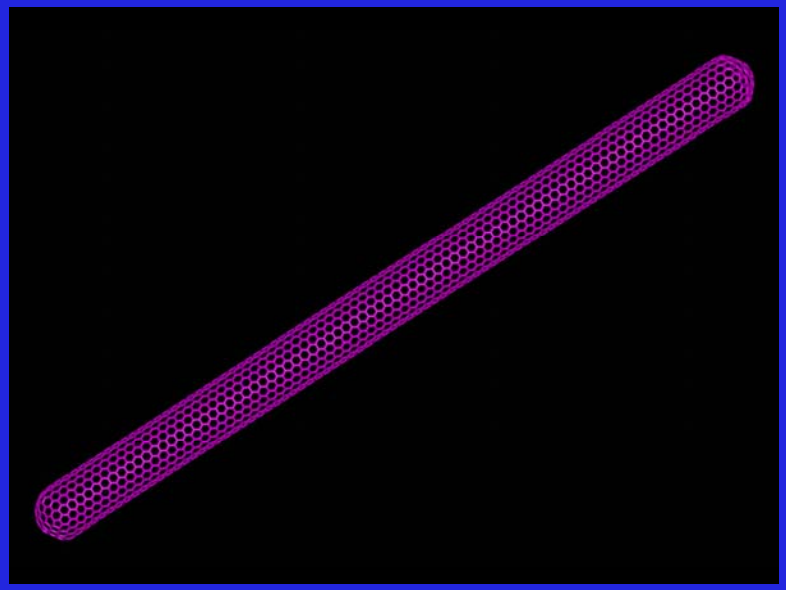
2. H_2 storage -- light weight materials for pressure tanks and LH_2 vessels, and/or a new light weight, easily reversible hydrogen chemisorption system (material X).

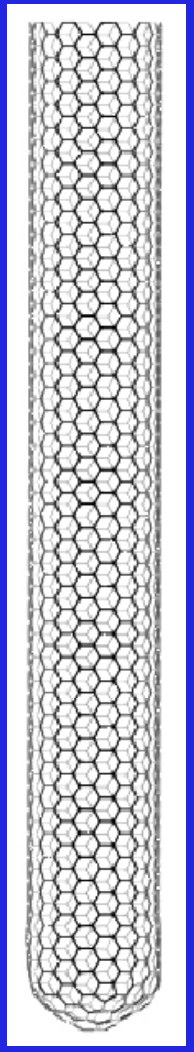
3. Fuel cells -- drop the cost by 10-100x + low temp start + reversible

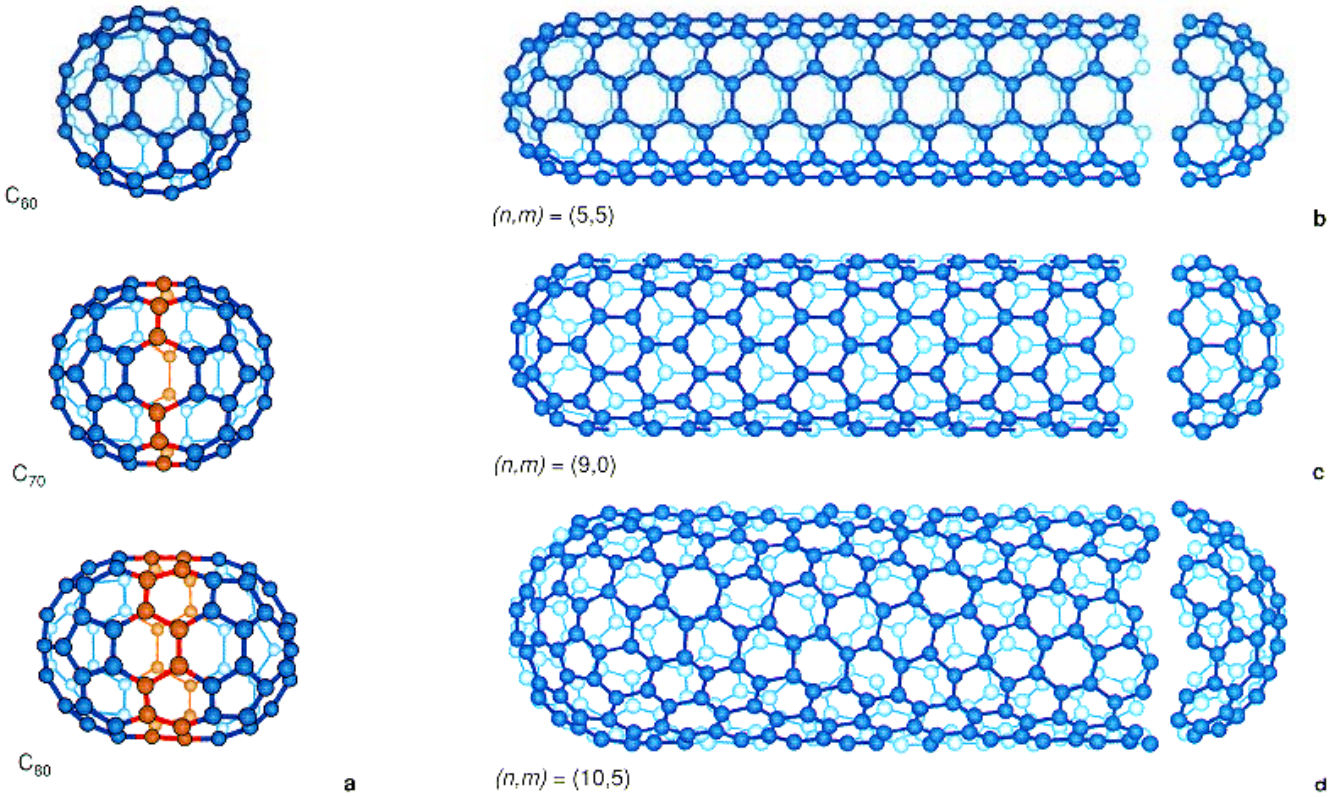
Buckytubes to the Rescue !
The New Miracle Polymer

