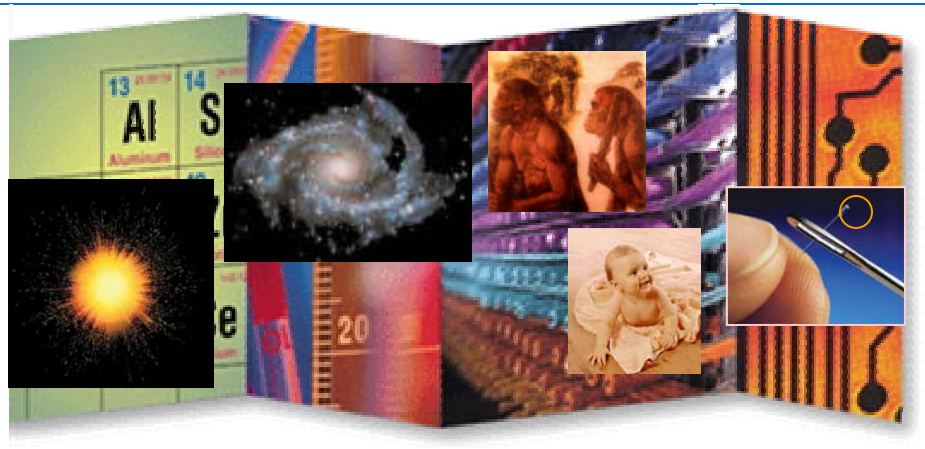
NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.



Nanotechnology:The New Frontier for Power Electronics

Dr. Anthony F. Laviano
a.f.laviano@wescon.com
310. 524-41245
February 2004

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Acceptance of Ideas for Application

Innovators	First	2.5%
Early Adapters	Next	13.5%
Early Majority	Next	34%
Late Majority	Next	34%
Laggards	Remaining	16%

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

You may ask me, "What is Nanotechnology?"

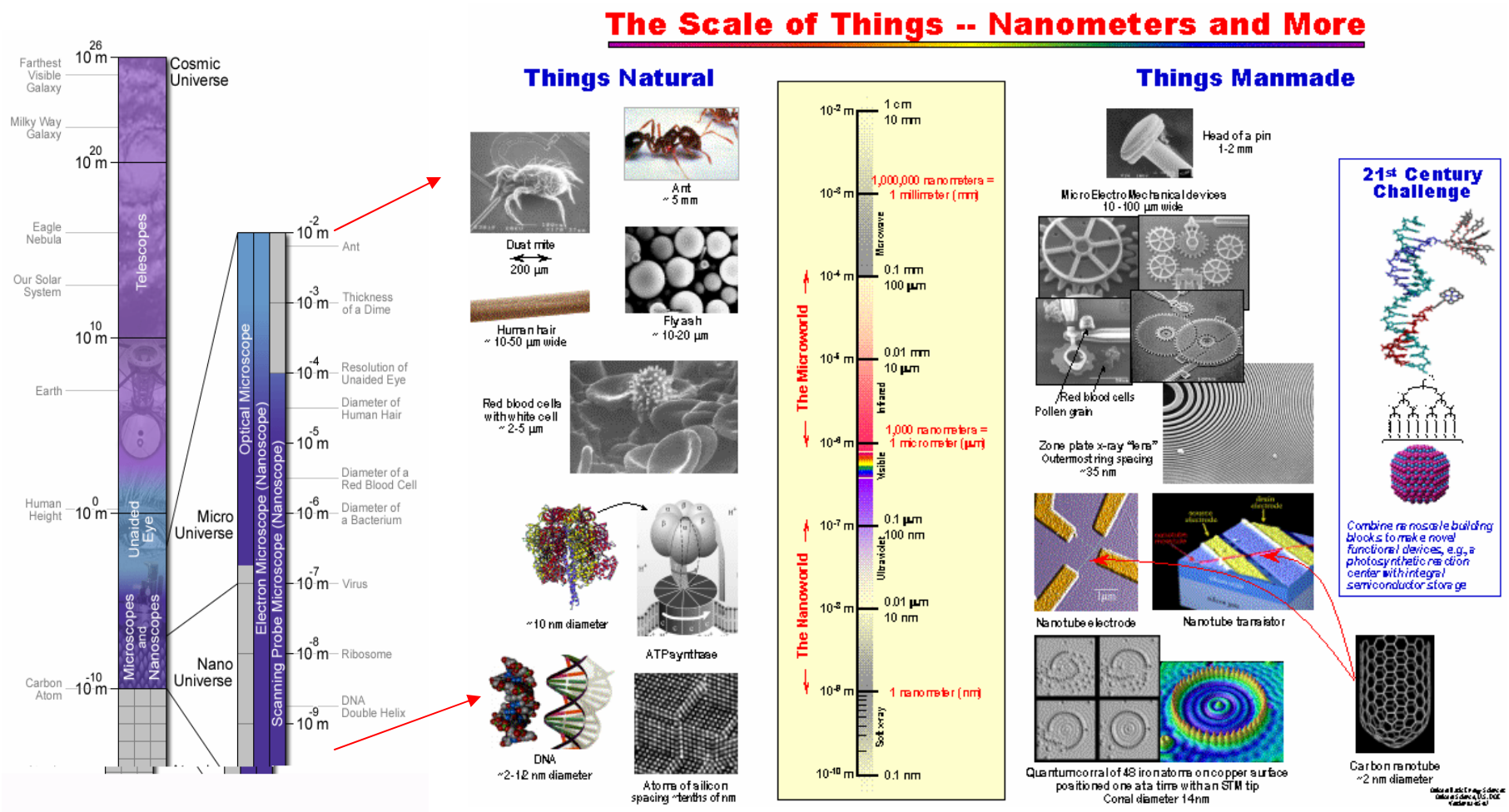
My answer is this.

