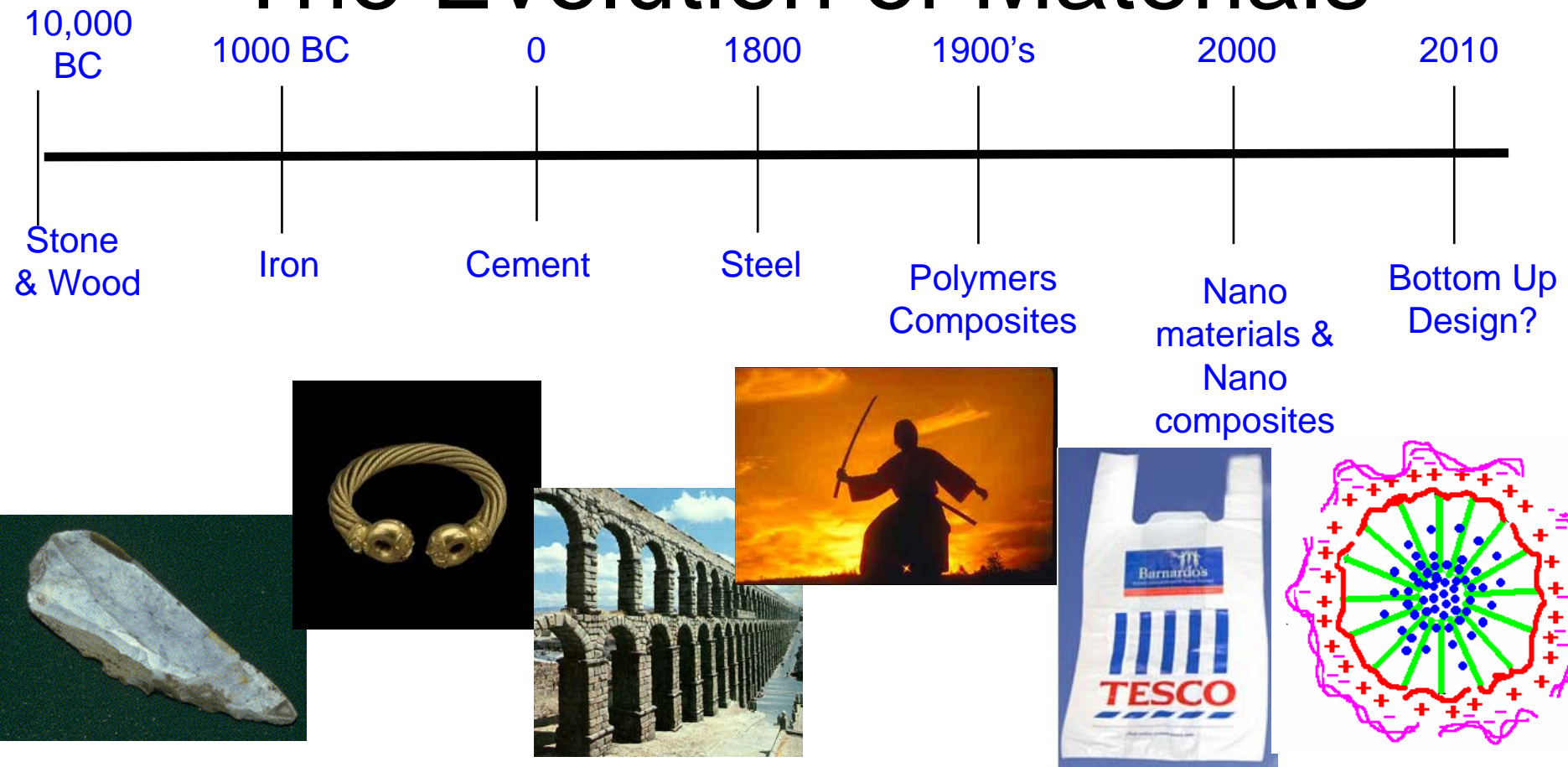


The Impact of Novel Materials on Clean Energy

Tim Harper
Cientifica Ltd

- Cientifica is a world leader in technical, scientific and financial information on emerging technologies, with a specialization in nanotechnology
- Develops technology impact and exploitation strategy for global organisations
- Cientifica provides companies, governmental institutions and venture capitalists all over the world with accurate and critical business information

