



International Conference

MOON BASE

a Challenge for Humanity



ENABLING
TECHNOLOGIES

Paolo Lugli

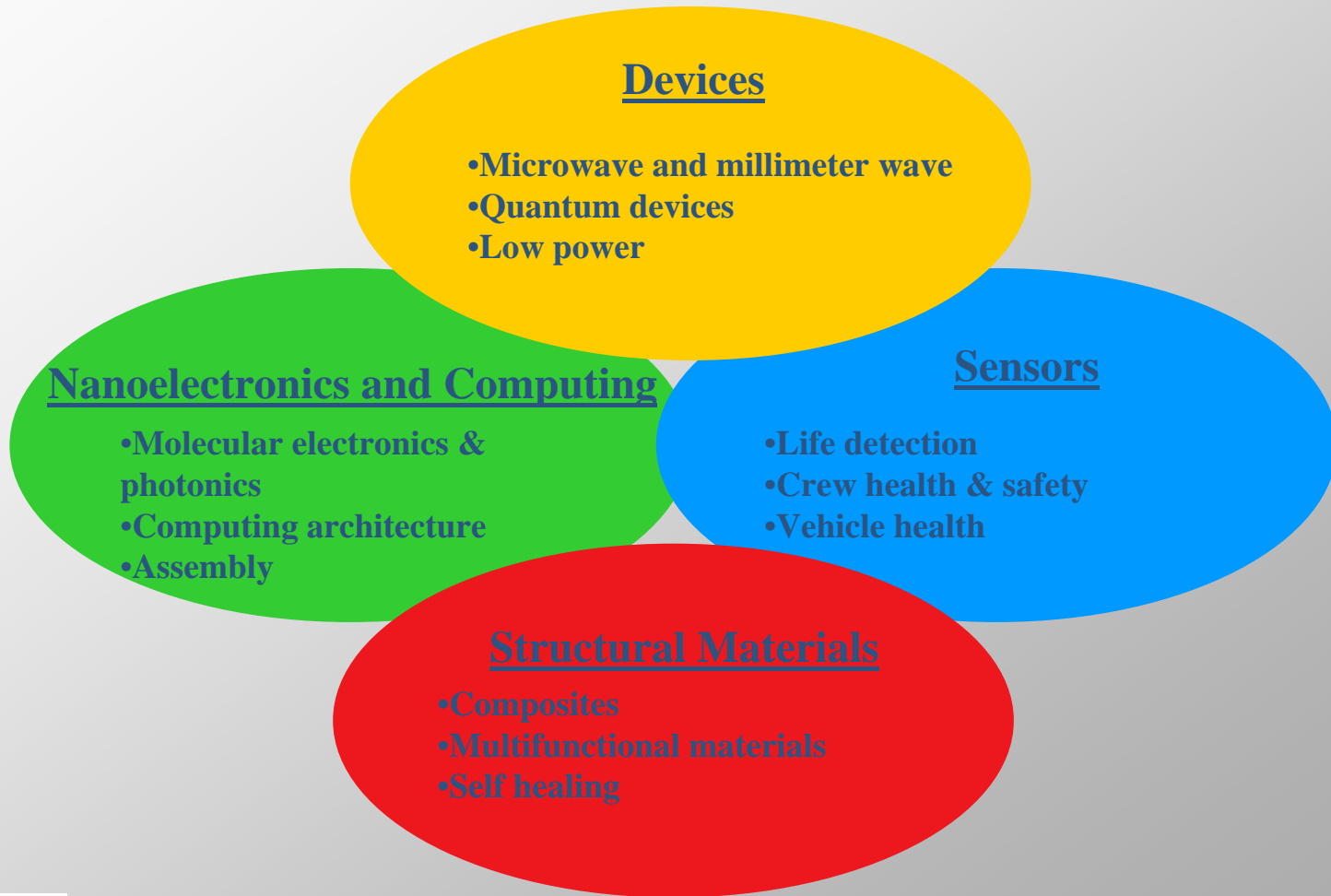
Institute for Nanoelectronics
Technische Universität München

Meyya Meyyappan

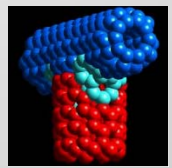
Center for Nanotechnology
NASA Ames Research Center



Technologies, devices and systems



NASA Mission Needs



- Onboard computing systems for future autonomous intelligent vehicles
 - powerful, compact, low power consumption, radiation hard
- High performance computing (Tera- and Peta-flops)
 - processing satellite data
 - integrated space vehicle engineering
 - climate modeling