"Nanotechnology is the collaboration of chemistry, biology, physics, computer, and material sciences integrated with Engineering, Application and Education entering the Universe of Nanoscale. This means science and engineering focused on creating materials, devices, and systems at the atomic and molecular level."

Dialogues for The Cookie Jar by Dr. Anthony F. Laviano

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

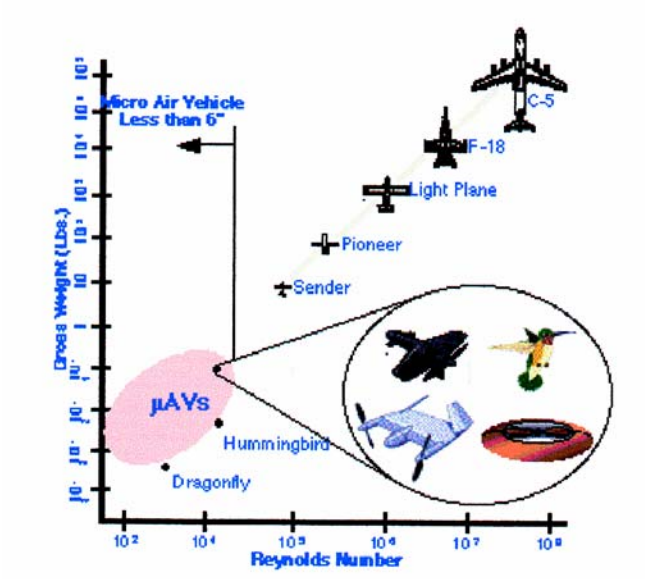


NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Then

Electronics, January 22,1960
Button like Amplifier



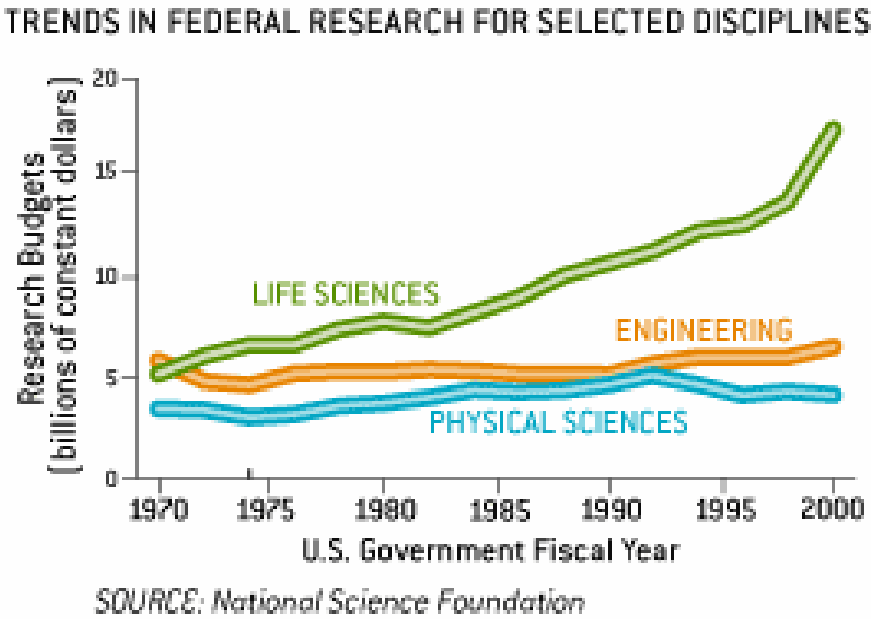
Now

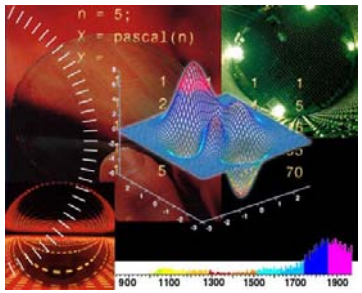
Now and Beyond
Palm Airplane

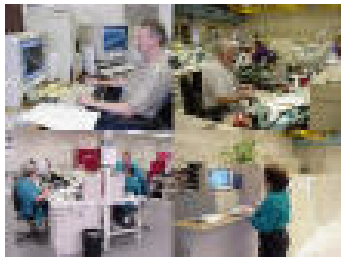
NANOWorld℠

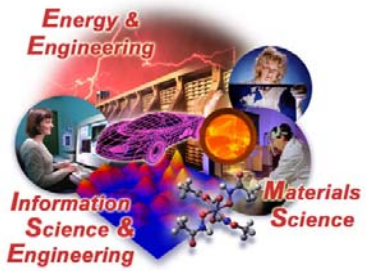
"…harmonizing things seen and not seen." – S.A.G.

