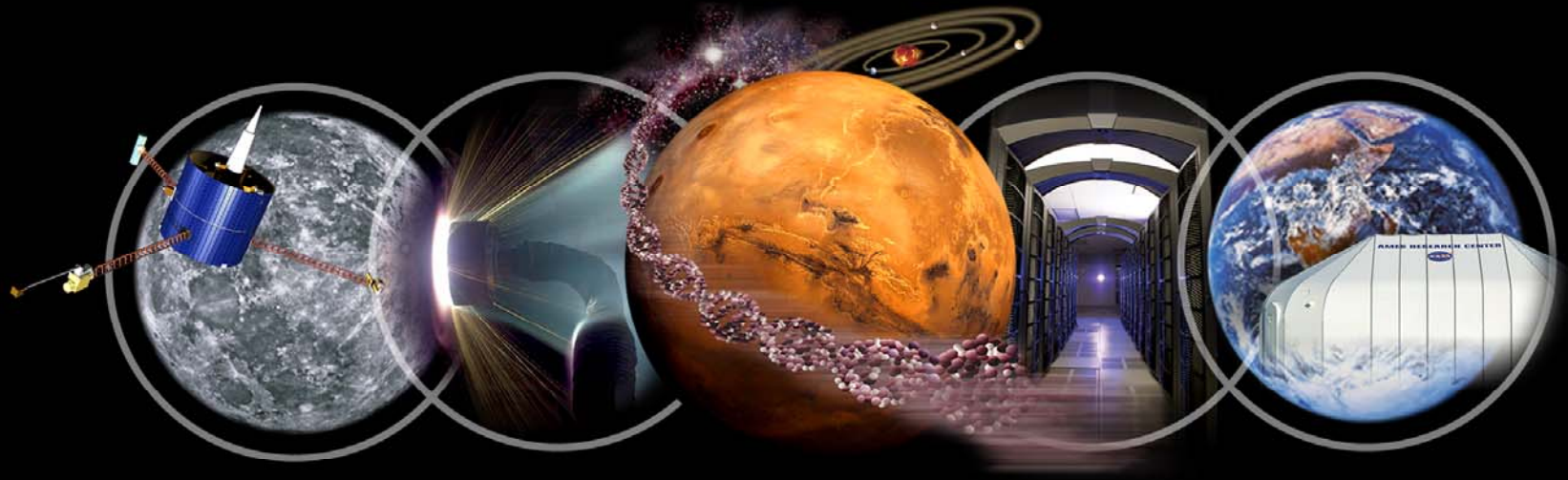
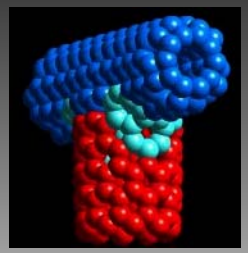
Discovery ➲ Innovation ➲ Solutions



# Nanotechnology for Space Exploration




Jim Arnold for Meyya Meyyappan*

*Director, NASA Ames Center for Nanotechnology(NACNT)

http://www.ipt.arc.nasa.gov

POC: Julie Schonfeld (650) 604 - 6504


NACNT
ARC
UARC
ELORET

Visibilty ➲ Excellence ➲ Impact

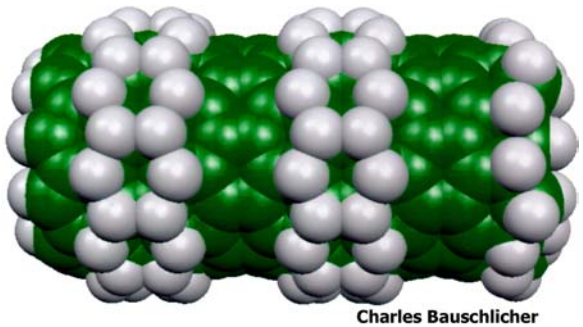
Ames Research Center

# What is Nanotechnology?

Nanotechnology is the creation of **USEFUL/FUNCTIONAL** materials, devices and systems through control of matter on the nanometer length scale and exploitation of novel phenomena and properties (physical, chemical, biological) which arise due to that length scale (NNI)