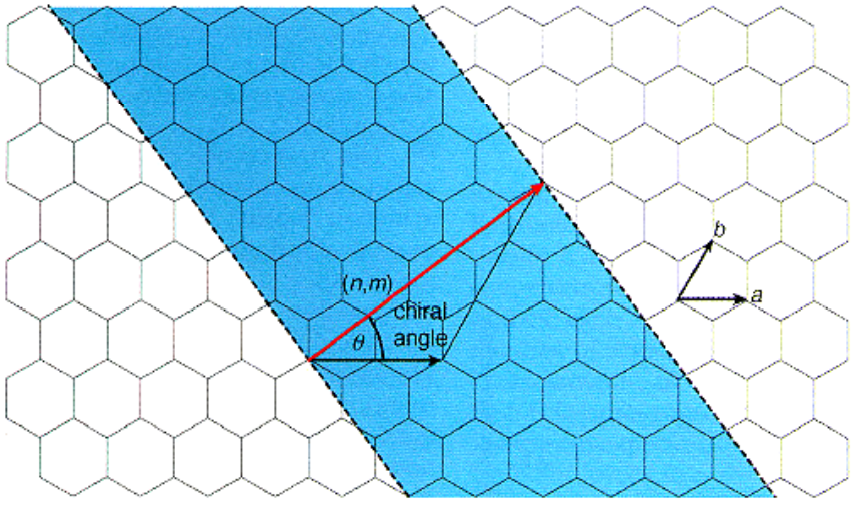
- The Strongest fiber that will ever be made.
- Electrical Conductivity of Copper or Silicon.
- Thermal Conductivity of Diamond.
- The Chemistry of Carbon.
- The size and perfection of DNA.

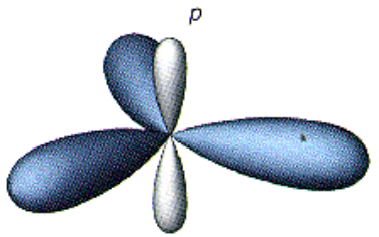







C_{60}
C_{70}
C_{80}
a
(n,m) = (5,5)
b
(n,m) = (9,0)
c
(n,m) = (10,5)
d


(n,m)
chiral
angle
θ
b
a
e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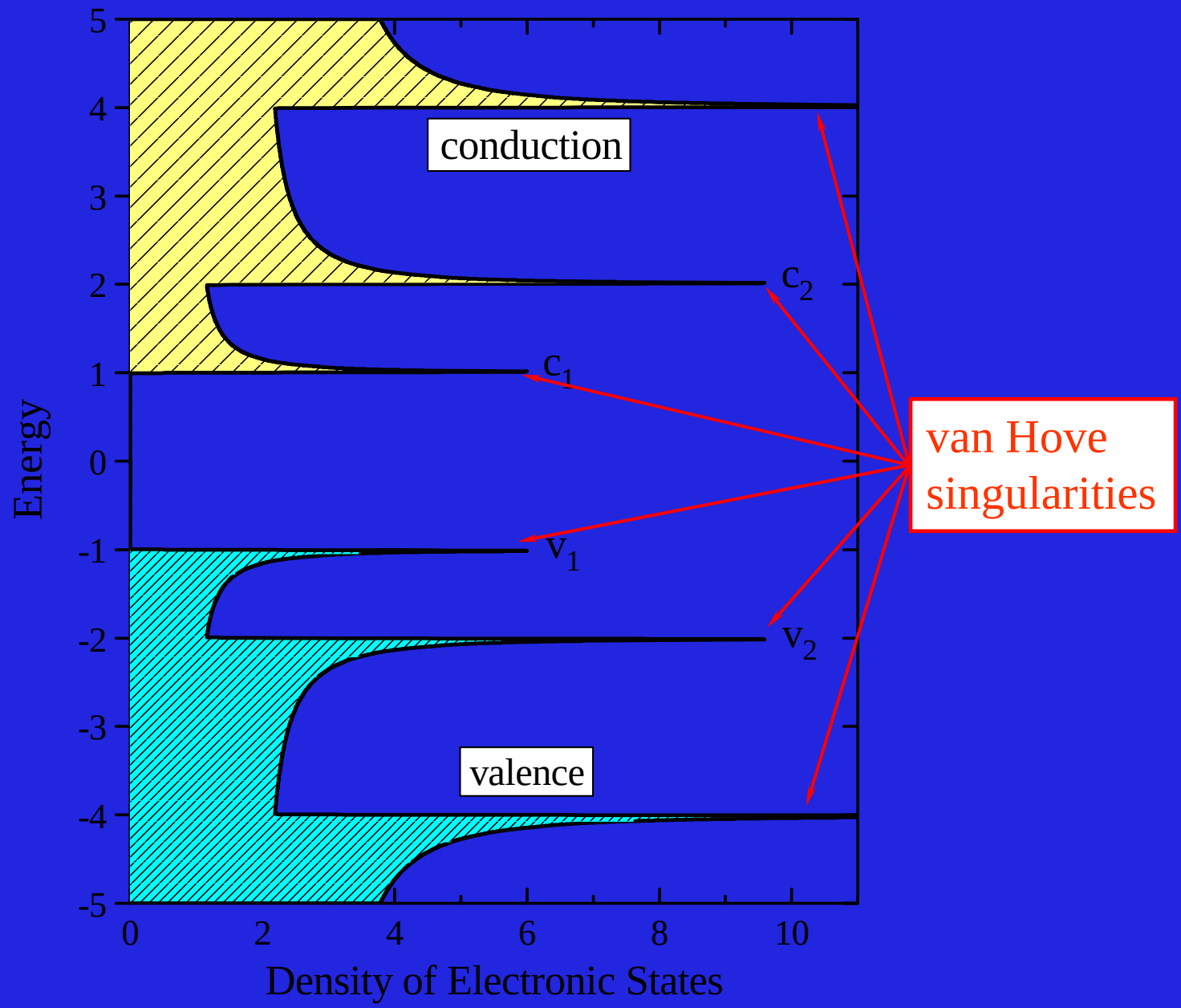
Electronic States of Semiconducting SWNT