- Revolutionary computing technologies
- Smart, compact sensors, ultrasmall probes
- Advanced miniaturization of all systems
- Microspacecraft
- 'Thinking' spacecraft
- Micro-, nano-rovers for planetary exploration
- Novel materials for future spacecraft



NASA Nanotechnology Roadmap



C A P A B I L I T Y

Multi-Functional Materials



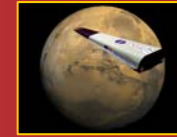
High Strength Materials
(>10 GPa)



Reusable Launch Vehicle
(20% less mass, 20% less noise)



Revolutionary Aircraft Concepts
(30% less mass, 20% less emission, 25% increased range)



Autonomous Spacecraft
(40% less mass)

Bio-Inspired Materials and Processes



Adaptive Self-Repairing Space Missions

Increasing levels of system design and integration →

Materials

- Single-walled nanotube fibers
- Nanotube composites
- Integral thermal/shape control
- Smart "skin" materials
- Biomimetic material systems

Electronics/computing

- Low-Power CNT electronic components
- Molecular computing/data storage
- Fault/radiation tolerant electronics
- Nano electronic "brain" for space Exploration
- Biological computing

Sensors, s/c components

- In-space nanoprobes
- Nano flight system components
- Quantum navigation sensors
- Integrated nanosensor systems
- NEMS flight systems @ $1 \mu\text{W}$

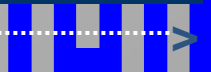
2002

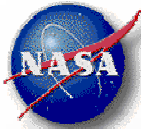
2004

2006

2011

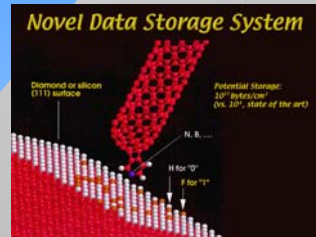
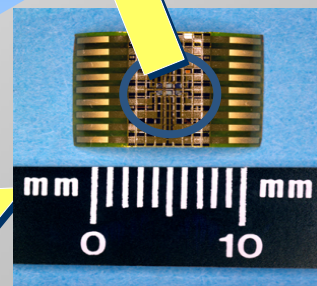
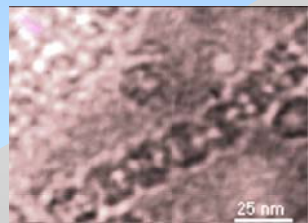
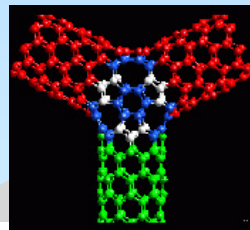
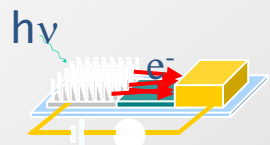
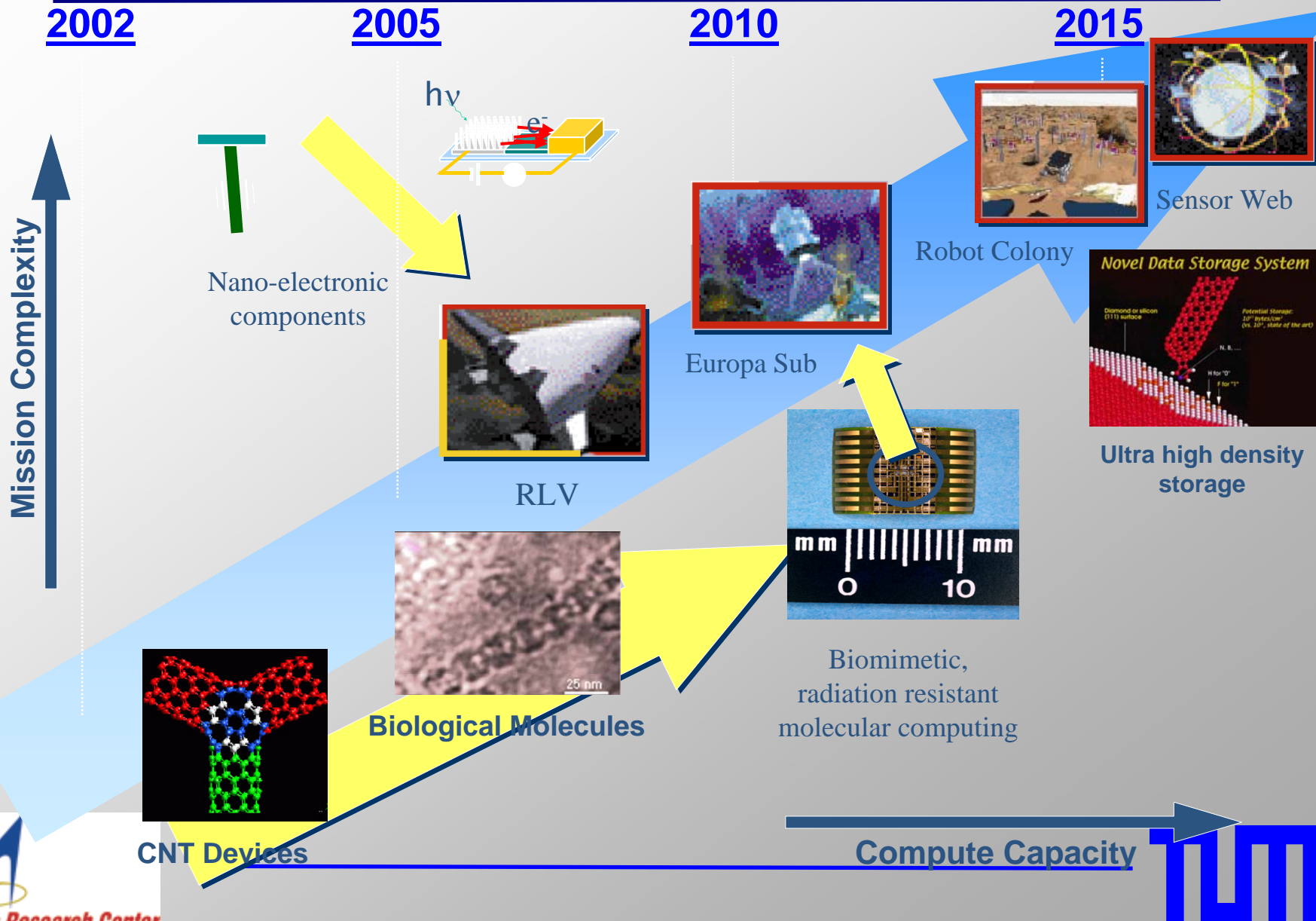
2016