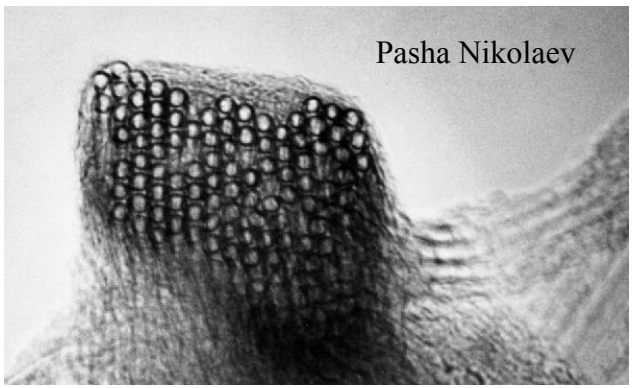
**Experimental and Computational Synergy**

Hydrogenated CNT



Charles Bauschlicher

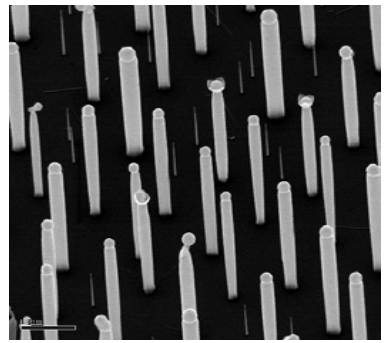
Micrograph of CNT Rope




## Carbon Nanotubes

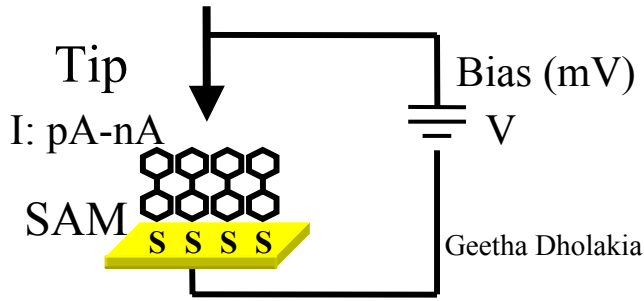
- Tensile Strength 100 X Steel at 1/6 weight
- Thermal Conductivity 2 X Diamond
- Electrical Conductivity 7 X Copper & Semiconductor
- Surface area of 4 grams CNT = Football Field
- U of Tx: CNT Composite Fibers: 4 X Tensile Strength of Spider Silk and 17 X Kevlar

## InSb Nanowires



Hou Tee Ng

## Molecular Electronics



# Take-Home Message

- Nanotechnology is impacting current NASA Missions. Impact will dramatically increase in importance as the field matures.

- NASA must embrace nanotechnology to ensure that the agency is not relegated to using obsolete technology, no longer supported by industry focused on terrestrial applications - especially true for electronics.

- Long Term, example impacts Ames Center for Nanotechnology can provide for NASA in partnership with industry include:
  - A single protective shield, replacing three -> Increased deep space mission affordability while sustaining safety.
  - Radiation resistant/fault tolerant space borne electronics with capabilities exhibited by today's ground processors.
  - Sensors with distributed, nerve-like capability for Integrated System Health Management
  - Novel chemical detectors for Space and Earth Sciences with unparalleled reductions in operational resources: power, mass and volume.
  - In-situ biomarker detectors which can incontrovertibly answer "is life there?"
  - Integral contributions to Ames interests in Bio/Info/Nano Fusion

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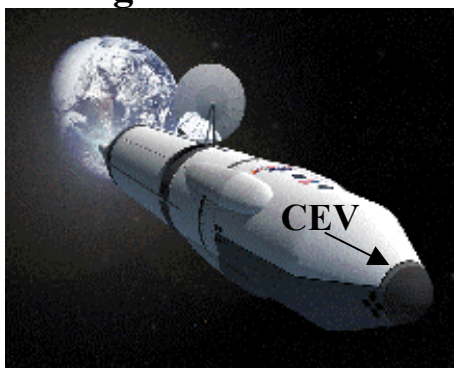
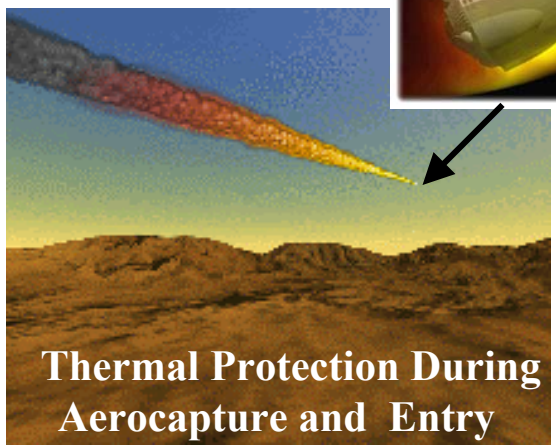
  - A New X-Ray source ready for Space Science mission insertion -> 10 X reductions in science instrument mass.
  - First Generation chemsensors to be flown on a U.S. Naval Academy Flight Experiment.
  - CNT Atomic Force Microscope Tips to Analyze Mars Dust, In Situ and Returned Stardust (2006).
  - 2 - 4 X Improvements in Closed Loop Air Revitalization compared to activated charcoal