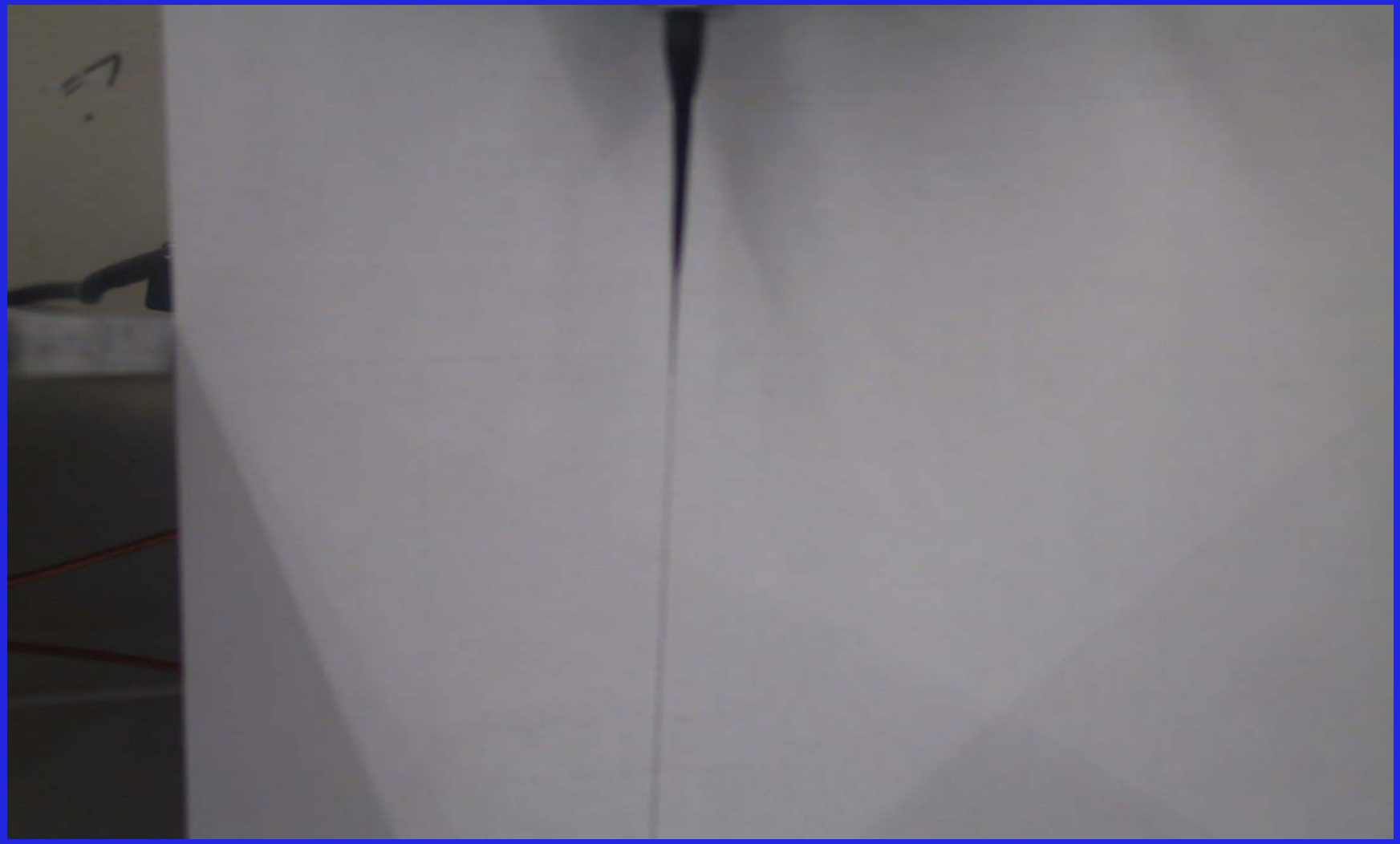
QUANTUM WIRE PROJECT

ELECTRICAL CONDUCTIVITY
OF COPPER AT 1/6 THE WEIGHT
WITH NEGLIGIBLE EDDY CURRENT LOSS

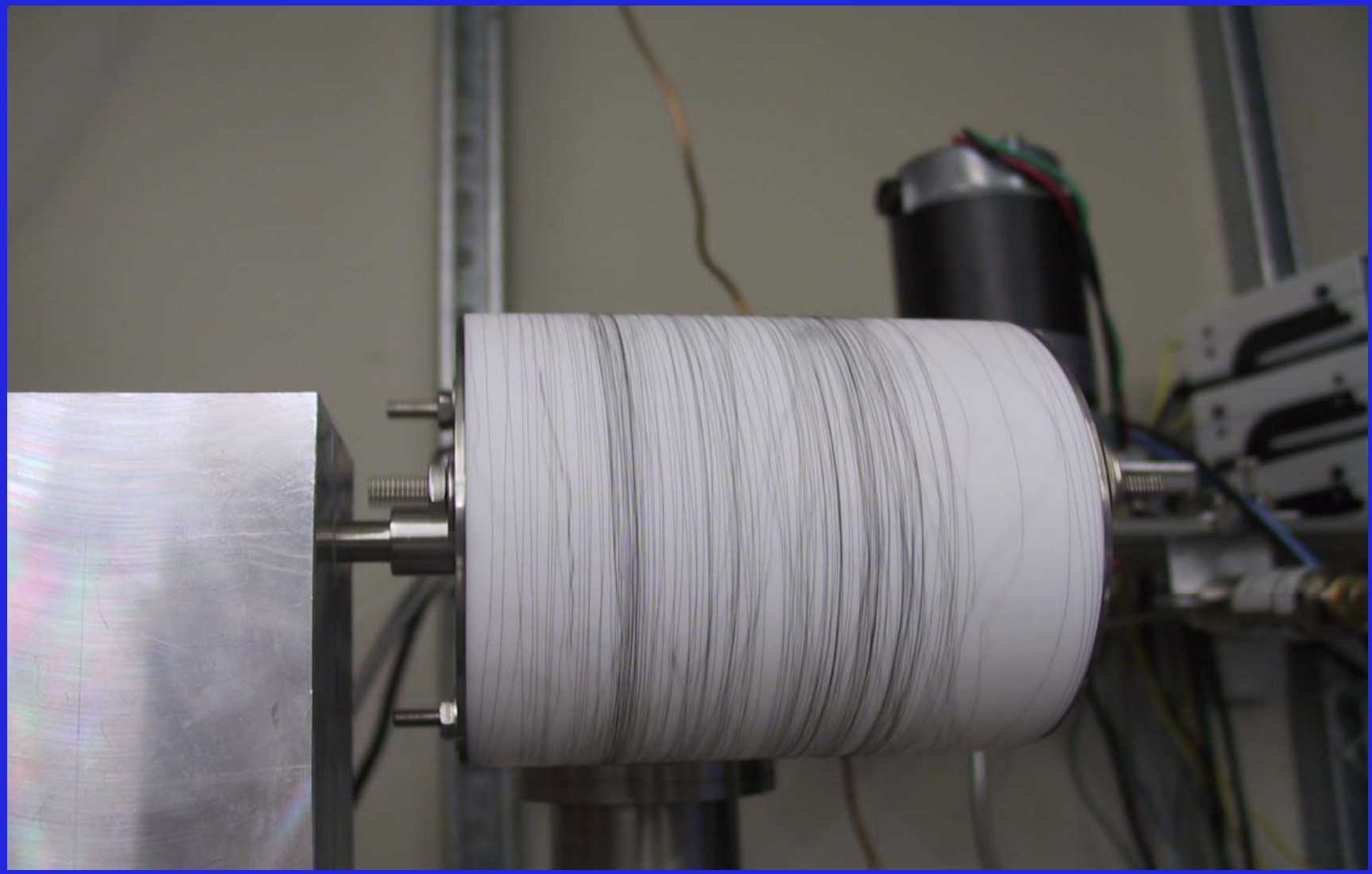
- cut SWNT to short lengths (< 50 nm)
- select out the (n,m) tubes with n=m (the “armchair tubes”)
- Attach catalyst to open ends
- grow from these seeds to >10 micron lengths (“cloning”)
- spin them into continuous fibers

- SWNT cloning technology also enables optimization of all other swnt applications including molectronics, RFI shielding, sensors, batteries, and microwave absorption