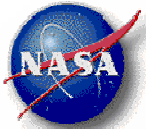




Nanoelectronics and Computing Roadmap

Impact on Space Transportation, Space Science and Earth Science

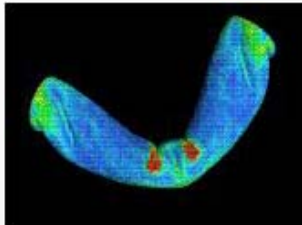




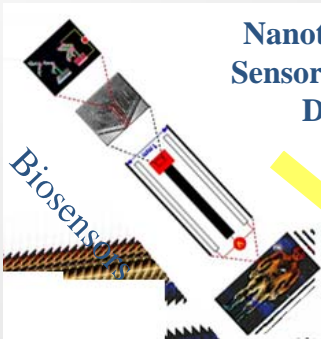
Nanosensor Roadmap

Impact on Space Transportation, HEDS, Space Science and Astrobiology

2002



2005



Nanotube Vibration Sensor for Propulsion Diagnostics



2010



Spacestation



Sharp CJV

2015

Optical Sensors for Synthetic Vision



Europa Sub



Mars Robot Colony



Sensor Web

2020

Multi-sensor Arrays (Chemical, optical and bio)

Missions too early for nanotechnology impact

Nanopore for in situ biomark-sensor



Sensor Capacity

Mission Complexity

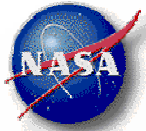
Enabling
Enhancing



1999

DSIRAX
Ames Research Center





Nano-Materials Roadmap

Impact on Space Transportation, Space Science and HEDS

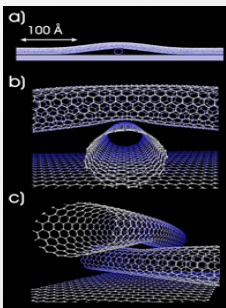
2002

2005

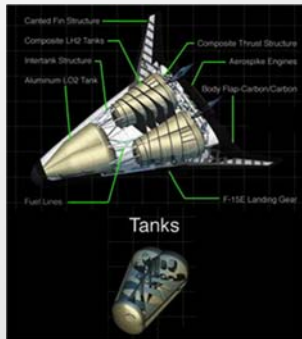
2010

2015

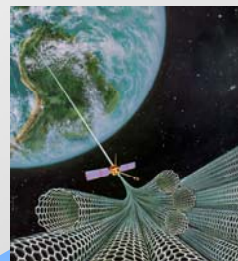
Mission Complexity ↑



Production of single CNT

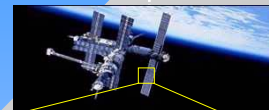


RLV Cryo Tanks

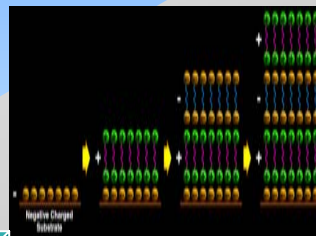


CNT Tethers

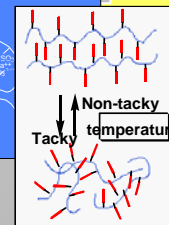
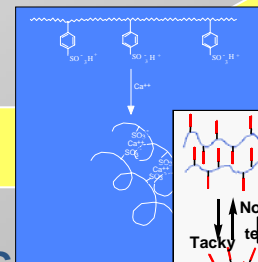
Generation 3 RLV
HEDS Habitats



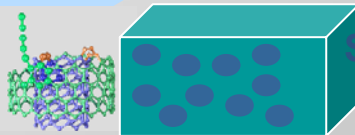