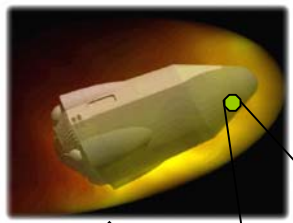
# Examples of Mission Impacts TRL 5-6 in 4 - 15 years

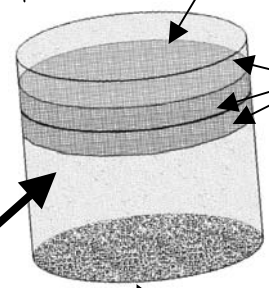
# Examples of Mars Mission Impact: Thermal, Radiation and Impact Protective Shields (TRIPS)

**Radiation, Impact Shield During Transit to Mars**



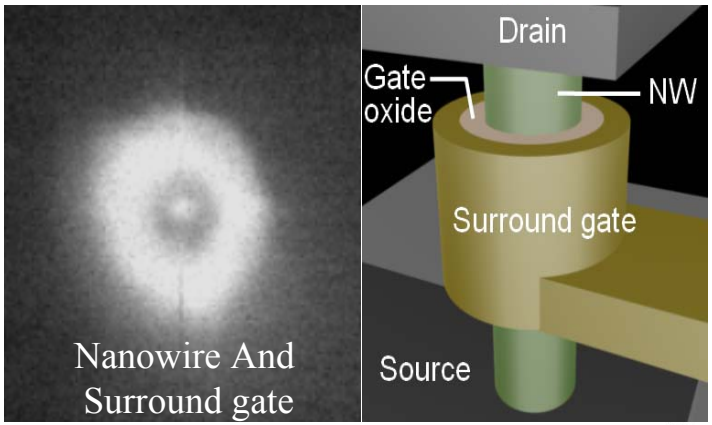



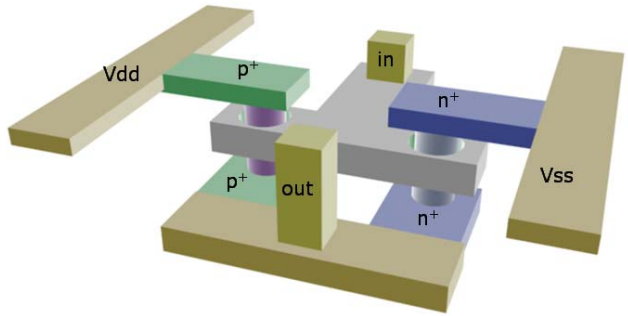

## Spiral Development Proposal

- Determine Rad shielding of existing Carbon Phenolic (CP)
- TRIPS at TRL 4 by 2008
- Thermal , Radiation on mid-density CP for Out-of-Orbit CEV
- TRIPS on Lunar return CEV
- TRIPS on Mars CEV

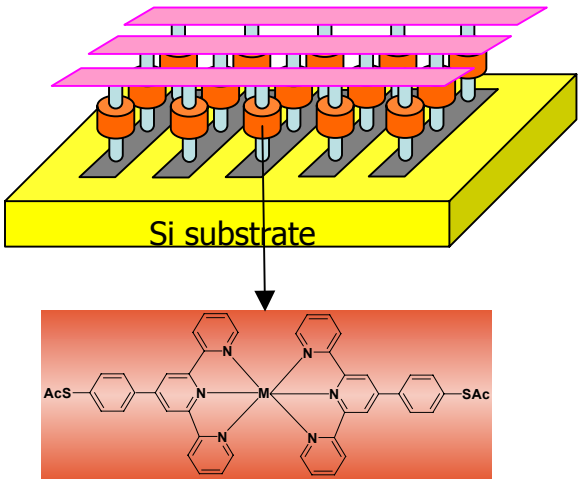
IMPACT: One shield replaces three -> Reducing mass & cost while improving mission safety