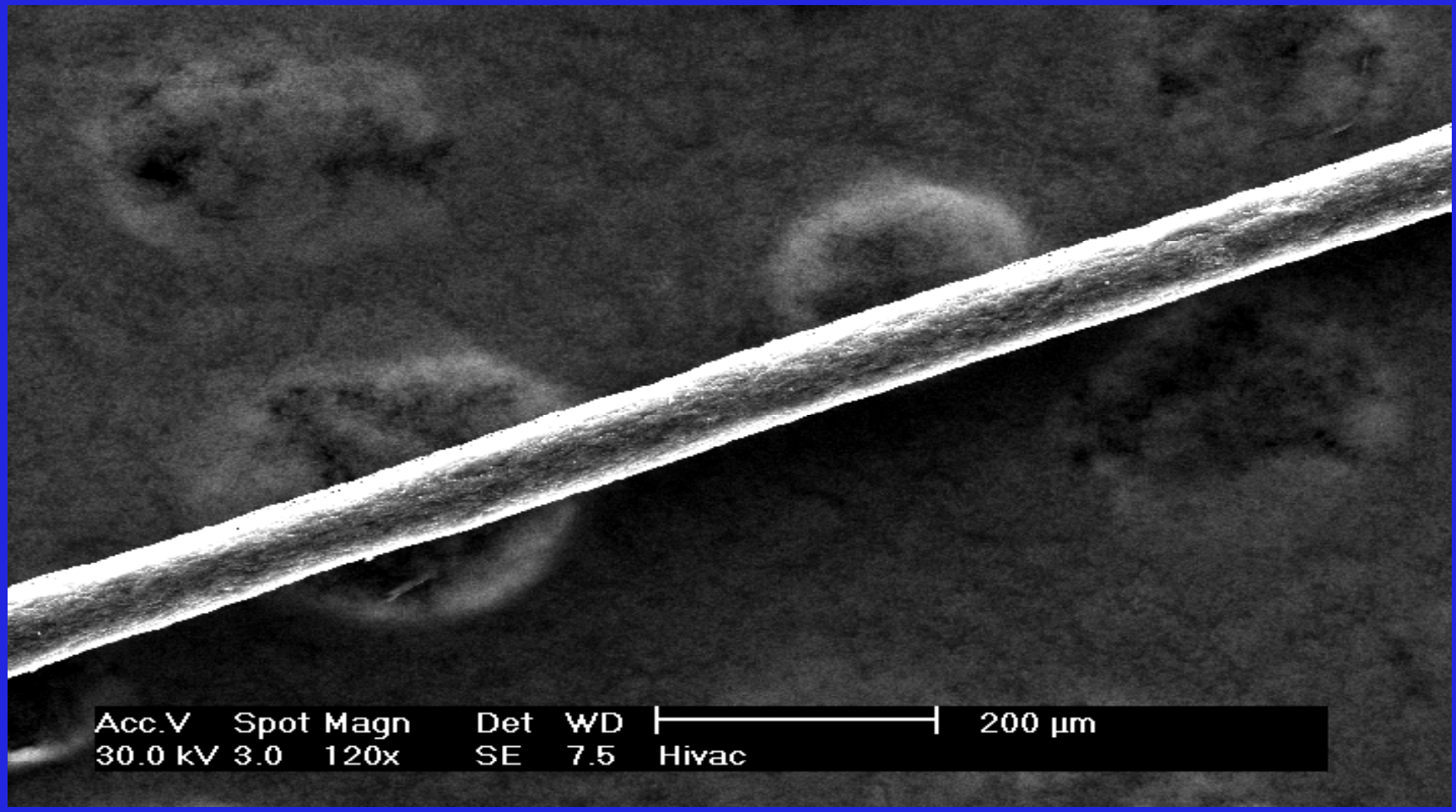
Fiber Spinning in Progress Close-up



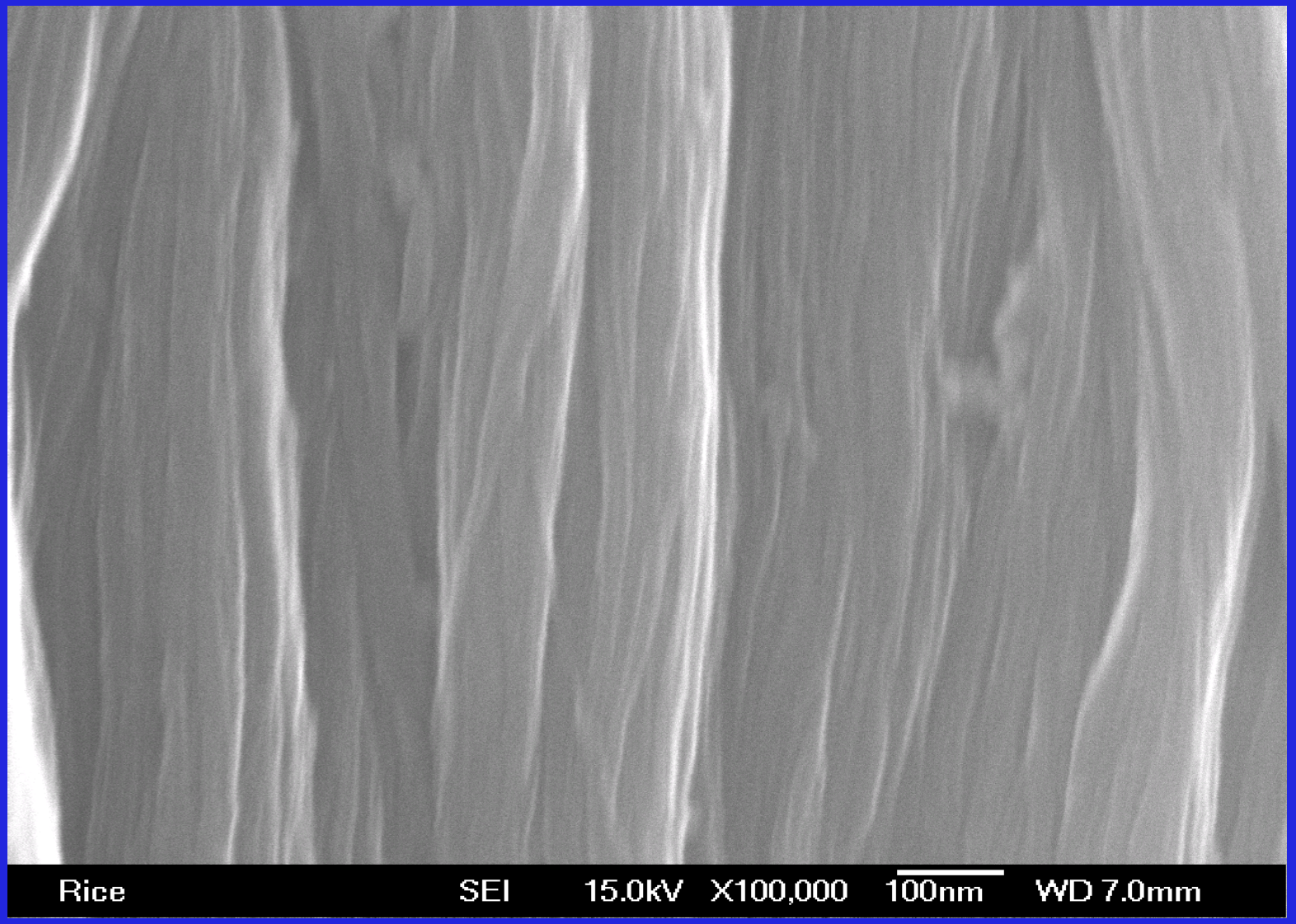
Take-up of Spun fiber



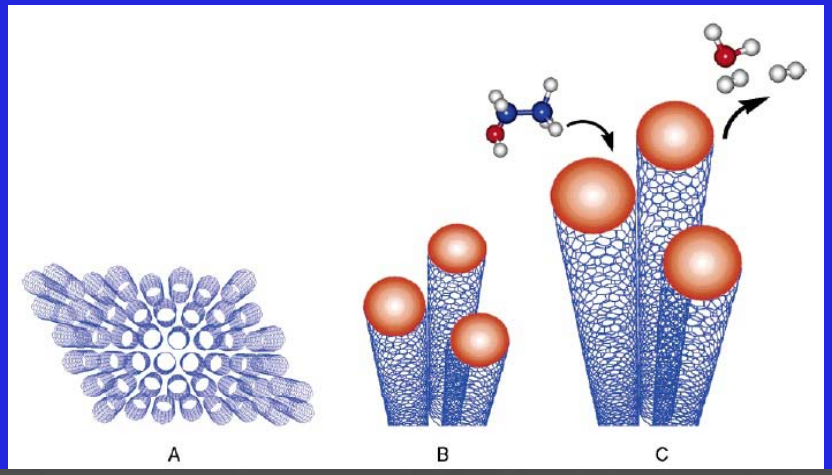
An overview of SWNT Fiber

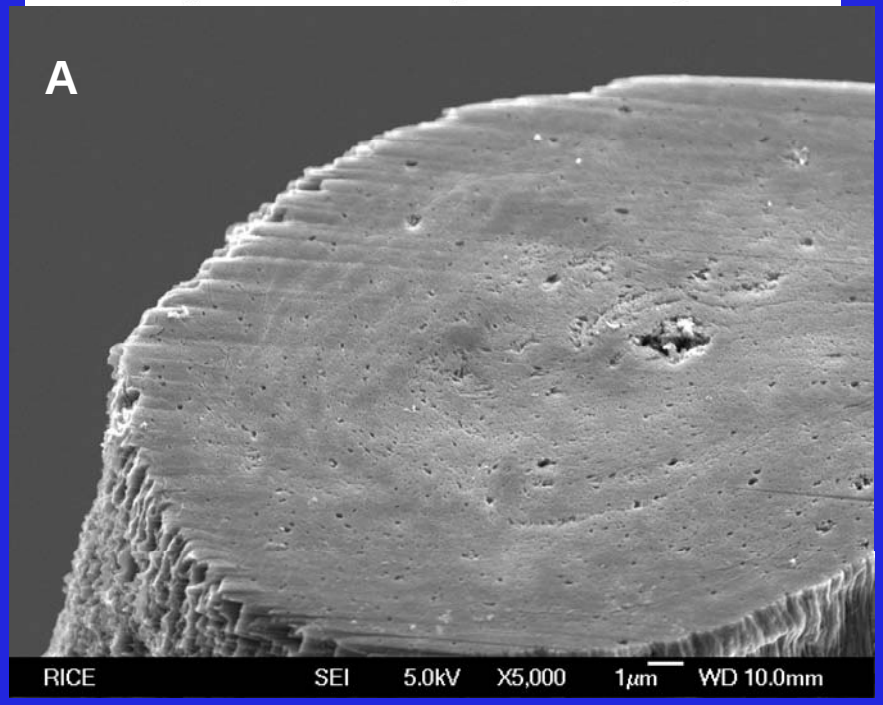