U.S. Funding Trends









NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

HISTORY -
National Nanotechnology Initiative Timeline

- November 1996 — Nanotechnology Group (bottom-up)
- September 1998 — NSTC establishes IWGN (later NSET)

- March 1999 — OSTP/CT presentation on NNI
- May-Sept. 1999 — Congress hearings; Three publications; IWGN Plan

- Oct. - Dec. 1999 — PCAST, OMB
- January 2000 — OSTP and WH Approval

- February 2000 — WH release 1st year of NNI
- November 2000 — Congress appropriates $422M for FY 2001

- December 2001 — Congress appropriates $604M for FY 2002
- February 2002 — WH requests - $710M for FY 2003

M.C. Roco, NSF

Nanotechnology R&D Funding by Agency

Fiscal year	*2000*	*2001* Enacted /eff./	*2002* Enacted	*2003* Request
National Science Foundation	97	150 /150/	199	221
Department of Defense	70	110 /125/	180	201
Department of Energy	58	93 /88/	91.1	139.3
National Institutes of Health	32	39 /39.6/	40.8	43.2
NASA	5	20 /22/	46	51
NIST	8	10 /33.4/	37.6	43.8
Environmental Protection Agency	-	/5.8/	5	5
Depart. of Transportation/FAA	-		2	2
Department of Agriculture	-	/1.5/	1.5	2.5
Department of Justice	-	/1.4/	1.4	1.4
TOTAL	270.0	422.0 /464.7/	604.4	~ 710.2

Other five departments/agencies participating to NNI are:
DOC, DOS, DOTreas, NOAA, NRC, USG

M.C. Roco, NSF, 1/20/02

State participation

Illustrations from 12 states

CA	California NanoSystem Institute	$100M over 4 yrs
NY	Center of Excellence in Nanoelectronics	$50M
IL	Nanoscience Center	$36M
IN	Nanotechnology Center	$5M
PA	Nanotechnology Center	$10.5M over 3 yrs
TX	Nanotechnology Center	$0.5M over 2 yrs
SC	NanoCenter	$1M
NM	Consortium University of NM and National labs	
NJ	Support at NJIT and future nanophotonics consortium	
FL	Center at the University of South Florida	
GA	Center at Georgia Tech	
OK	Nano-Net	

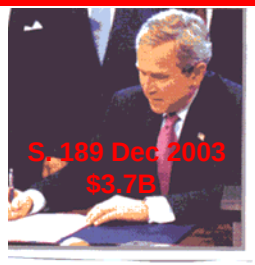
M.C. Roco, NSF, 02/05/02

Also….Universities and IEEE

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Approved by Congress
Signed by President