The Evolution of Materials



The Myths of Nanotech 2000

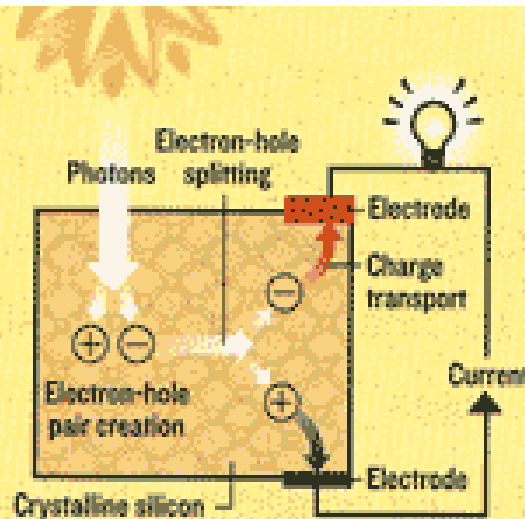
- Nanotech will replace all manufacturing within five years
- Carbon nanotubes will replace silicon
- Carbon nanotubes will store hydrogen
- Nanotechnology will cure cancer

The Myths of Nanotech 2004

Cheap Affordable Solar Power (Within Two Years)

Lighting Up

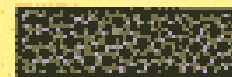
How efficiently solar cells turn light into power depends in part on how well they absorb light, generate pairs of positive and negative charges, and then drive the charges to electrodes. Crystalline silicon slabs do these jobs well but at high cost.



Thin films of light-sensitive nanomaterials can be cheaper to make. The trick: Find ingredients that absorb a wide spectrum of light and create easy paths for electrons.



Nanorods



Titanium dioxide



Nanobrushes

Strips of nanomaterials are painted on plastic film.



Solar Everywhere

MONITOR

Solar cells come down to earth

Sep 4th 2003

From *The Economist* print edition

Solar cells are still ten times too expensive for use in housing. Recently developed nanorod composites could change that



Nanorod stew

electricity needs. But at \$9 per watt, the system would cost a homeowner around \$32,000 to install.

MILLIONS of people around the world would like to heat their homes and run household appliances with solar power. But the cost of doing so puts it out of the question. The first problem is that the cells convert only 10-15% of the radiation from the sun into energy. The second is that the photovoltaic (PV) material used is a form of silicon that has to be made under high-vacuum conditions and heated in special kilns to 1,400°C. That makes photovoltaic solar cells horrendously expensive.

Consider the small model home set up in Raleigh by the North Carolina Solar Centre. Its 3.6-kilowatt PV system generates about half of the house's

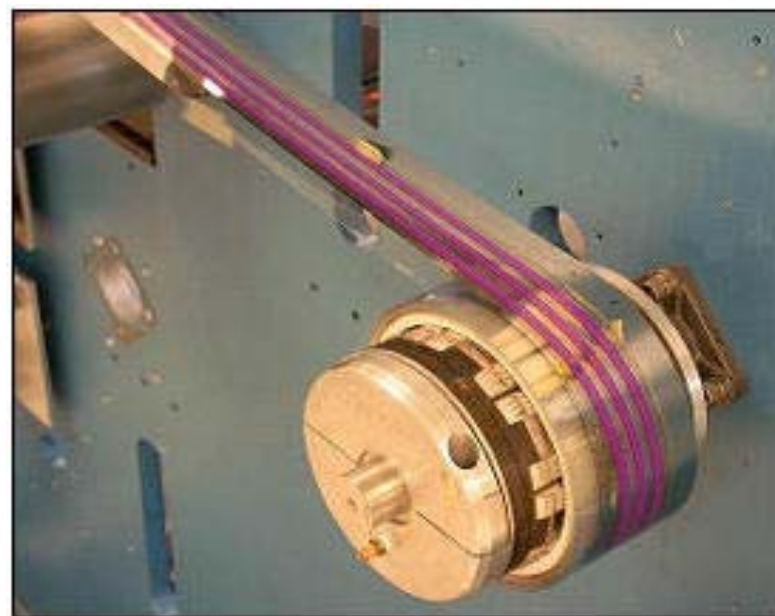
“We will integrate composite solar cells into decorative roofing tiles or sidings...with efficiencies of 30%”

“On Hold”

Polymer Solar Cell

“Konarka Secures
Technology Licensing
Deal, Manufacturing to
Begin”