# 3-D Nanoelectronics



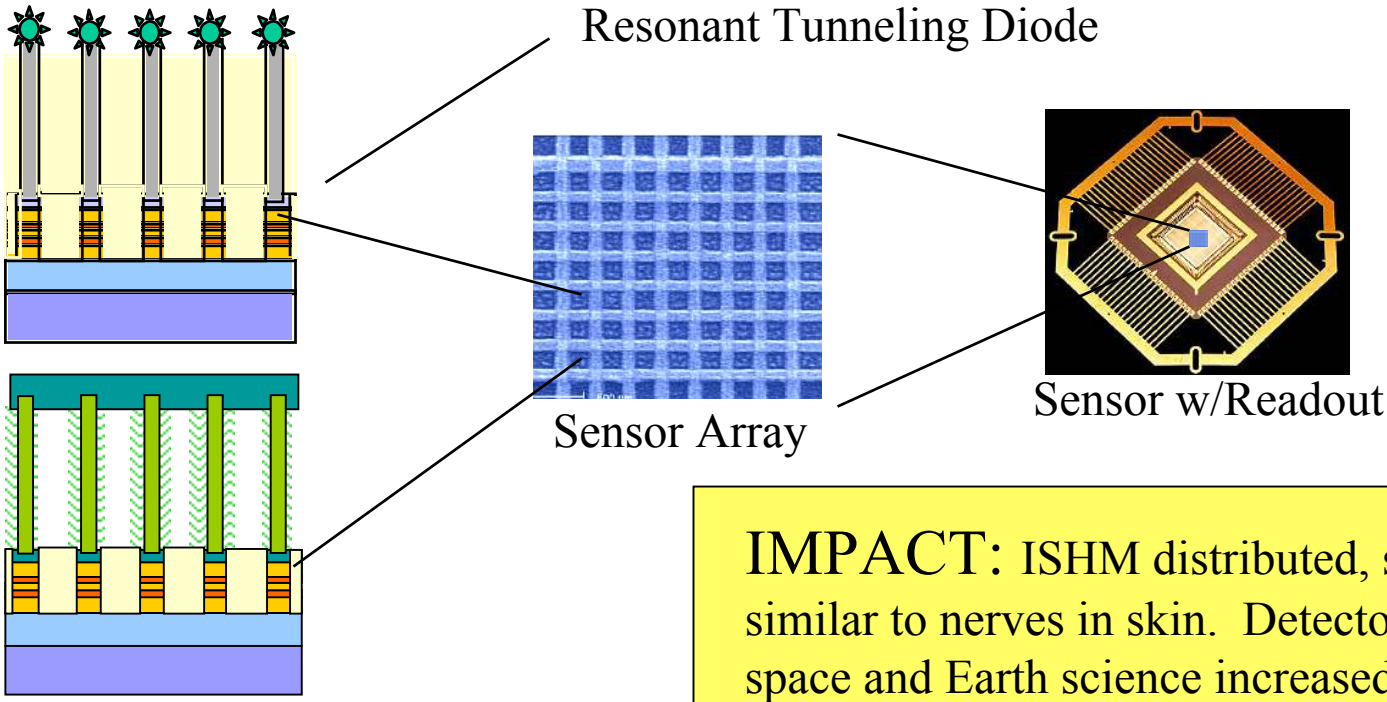

Logic




Non-Volatile Memory

IMPACT: Radiation resistant, in-space electronics with processing up to today's ground capability - Radiation resistance critical for all deep space missions, especially JIMO

# 3 -D Sensor Development



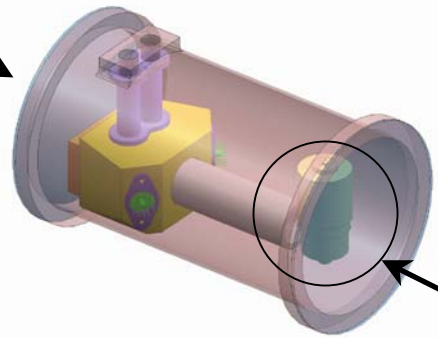

IMPACT: ISHM distributed, sensors similar to nerves in skin. Detectors for space and Earth science increased sensitivity & selectivity while drastically reducing power/volume/mass