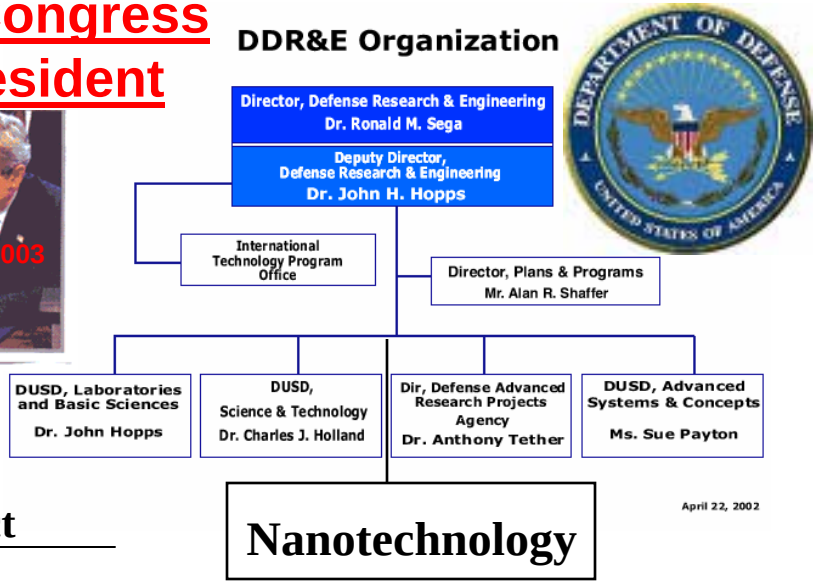


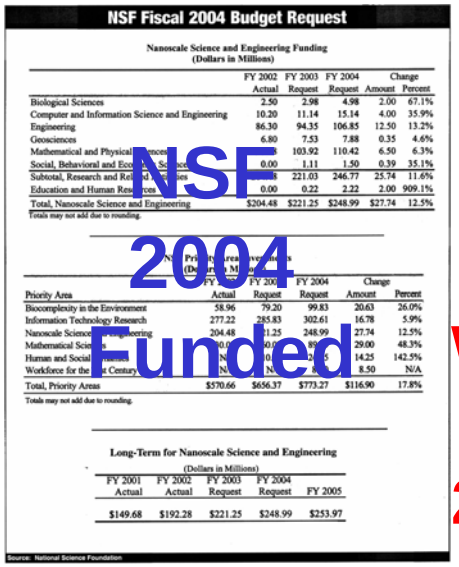
Senate Bill 2515 dated 27 June 2002

Established Nanotechnology in DOD Organization

House Bill 766 dated 7 May 2003

Nanotechnology Research and Development Act





NSF 2004 Funded

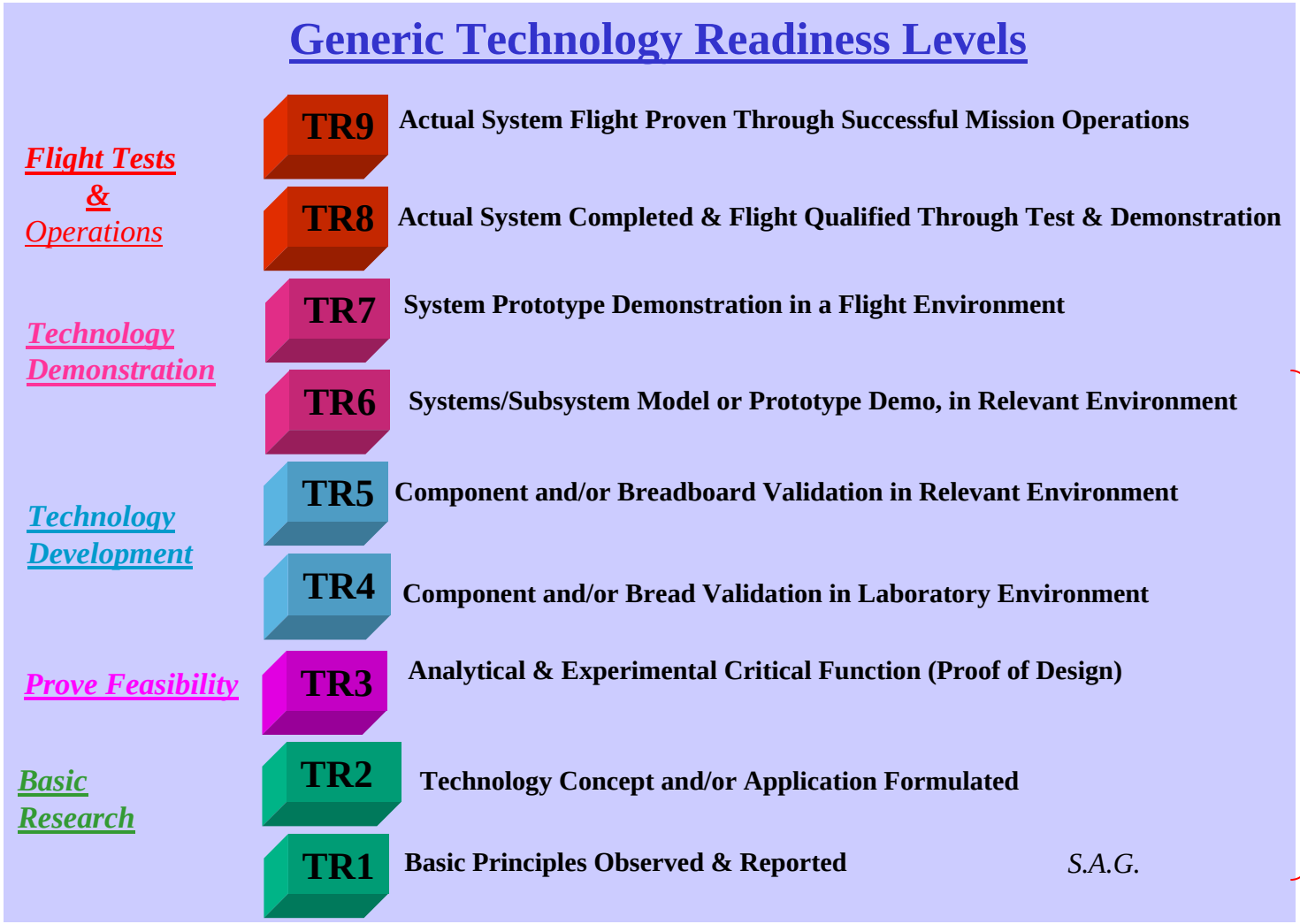
Education

Workforce For 21st Century

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Generic Technology Readiness Levels