- Aug 7 2006



Source: Konarka

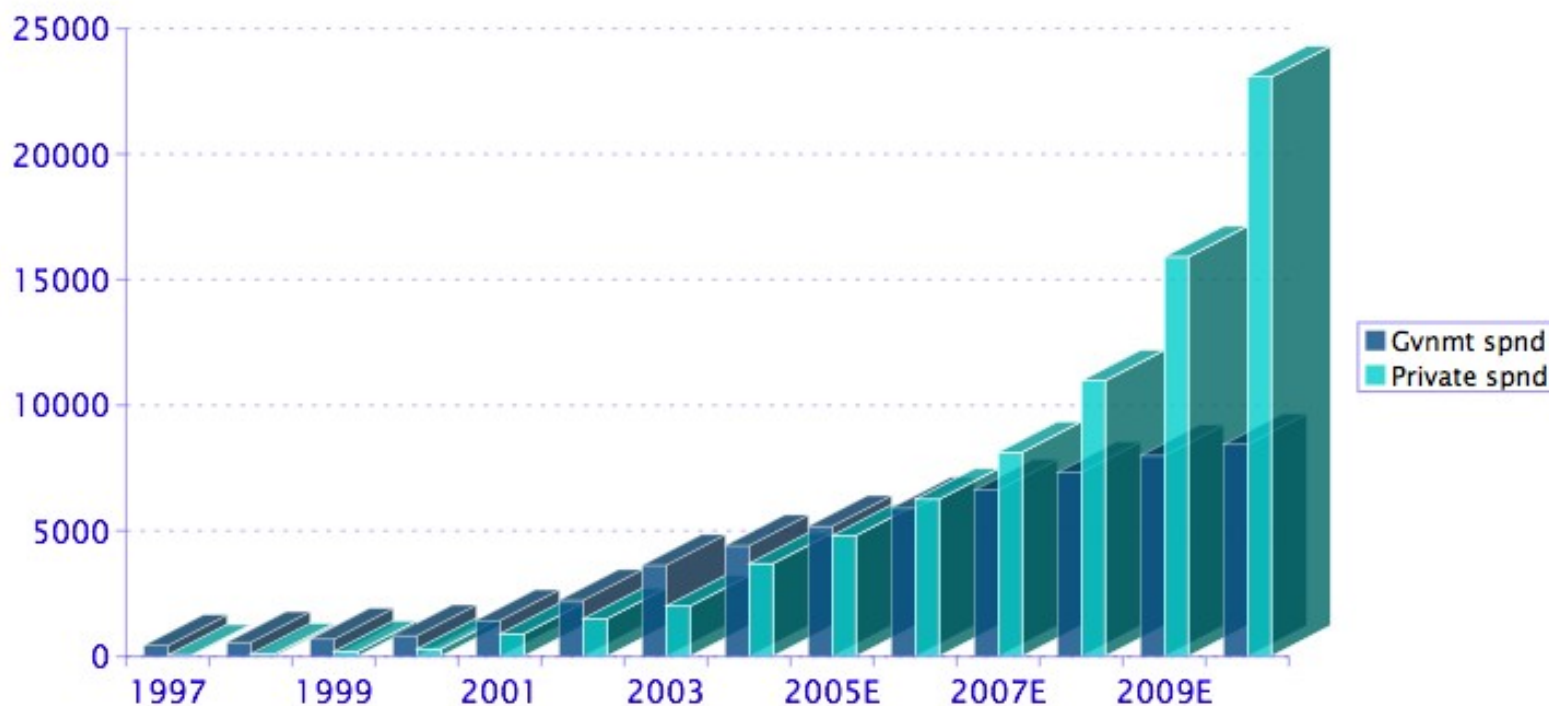
Still 6 months from market!

The Picture in 2006

- More rational
- Healthily sceptical but
- Nine years of nanotech funding is showing some results



Getting The Timing Right



Key Areas for Materials

- Generation
- Efficiency



CNT R&D - Total \$53m



Nanofilms R&D - Total \$49m



Solar Trends

- Thin film and flexible
- Lower cost (70-90% lower than silicon)
- Leveraging advances in
 - Materials
 - Semiconductors
 - Polymers



Generation: Nanosolar

Closed \$100m funding in June 2006

- \$75m Series C Round + subsidies
- Combines nano structured materials with
 - Printable semiconductors
 - Rapid Thermal Processing
 - Roll to Roll Processing on Polymer Substrate
 - embeds CIGS (copper-indium-gallium-selenium) into thin polymer films
- Planned production in San Francisco and Berlin