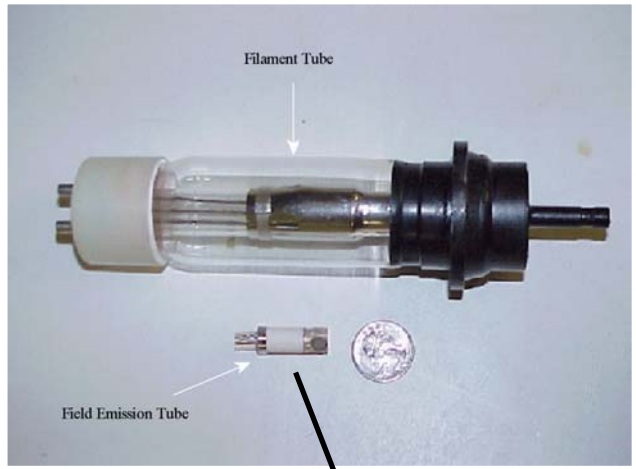
Projected capability: Nanosensors in 3D geometry. Sensitivity: < 500 ppt in gases and < 1000 molecules in water. 1 cubic micron, 1 mW power, several seconds response time

# Impacts on Current Missions

# Carbon Nanotube Field Emitters for Spacecraft Instruments

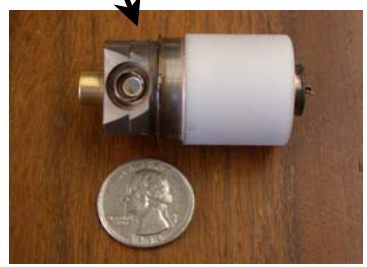
CheMin XRD/XRF instrument, intended for quantitative mineralogy of Venus surface (1 liter, 2 kg, 5 watts).






- Surfaces: Sample gathering and analysis with attendant requirements for new surface science instruments, e.g. inorganic chemistry and Bio measurements.

Miniature carbon nanotube field emission X-ray tube



Work Ongoing GSFC/ARC: Incorporate CNT Field Emission X-Ray into 1-2 Kg Mass Spectrograph

IMPACT: 10 X Reductions in Science Instrument Mass

# Passive Heat Pipes for Thermal Control

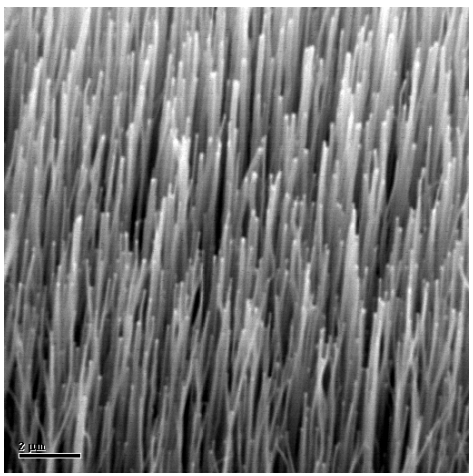
## Current Problem:

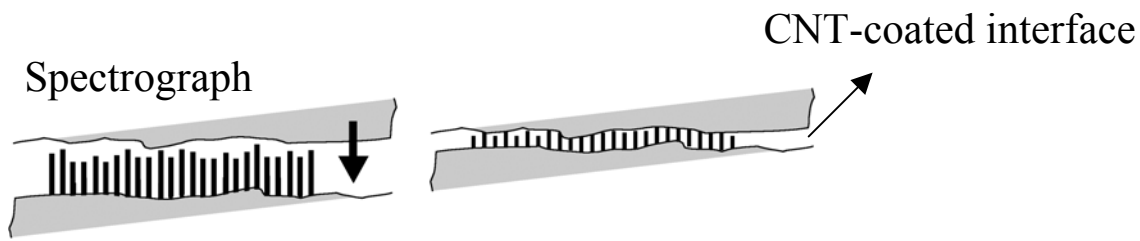
**Hubble Space Telescope Imaging Spectrograph overheats, causing data degration**

## Proposed Solution:

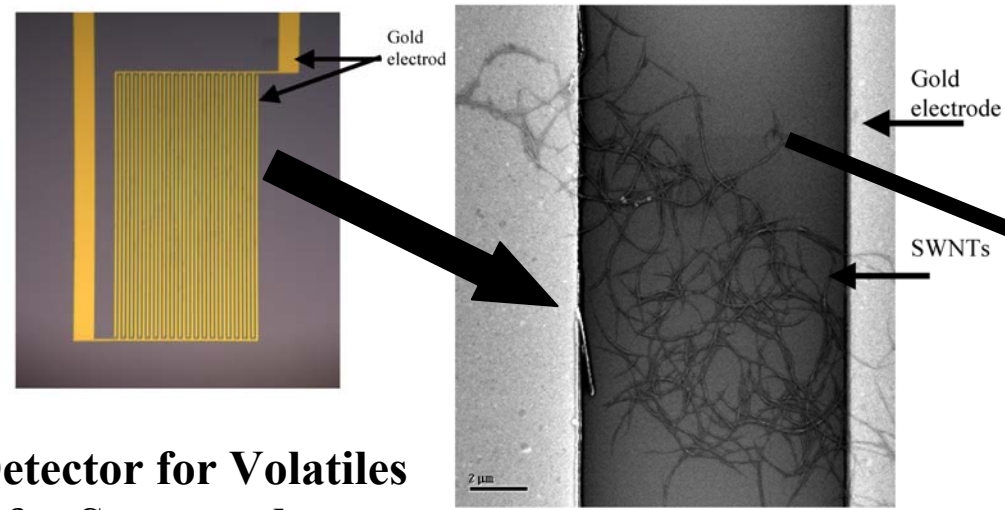
**Carbon Nanotube (CNT) may greatly improve HST's ability to dissipate excess heat. (2X is the goal)**