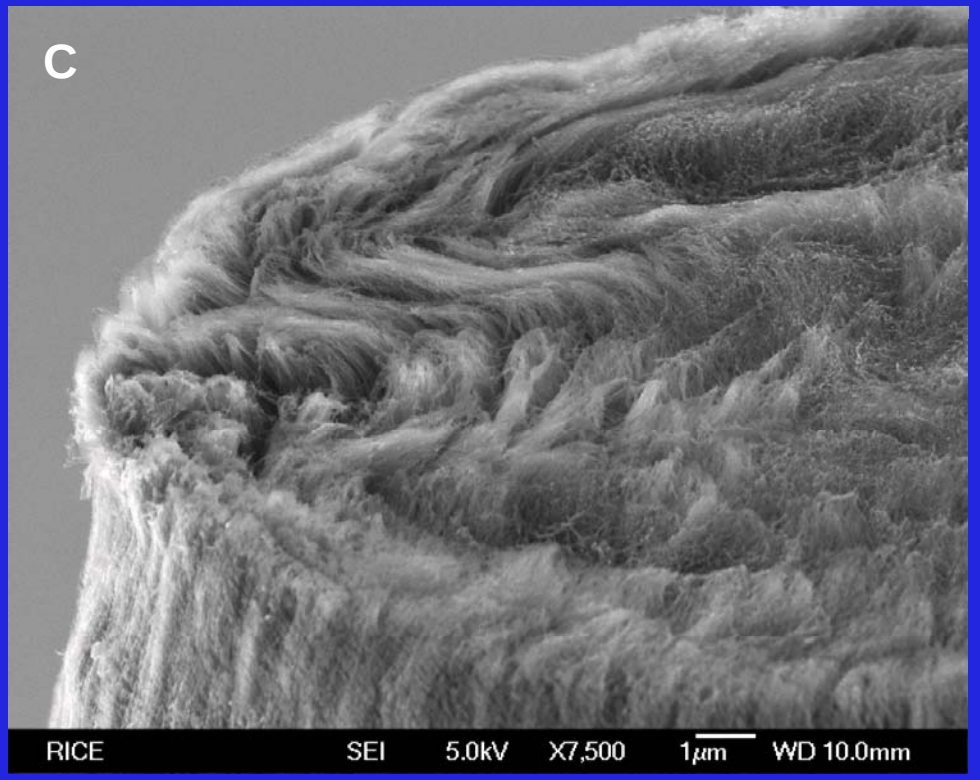
A close look at the ropes

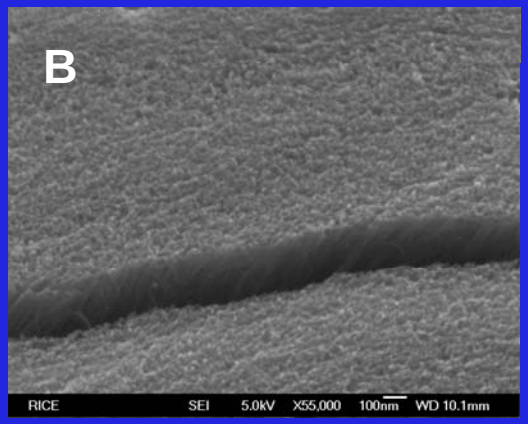


Seeded Growth from Cut Fibers









A: Typ. FIB-cut Fiber
B: Typ. Cleaned & Catalysed Fiber
C: After CVD Growth

(FIB cut swnt fiber Collaboration with WPAFB)

Carbon Nanotechnology Laboratory

Making BuckyTubes Be All They Can Be.

- Established at Rice Univ. - September, 2003
- Dr. Howard K. Schmidt - Executive Director
- Dr. Robert H. Hauge – Technology Director
- Principal Commercialization path: CNI