Nanosolar

Investors include

- Mohr Davidow Ventures (MDV), Benchmark Capital, OnPoint Technologies, and Mitsui
- SAC Capital and GLG Partners, insurance firm Swiss Re, photovoltaic power plant system integrator Beck, Grazia Equity (which was an original backer of Conergy),
- SAP founders Klaus Tschira and Dietmar Hopp, and Jeff Skoll, eBay's first president
- Larry Page and Sergei Brin

The Usual NanoHype Caveats

“Nanosolar has begun ordering parts for the fab, which will be completed in 2007. The company previously told Red Herring it expected to commercialize its cells by 2006.”

Competitor Heliovolt at a similar stage
with 10x less funding

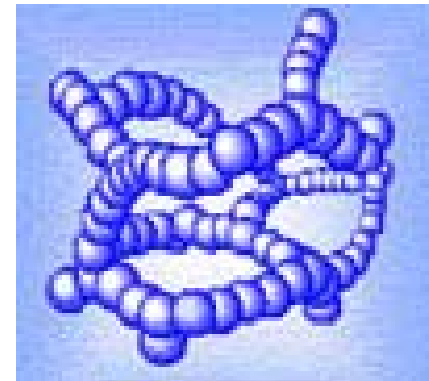
Efficiency Trends

- Insulation
(Aerogels)
- Weight reduction
(composites)



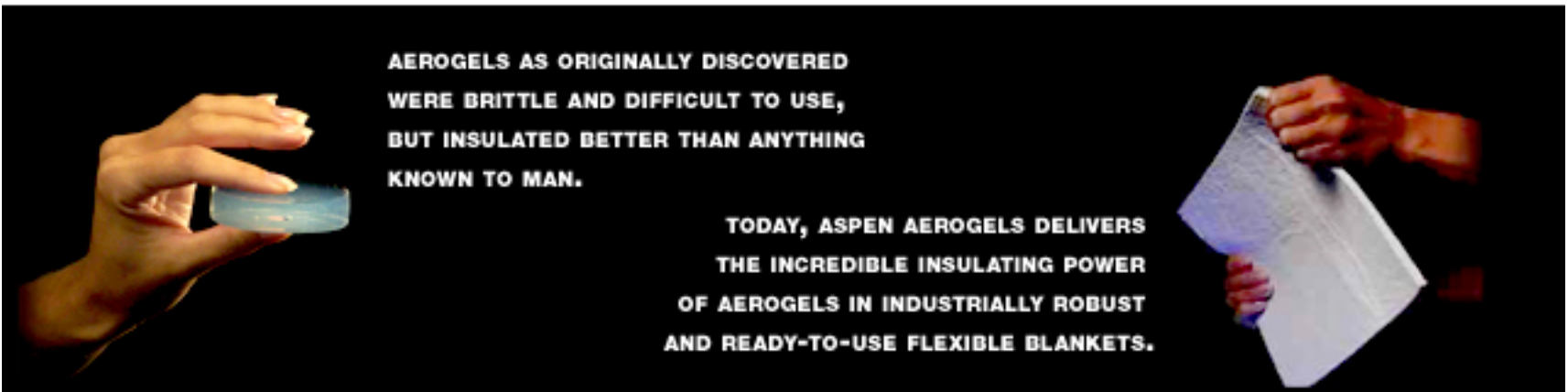
Aerogels

- 90-95% porous
- Discovered 1931 but not commercialized until 2002
- High optical transmission



**AEROGELS AS ORIGINALLY DISCOVERED
WERE BRITTLE AND DIFFICULT TO USE,
BUT INSULATED BETTER THAN ANYTHING
KNOWN TO MAN.**

**TODAY, ASPEN AEROGELS DELIVERS
THE INCREDIBLE INSULATING POWER
OF AEROGELS IN INDUSTRIALLY ROBUST
AND READY-TO-USE FLEXIBLE BLANKETS.**



Aerogel Applications

LNG Systems

- Smaller outer pipes in pipe-in-pipe systems, reducing the need for steel thereby saving money in materials and installation costs.
- Better insulation performance of storage facilities than with other insulation systems, reducing boil off gas, resulting in substantial OPEX savings.
- Dramatically improved carrier ships which are able to carry between 5000 to 11500 additional cubic meters of LNG for a given hull size.