Impact: First nanostructured solution for passive spacecraft thermal control

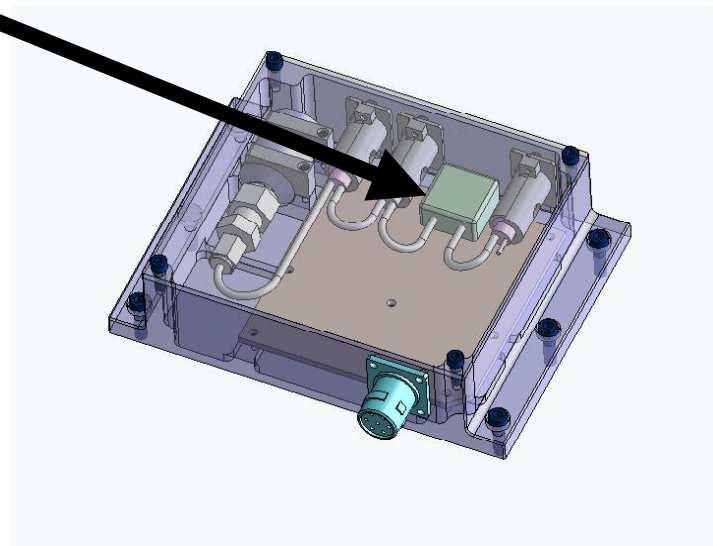


# First-Generation Nanosensors




**$NO_2$ Detector for Volatiles for Space and Earth Science Applications**

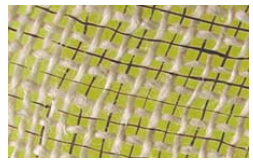


**USN Academy Flight Experiment**
**CDR: April, 2004**
**Hardware Delivery: Dec. 2004**
**Flight: Sept. 2006**

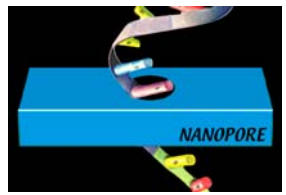
IMPACT: For Earth Science:
100 X Lighter, 10 X Smaller with
Today's Capability -> UAV's
Versus Piloted Vehicles

# Non-Industrial Collaborations

- NASA: GSFC, GRC, LaRC, JSC and JPL
- Academia: UARC -> UC, URETI's (Purdue/UCLA), Rice, plus more, too numerous to mention
- National Nanotechnology Initiative (OSTP, DoC, DoD, DoE, DHS, NIST, DoE, EPA & NIH)
- U.S. Army
  - Natick Soldier Center, CNT characterization for next generation Kevlar
  - MOU with ARL, Aberdeen Proving Ground
  - MOU with ARL, Adelphi

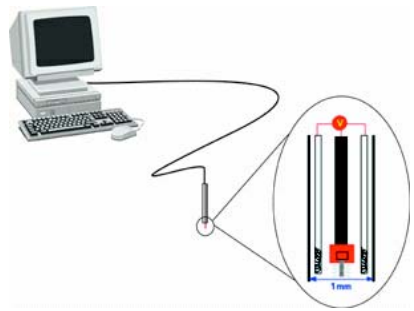


- U.S. Navy
  - Flight test of Ames chemical sensor
  - MOU with Naval postgraduate school




- U.S. Air Force: AFOSR optoelectronics work
- DARPA nanopore/gene sequencing
- TSA chemical sensor work
- NIST collaboration on nanotube AFM probes
- NIH cost sharing on biosensor work
- DOE collaboration

