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Why Nanotechnology at NASA?
- Improved systems design and integration
- Increased efficiency of vehicles
- Reduced costs and time for development
- Enhanced performance and reliability
- Collection of spacecraft making a variety of measurements

Nanoelectronics and Computing Roadmap
Impact on Space Transportation, Space Science and Earth Science

NASA's Own Moore's Law
- Increased levels of system design and integration

Nanotechnology Roadmap
Impact on Space Transportation, Space Science and Aeronautics
- Optical sensors for advanced vehicles
- Multispectral Arrays (Chemical, optical and test)
- Nanosatellites for in-situ mission concepts
- Enhanced sensor capacity
Nano-Materials Roadmap
Impact on Space Transportation, Space Science and Earth Science

CNT = Carbon Nanotube

Biomimetics and Bio-inspired Systems
Impact on Space Transportation, Space Science and Earth Science

Experimental Work:
- Meyya Meyyappan (Program Director)
- Viktor Stolic (Genomics/Nanopore)
- Jonathan Trent (Protein Nanotubes)
- Jie Han (Bio-Sensors)
- Jun Li (Bio-Sensors)

Carbon Nanotube

- CNT is a tubular form of carbon with diameter as small as 1 nm.
  Length: few nm to microns.
- CNT is configurationally equivalent to a two-dimensional graphene sheet rolled into a tube.
- CNT exhibits extraordinary mechanical properties: Young's modulus over 1 Tera Pascal, as stiff as diamond, and tensile strength ~ 200 GPa.
- CNT can be metallic or semiconducting, depending on chirality.
Solid-state nanopores for DNA sequencing:

the fastest method for sequencing nucleic acids

1 subunit/microsecond = 1 human genome in 2hrs

HGP: 13 years/single genome/ $3 billion
**Impact/Applications:**

Rapid extraction of genetic information to enable:

1. *In-situ* detection of DNA, RNA, or protein on other planets.
2. Identification of the genetic basis of phenotypic variation among all organisms on Earth.
3. Personalized molecular medicine

1 subunit/microsecond = 1 human genome in 2hr.

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**Protein Nanotubes**

- Heat shock protein (HSP 60) in organisms living at high temperatures ("exotrophs") is of interest in astrophysics.
- HSP 60 can be purified from cells as a double-ring structure consisting of 16-18 subunits. The double rings can be induced to self-assemble into nanotubes.

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**Computer Simulations:** Characterization and Discovery of New Materials/Devices!
- High value of Young's Modulus (1.2 - 1.3 T Pa for SWNTs)
- Elastic limit up to 10-15% strain

Computer Simulations: Characterization of New Materials!

Nanostructured skin effect!

Computer Simulations Generating new IP!


Threshold Logic and Analog Logic Gates

Cerebral Sensory System (inner-neurons) of a cricket

A 4-level dendritic neural tree: 14 branched carbon nanotube junctions

Biological Dendritic Neural Tree
- One-dimensional cable theory
- Hodgkin-Huxley model for action-potential based information flow
- Information processing is coded in (a) branching at the junctions, and (b) time-series sequencing of the signal spikes
- Input - output - control: is based on (a) structural details of the branches and junctions, and (b) via chemical environment
- Short and long term memory is part of the structure: evolutionary in nature

Carbon Nanotube: Dendritic Tree
- Electronic, acoustic, thermal, and chemical signal transmission and information processing
- Information processing can be based on (a) branching - switching at the junctions, and (b) time sequence sequencing of signal spikes
- Input - output - control: can be based on (a) structural details, (b) chemical environment, and (c) physical contacts at the ends
- Short and long term memory can be part of structure by defect and chemical adsorbate placement: design for specific purposes/functionality

External Collaborators:
- Prof. K. Cho (Stanford University)
- Prof. Don Brenner (NC State University)
- Dr. Madhu Menon (University of Kentucky)
- Dr. Antonis Andriotis (Crete, Greece)
- Dr. Uri Sagman (CSixty, USA)