Aerogel Applications

Building Systems

- High strength
- Light weight
- Low thermal conductivity
- More daylight with better insulation



From Insulation to Logistics

LOGISTICAL SAVINGS FOR AEROGEL-BASED PIPE INSULATION
INSULATION NEEDED FOR 2 MILES OF 8" PIPE FOR IDENTICAL THERMAL PERFORMANCE

INSULATION MATERIAL **PYROGEL® 6350**

MINERAL WOOL

MATERIAL THICKNESS

0.75 IN. (3 PLYS)

3 IN.

PACKED MATERIAL WT.

12,300 LB.

72,200 LB.

PACKED MATERIAL VOL.

2,400 CU. FT. (50 ROLLS)

16,000 CU. FT.
(1760 CARTONS)

NO. OF 53' CARRIERS

1

7

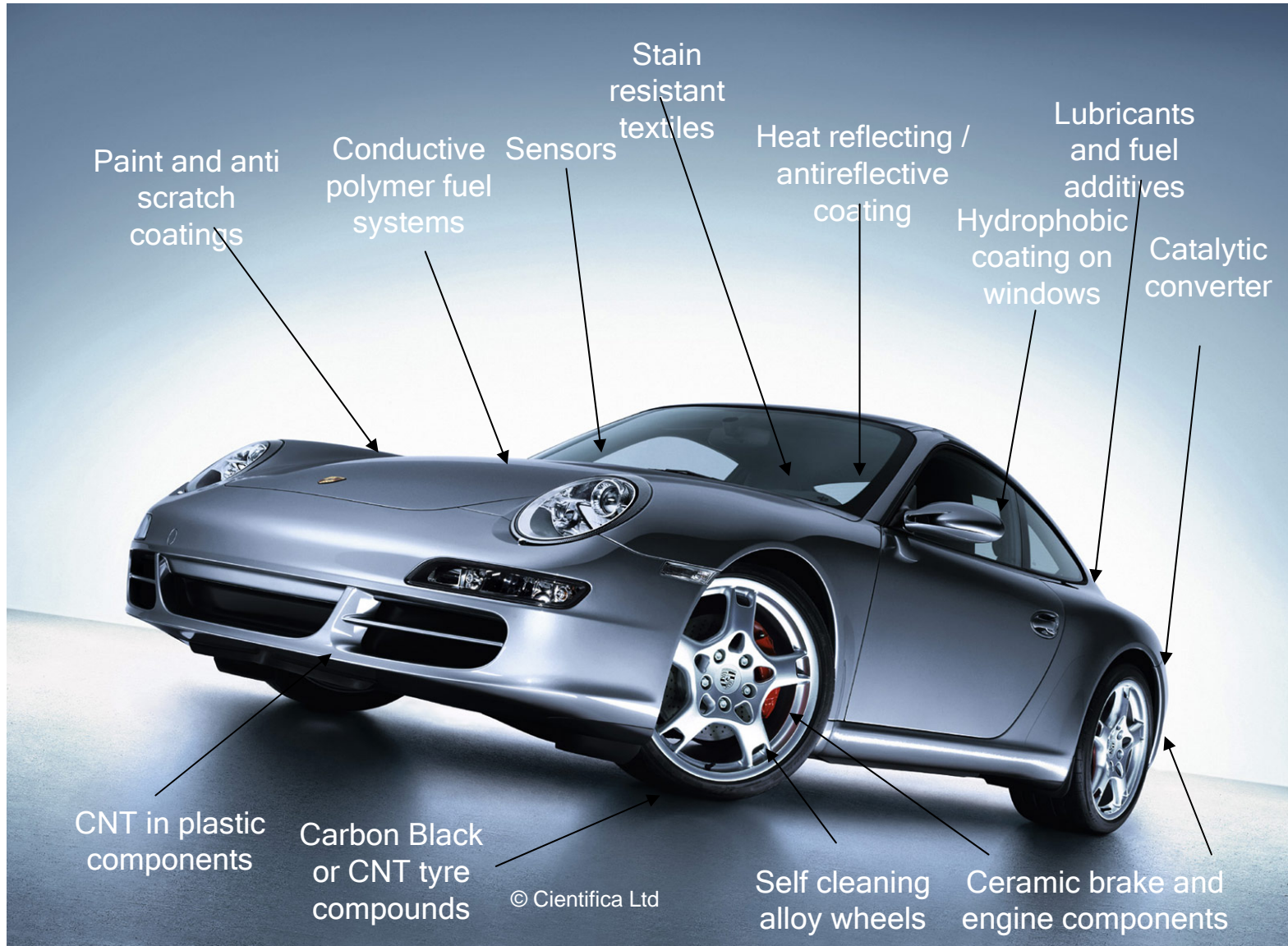


Business Information and Consulting

London . Oslo . Singapore . Mumbai



cientifica



Short Term Solutions

- Save weight, Use Composites!
- Most commonly, composite materials have a bulk phase, which is continuous, called the matrix, and one dispersed, non-continuous, phase called the reinforcement, which is usually harder and stronger.
- Composite materials replacing metal in applications from aerospace to automotive