SELF-HEALING MATERIALS



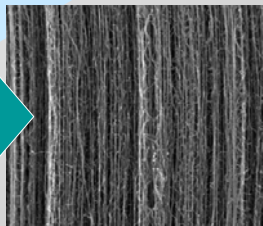
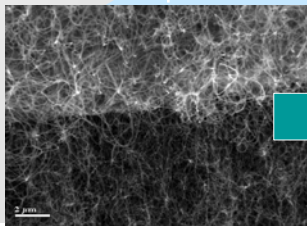
SELF-ASSEMBLING MATERIALS



MULTIFUNCTIONAL MATERIALS



NANOTUBE COMPOSITES

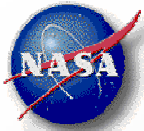


Nanotextiles

Strong Smart Structures



CNT = Carbon Nanotubes



Biomimetics and Bio-inspired Systems

Impact on Space Transportation, Space Science and Earth Science

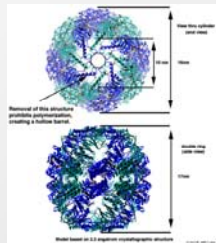
2002

2010

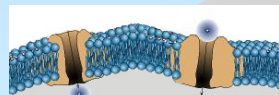
2020

2030

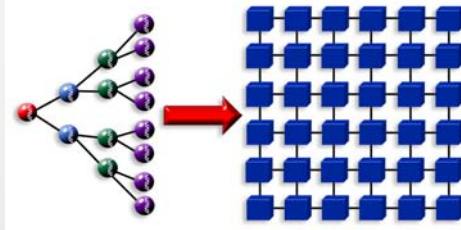
Mission Complexity ↑



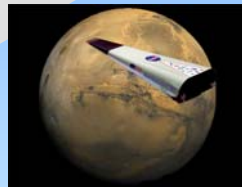
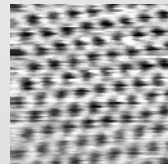
Extremophiles



Biological nanopore
low resolution



Embryonics Self Assembled Array



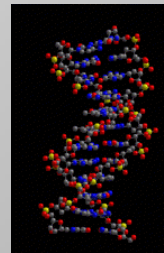
Mars in situ
life detector



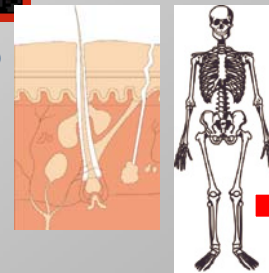
Artificial nanopore
high resolution



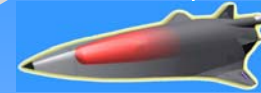
Sensor Web



DNA
Computing



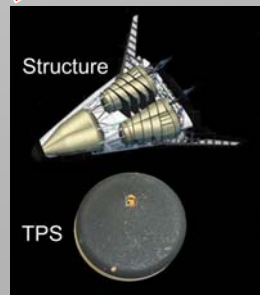
Skin and Bone



Space Transportation



Brain-like
computing



Self healing structure
and thermal protection
systems

Biologically inspired
aero-space systems

Biological Mimicking



OUTLINE

Novel Materials

Gallium Nitride

Organic semiconductors

Nanotechnology

Nanowires

Quantum devices

Carbon Nanotubes

Nanobio-fusion

Conclusions