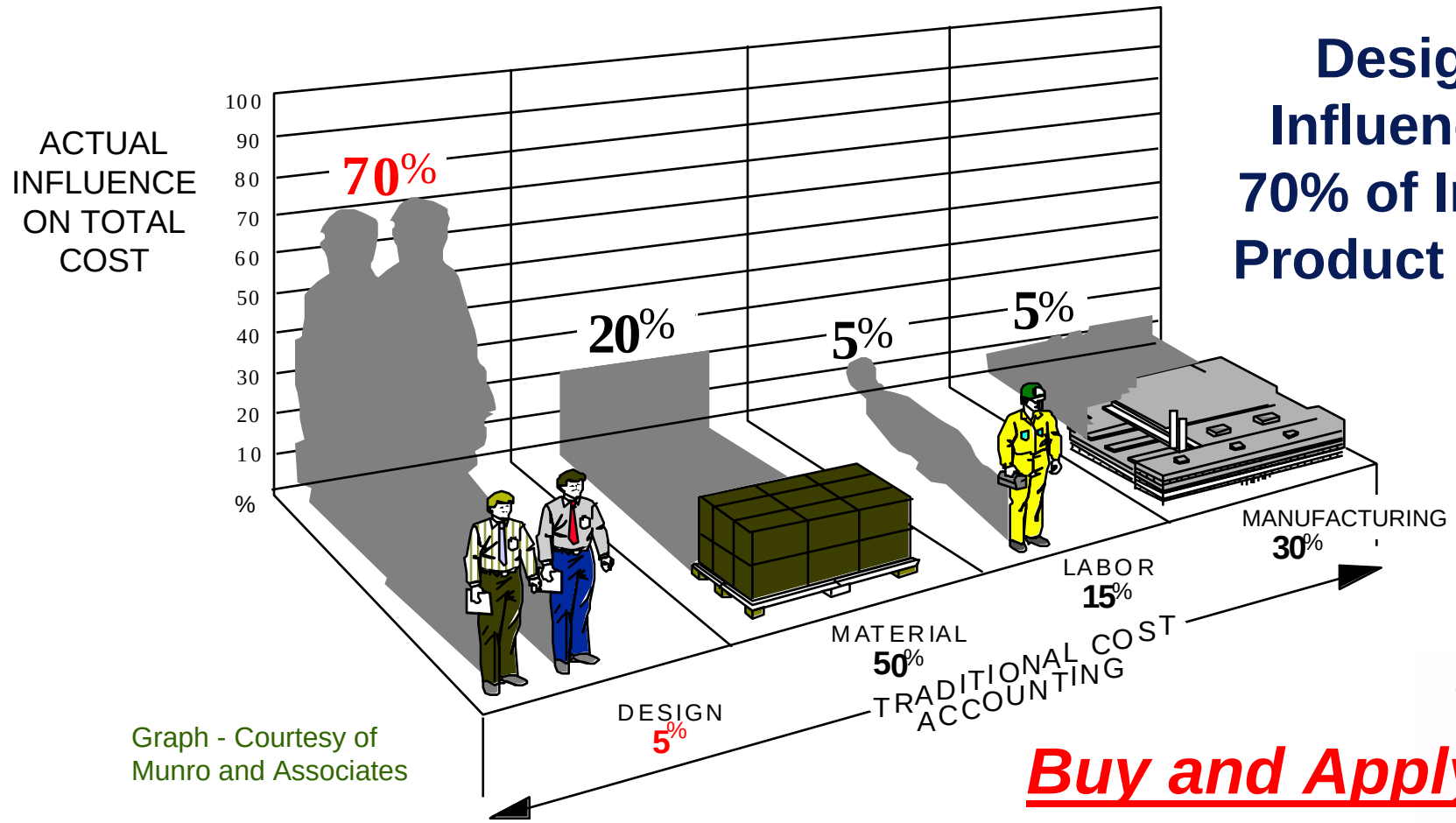
Life Sciences

Aerospace

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Competitive Cost Through Engineering



Design Influences 70% of Initial Product Cost

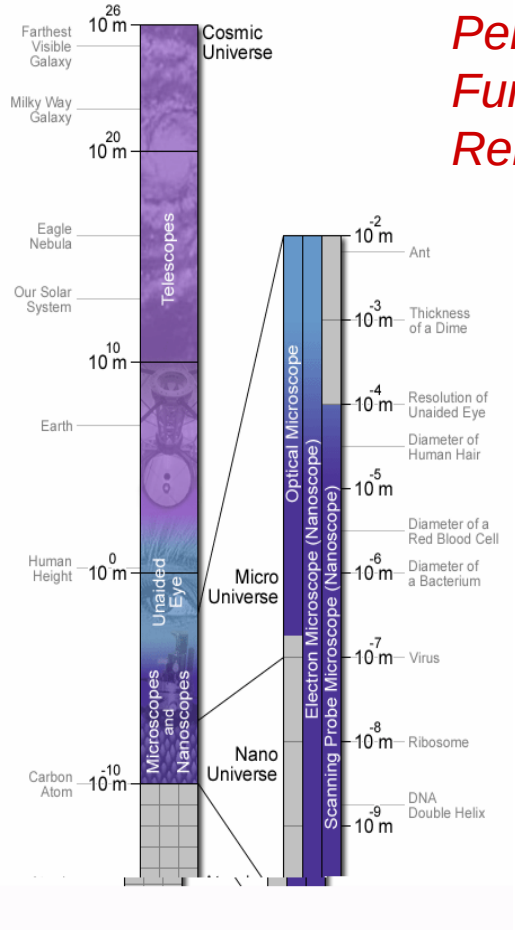
Graph - Courtesy of Munro and Associates