First 787 Composite Fuselage Section Jan, 05

How Switching to Composites Saves Energy

- Composites will make up 100% of the 787's skin and 50% of all the materials in the plane.
- Jets made of composites require far fewer parts, so there's less to bolt together.



Less Energy to Assemble

- One metal barrel requires some 1,500 sheets of aluminum held together by nearly 50,000 rivets. With plastics, the number of fasteners drops by 80%.
- Boeing hopes to assemble each 787 in just three days, down from 11 days for the 737.

Less Weight, Less Fuel

- Since plastics weigh less than aluminum, the planes should burn less fuel.
- Boeing claim 20% drop in fuel costs compared with other planes.



Retrofitting Composites

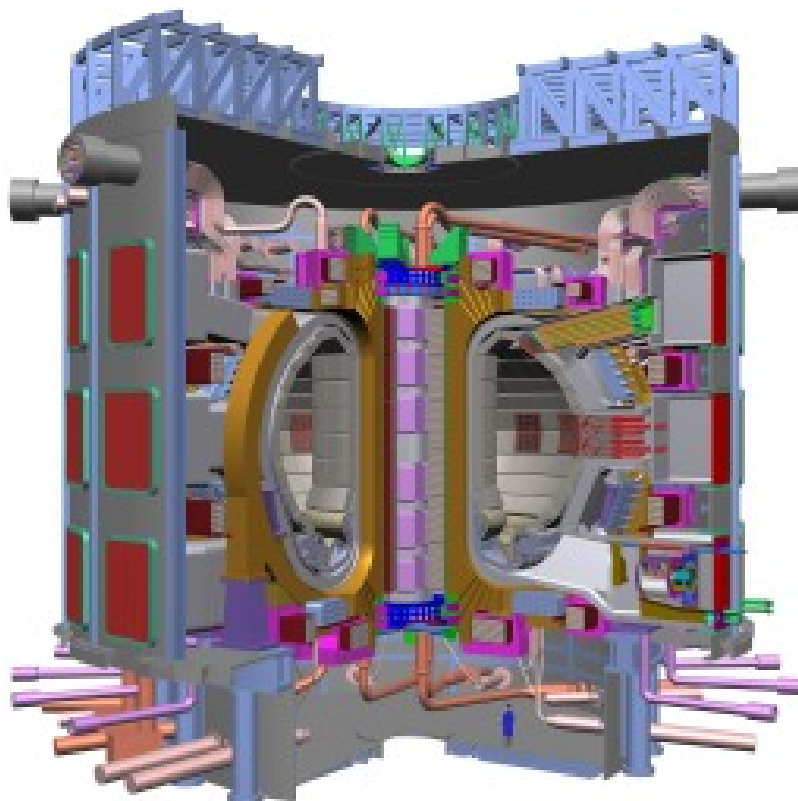
- The GEnx engine incorporates both a front fan composite containment case and composite fan blades.
- Will reduce the aircraft's weight, increase its payload capacity and extend its range
- Will be fitted to 747-8



Biggest savings will be inspections.