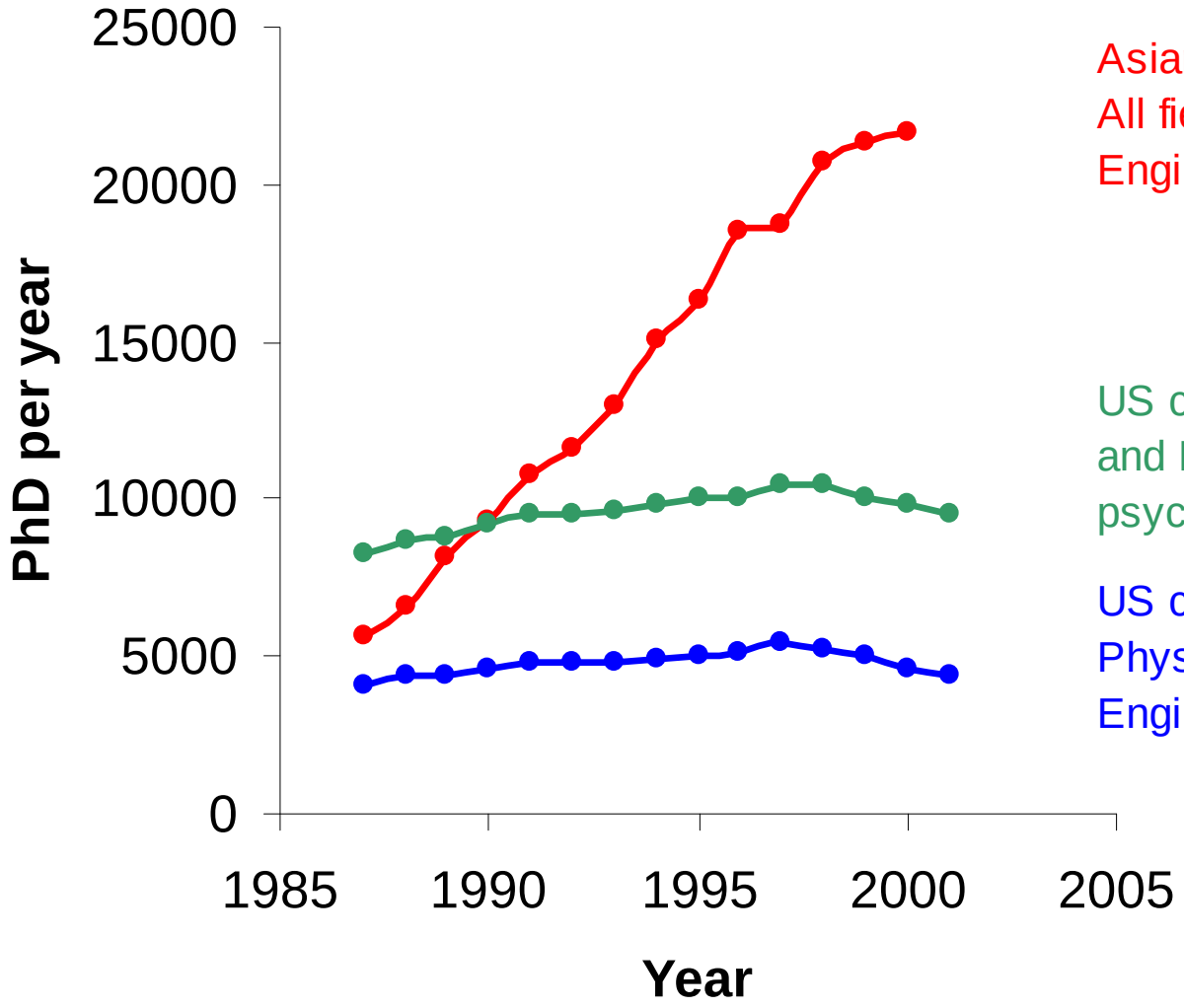
The biggest single challenge for the next few decades:

ENERGY

for 10^{10} people

- . **At MINIMUM we need 10 Terawatts (150 M BOE/day) from some new clean energy source by 2050**
- **For worldwide peace and prosperity we need it to be cheap.**
- **We simply can not do this with current technology.**
- **We need Boys and Girls to enter Physical Science and Engineering as they did after Sputnik.**
- **Inspire in them a sense of MISSION (BE A SCIENTIST SAVE THE WORLD)**
- **We need a bold new APOLLO PROGRAM to find the NEW ENERGY TECHNOLOGY**

PhD Degrees in Science and Engineering



Asians citizens
All fields of Science & Engineering

US citizens, all fields of Science and Engineering, (excluding psychology & social sciences)

US citizens,
Physical Sciences and Engineering only

Source: Science and Engineering Indicators, National Science Board, 2002

The Nickel & Dime Solution

- **For FY05-FY10 collect 5 cents from every gallon of oil product**
  Invest the resultant > $10 Billion per year as additional funding in frontier energy research distributed among DOE, NSF, NIST, NASA, and DoD.
- **For the next 10 years collect 10 cents from every gallon;**
  invest the >$20 Billion per year in frontier energy research.
- **Devote a third of this money to New Energy Research Centers**
  located adjacent to major US Research Universities.
- **At worst this endeavor will create a cornucopia of new technologies and new industries.**
- **At best, we will solve the energy problem before 2020,**
  and thereby lay the basis for energy prosperity & peace worldwide.

We Know We Have to do this: Revolutionize Energy

WHAT ARE WE WAITING FOR?

- An Energy Crisis ?
- A Global Warming Disaster?
- A New Administration?
- An Asian Technology Boom?

(or)

consensus in the S&T establishment, DOE, DoD, IC, State Dept.

and

POLITICAL LEADERSHIP

Reading Assignments

- Out of Gas, Daniel Goodstein
- The End of Oil, Paul Roberts
- The Prize, Daniel Yergin
- Hubbert's Peak, Kenneth Deffeyes
- The Hydrogen Economy, Jeremy Rifkin
- Twenty Hydrogen Myths, Amory Lovins (www.rmi.org)
- Matt Simmons, web site: (www.simmons-intl.com)
- M.I. Hoffert et. al., *Science*, **2002**, 298, 981,
- DOE BES Workshop Report on Hydrogen (www.sc.doe.gov/bes/hydrogen.pdf)
- 2003 State of the Future, (www.stateofthefuture.org)