Buy and Apply

Supply Chain Management

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

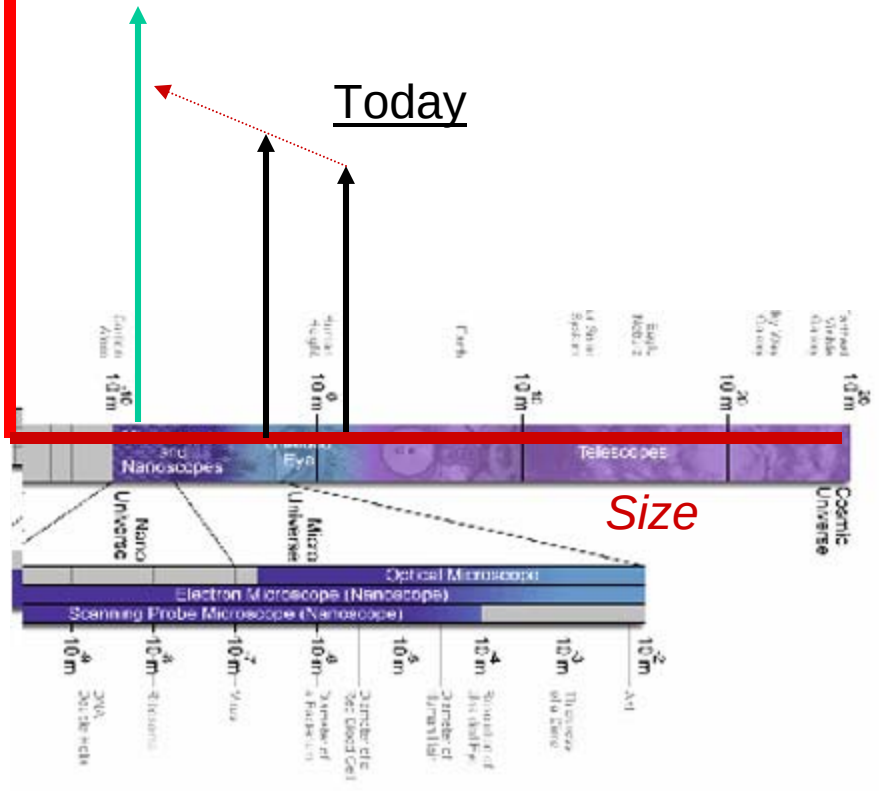


Performance, Functionality, Reliability, etc

Design

and Today

Today

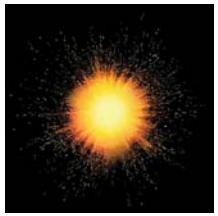


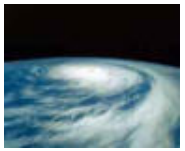
Size

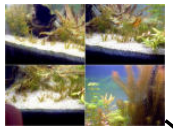
NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Time Line for Evolution of Life on Earth







15 billion – Universe begins (Big Bang)

5 billion – Formation of Sun and Solar System

4.5 billion – Life begins in oceans on Earth

2.5 billion – Continents form

2 billion – O_2 atmosphere forms by photosynthesis

1 billion – Simple plants form (algae)

550 million – Diverse animal species form (Cambrian explosion)

475 million – First land plants

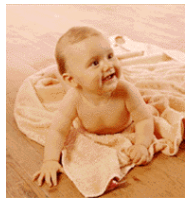
350 million – First land vertebrates

65 million – K/T mass extinction event (Dinosaurs become extinct)

2 million – First appearance of Homo habilus (fir… …ans)

400,000 – First appearance of Homo sapiens

Nano Engineer



15 billion years ago

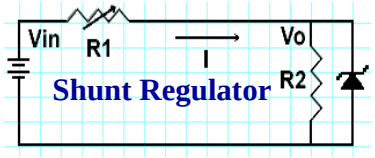
Years Before Present

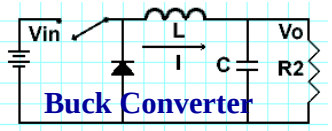
Today

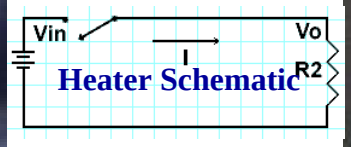
NANOWorld℠

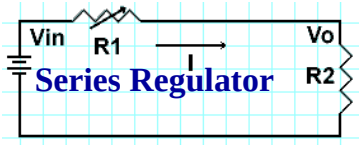
"…harmonizing things seen and not seen." – S.A.G.

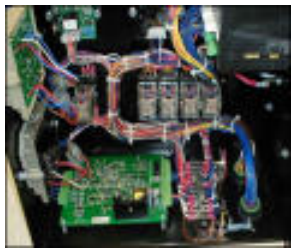
Power Electronics Today…





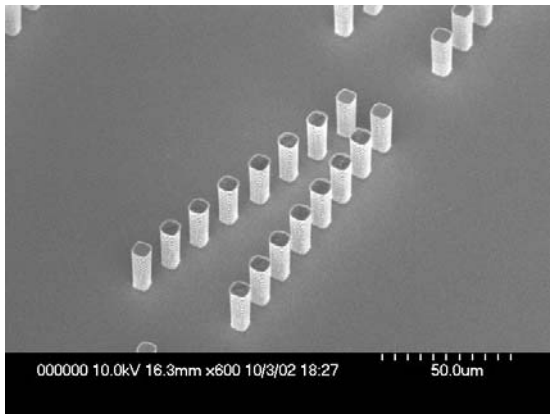


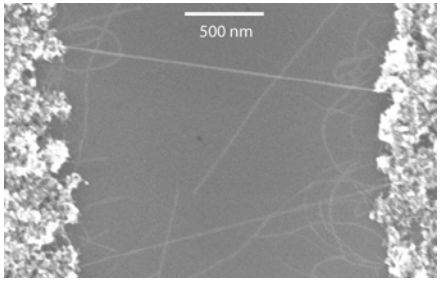


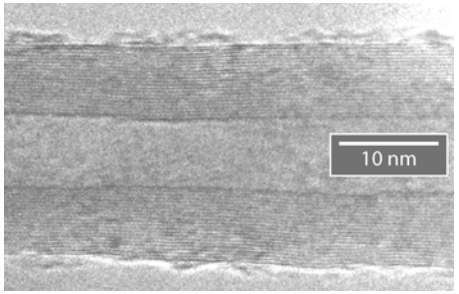


NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.