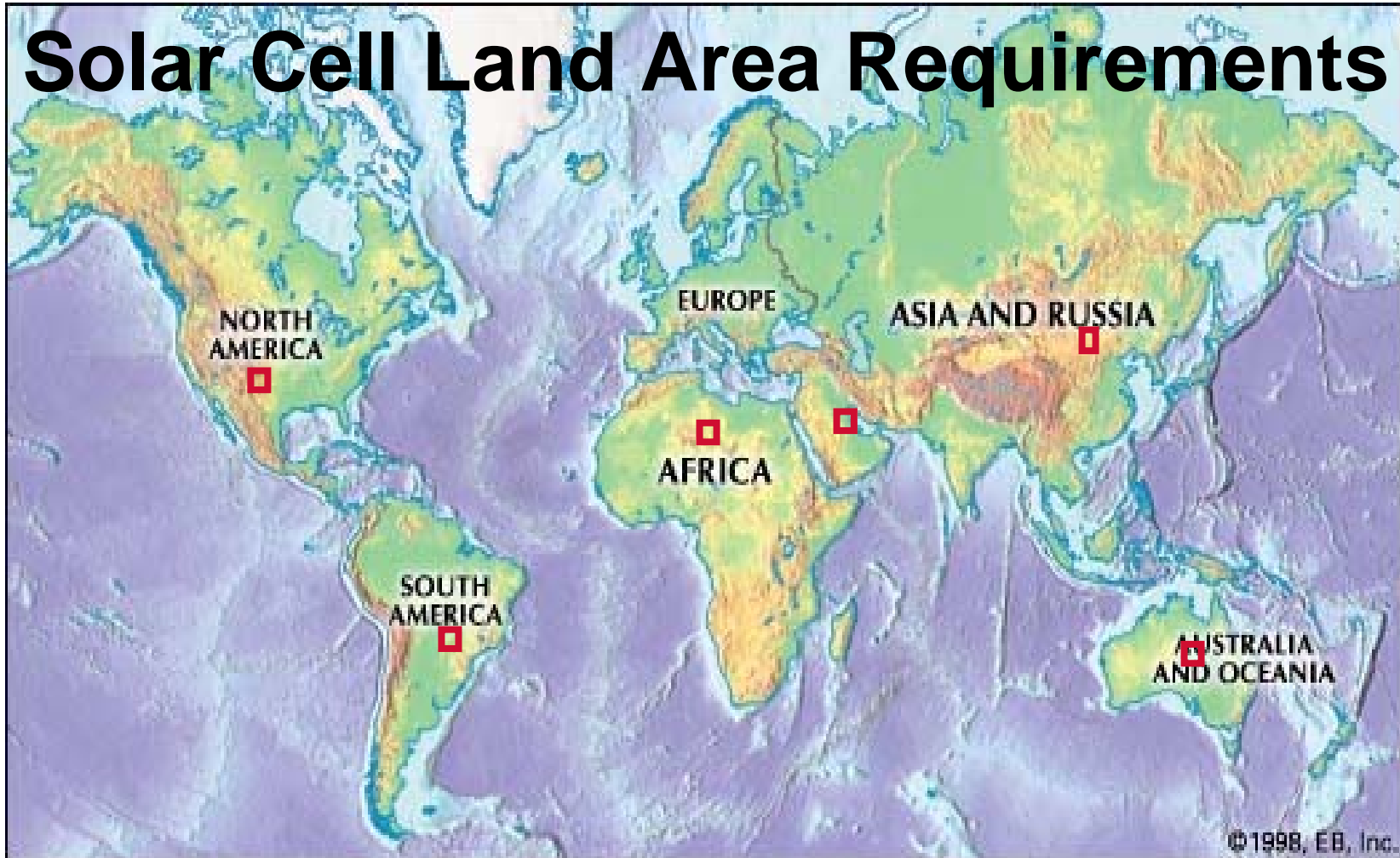
- Composite materials are more durable than aluminum, government regulators may call for fewer inspections.
- After just six years in service, a normal plane undergoes a meticulous and costly check for corrosion. The composite 787, in contrast, may remain in service for 12 years before its first structural test.
- By staying out of the shed, the 787 can make up to 113 additional flights.

Longer Term Solutions?



- Europe has spent over 10 Bn euros on nuclear fusion
- “It is not possible to say definitively whether fusion research is ... a matter of fundamental research or has progressed into the stage of development of an energy technology.”
 - Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag (TAB)

Solar Cell Land Area Requirements



6 Boxes at 3.3 TW Each = 20 TWe

Rebuilding The World Atom By Atom?



Will Nanotech Revolutionize Energy?

- Most improvements will be incremental
- Aerogels, composites, catalysts resulting from better control over properties of materials
- Many promising materials, but few will be commercialised

Our Energy Challenge



Energy & Nanotechnology Conference
Rice University
May 3, 2003

R. E. Smalley
Rice University

A photograph of the Earth from space, showing the Western Hemisphere. The Americas are visible in the upper right, and the Atlantic Ocean is in the lower left. The Earth is set against a black background.

BE A SCIENTIST -- SAVE THE WORLD