**- PNNL, biosensors & LBL nanomaterials**



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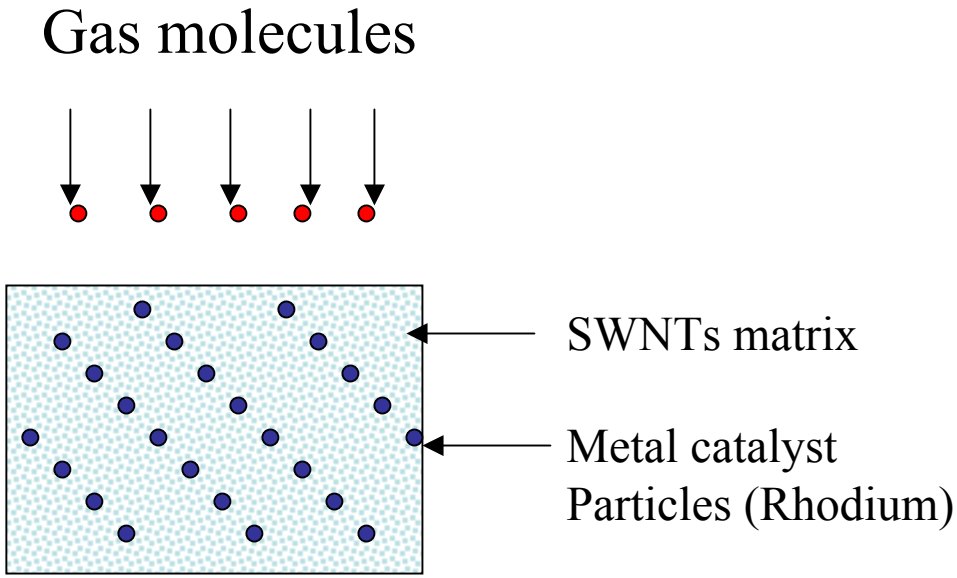
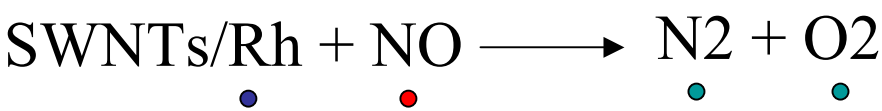
# BACK UP CHARTS

# Closed Loop Air Revitilization



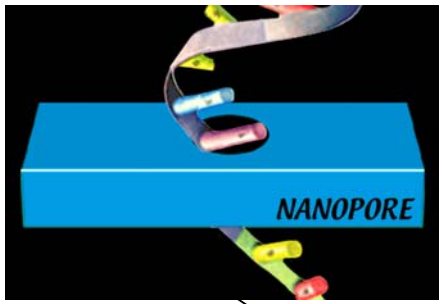

**Process**

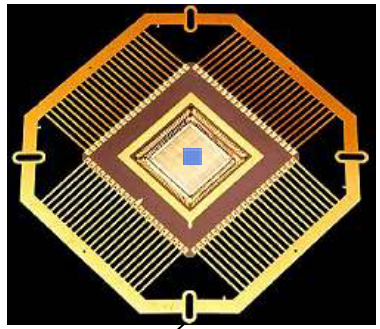
1. Adsorption
2. Catalytic reaction (e.g. decomposition of NO)