Nanotechnology

Nano-biosensors

Nanowires and nanotubes interact with the biochemical world for DNA, protein characterization and sensing

GHz frequency nano-electronics and NEMS

Understanding the ultimate speed limits of molecular electronics and single-electron-transistor devices

Nano-electromechanical devices

Nanotube and Nanowire growth

Chemical vapor deposition for devices beyond the lithographic limit

Development of thin-film based catalyst technologies

Towards THz electronic devices

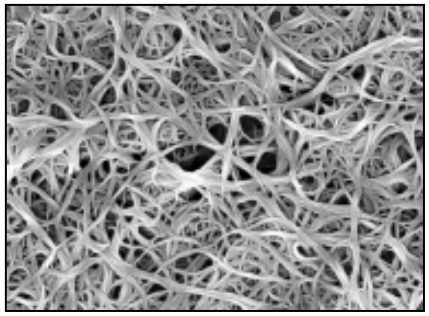
Deep-submicron HEMT devices

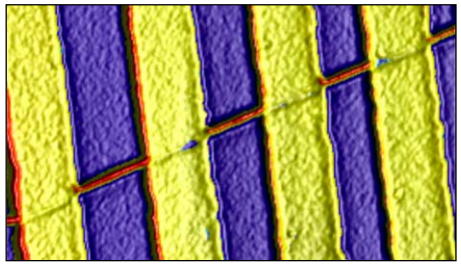
Quantum transport in the ballistic regime

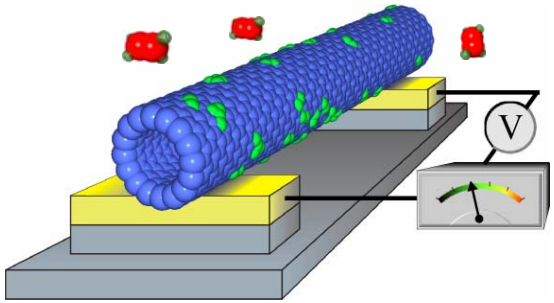
NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Electronics at the Molecular Scale







Synthesis of Novel Nanomaterials

We can now synthesize and characterize a wide range of nanowire and nanotube materials, allowing investigation of electronics at the scale of individual molecules.

Development and Testing of Nanoelectronics

Nanoscale circuits can be 100x smaller than state-of-the art electronics and can operate with single electrons or from quantum physics principles. To take advantage of these circuits, however, further research is required to learn how they truly operate.

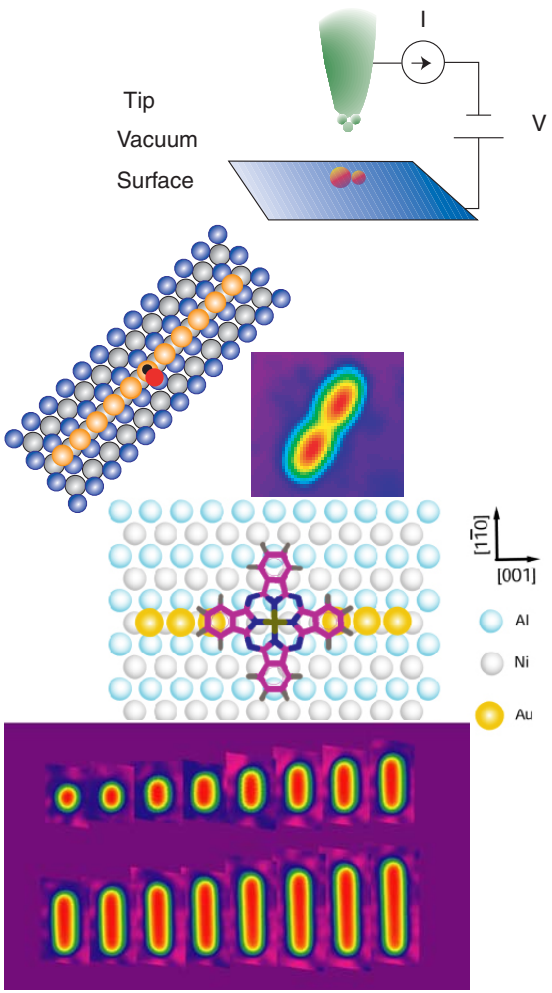
Nanocircuit Devices for Chemical Sensors

Nanowire electronics are exquisitely sensitive to tiny changes, such as when a molecule from the air lands on the device. This research is leading towards new types of detectors able to sense ultralow concentrations of harmful chemicals.

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Atomic & Molecular Basis of Nanotechnology



Atom by Atom Assembly of 1-D Metal Wire

The scanning tunneling microscope (STM) is used to move single atoms and to assemble them into 1-D chains, thus revealing the formation of band structure.

Chemical Sensors – single molecule on 1-D metal chain

The adsorption of a single CO molecule on a 1-D Au chain causes dramatic changes in the electronic structure which determines electrical conductivity.

Molecular Electronics – single molecule bridge

Individual atoms are moved to form two atomic chains separated by a gap. A molecule is manipulated to bridge this gap, connecting the molecule to two leads.