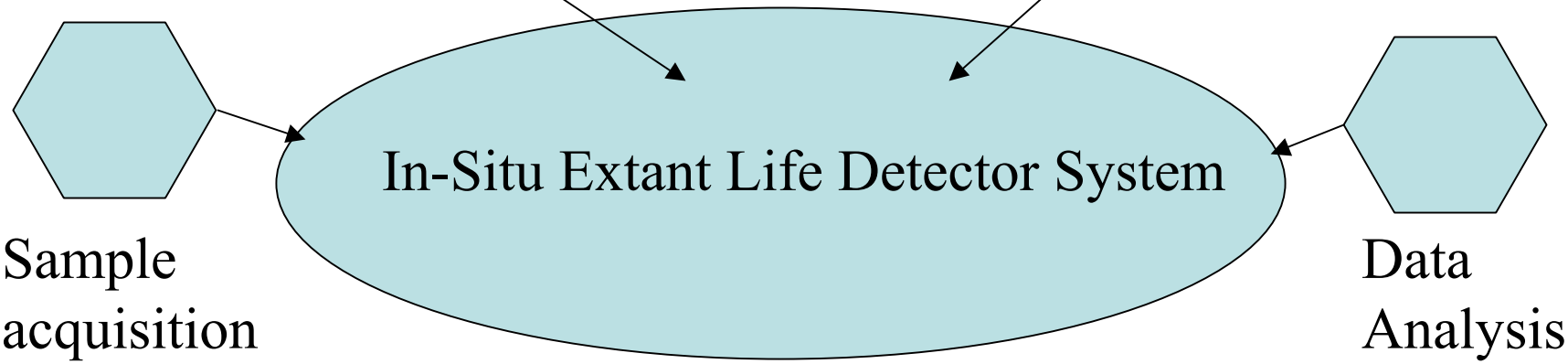



IMPACT: 2 - 4 X Effective as Activated Charcoal on Mass Basis

# Technology for NASA Space Science Missons



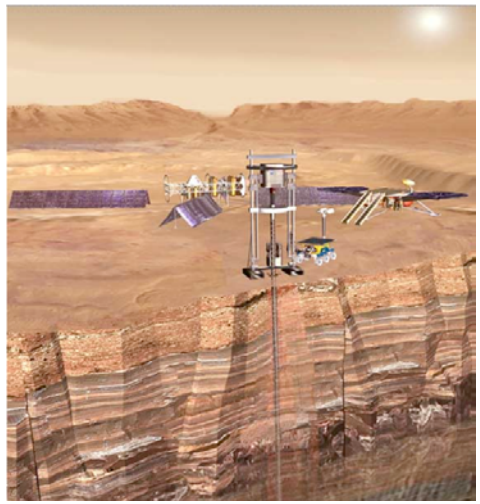






IMPACT:Alien “DNA” can be sequenced w/o prior knowledge, attendant chemicals and nutrients detected -> Incontrovertible Signs of Alien Life

# Uses of Biomarker Detector for NASA Robotic Exploration missons

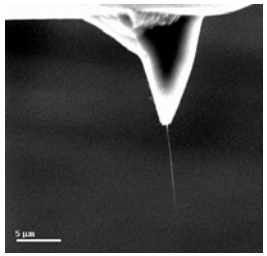
Europa Hydrobot



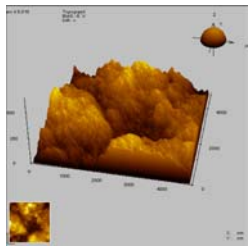
Mars Water Drillings

“Mars Dragonfly”

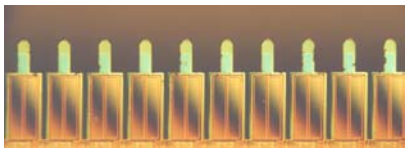
# Space Applications of High-Resolution Carbon Nanotube AFM tips



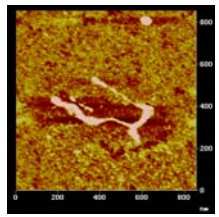
CNT AFM tips



AFM image of Mars dust simulant



Multi-probe AFM cantilevers in (MECA) Phoenix mission



DNA

## Objective

Insert Atomic Force Microscopy (AFM) utilizing Ames-Developed Carbon Nanotube (CNT) tips into ground and in situ applications within near-mid-long term Space Exploration Missions. The CNT tips have greatly extended the spatial resolution and useful life of the tips.

The AFM-CNT technique has broad application, e.g., measure morphologies of electronic devices, Mars Dust and biological analytes such as DNA and Cells

## Task Manager:

Cattien Nguyen, Ames Center For Nanotechnology
Eloret Corp. cvnguyen@mail.arc.nasa.gov
(650) 604-3958

## Participating Organizations:

University Affiliated Research Center
UARC (UC Santa Cruz), Eloret Corp., Purdue (URETI), NIST, IBM Almaden Research Center, Seagate Media Labs, Applied Materials

## Facilities:

**URL:** http://bionano.arc.nasa.gov/

## Funding Profile ($K): FY04-FY07

| FY 04 | FY 05 | FY 06 |
|---|---|---|
| | | |

## Milestones:

**FY04**: Generate AFM images of extracted dust particles from aerogel collector. Continue to develop techniques for biological samples

**FY05**: Fabricate carbon nanotube tips for multi-probe AFM and begin testing of multi-probe nanotube tips. Optimize aerogel extraction process.

**FY06**: Characteriztion of returned samples from Stardustust Mission. Continue testing of multi-probe nanotube tips on Mars dust simulants.

**FY07**: Flight of multi-probe nanotube tips (MECA). Inserted in Mars Missicn as Mars Smart Laboratory