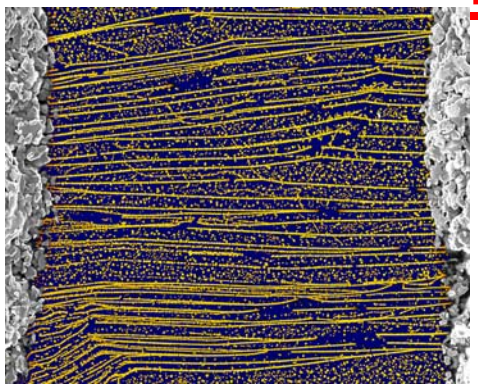
Nanomagnetism – novel magnetic nanostructures

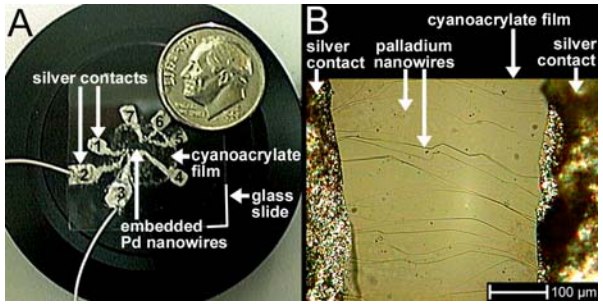
Magnetic atoms are assembled into novel nanostructures and molecules containing a magnetic atom are connected to two magnetic leads.

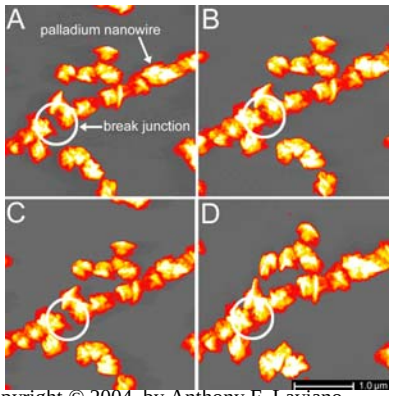
NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Nanowires in Analytical Chemistry







Nanowire Synthesis by Electrodeposition

A new method for preparing arrays of size-similar metal and semiconductor nanowires has been developed.

Effects of adsorbed molecule layers on Metal and Semiconductor Nanowires.

Why does the attachment of molecules to the surface of metal nanowires modify their conductivity?

BioSensors

By anchoring virus particles to metal nanowires, highly selective biosensors can be prepared.

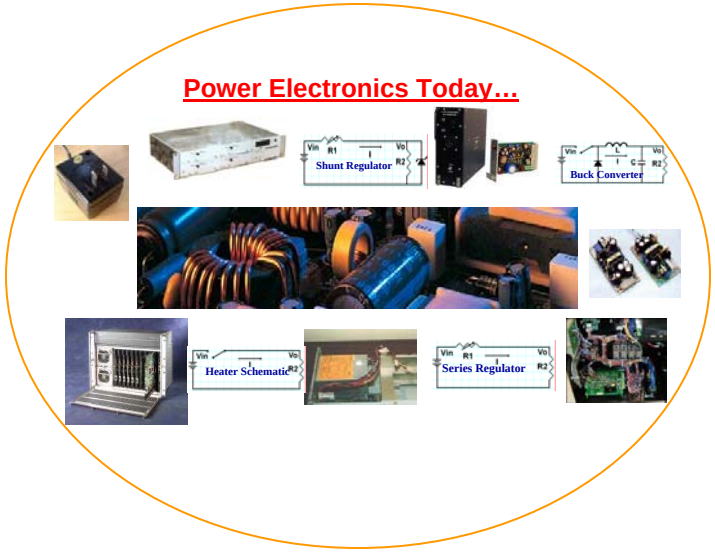
Gas Sensors

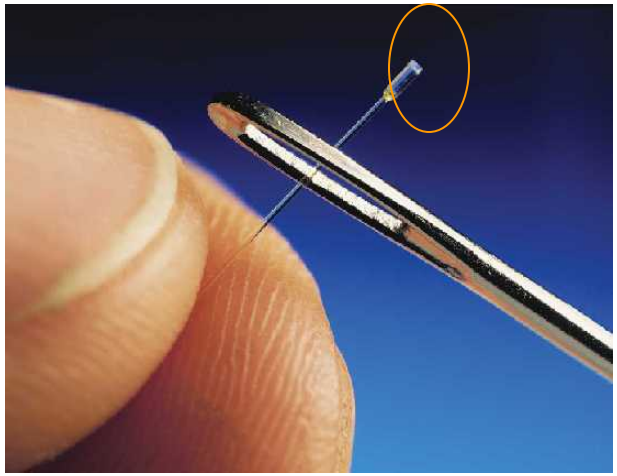
Metal nanowire arrays that rapidly and selectively detect gases including hydrogen and ammonia have been developed.

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

…and Today





On the Head of a Pin

NANOWorld℠

"…harmonizing things seen and not seen." – S.A.G.

Concluding Remarks

www.wescon.com/nanoworld

Acceptance of Ideas for Application

Innovators	First	2.5%
Early Adapters	Next	13.5%
Early Majority	Next	34%
Late Majority	Next	34%
Laggards	Remaining	16%

"Technology constantly changes. The thinking that ascertains technology's essence is in its application. This means using Nanotechnology for Power Electronics."