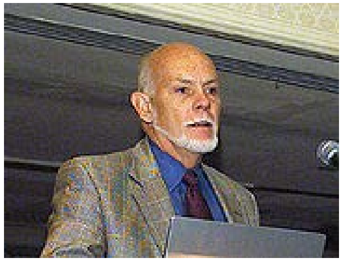
NASA and the National Nanotechnology Initiative

Michael A. Meador, NASA Game Changing Development Program, michael.a.meador@nasa.gov

NASA and the NNI – Past and Present

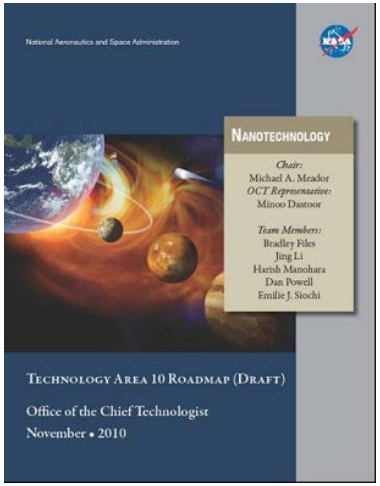
- One of the "founding members" of the NNI and the Interagency Working Group for Nanotechnology
- Reported funding in nanotechnology peaked at about \$50M in 2005, funding for FY17 was \$9.5M
  - Significant drop in NASA support for R&D in 2005, nanotechnology was no exception
  - Rebirth in nanotechnology in 2010 under NASA Chief Technologist, Bobby Braun
    - Nanotechnology included in Space Technology Roadmaps
    - New Project in Nanotechnology under the Game Changing Development Program
  - Current major sources of funding within NASA for nanotechnology are Aeronautics, Space Technology
- NASA views nanotechnology as a tool to develop better:
  - Materials
  - Sensors
  - Water and air purification/remediation
  - Power generation and storage
- Developing technologies in-house but also looking to leverage investments by other agencies
  - NNI is an integral part of that



Funded Rick Smalley to scale up HiPCO process (1990's)

CNT-based Electronic Nose Flew on ISS (2008)

Mechanically Robust Polymer Aerogels Demonstrated as Substrates for Conformal Antennas



Nanotechnology Space Technology Roadmap (2010, updated 2014)

“An innovative and sustainable program of exploration ...”

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations;”
- ***Space Policy Directive 4***

- **Structurally efficient launch vehicles and spacecraft**
  - Lightweight materials
  - Multifunctionality
  - Damage tolerant
- **Robust habitation and excursion systems**
  - Missions will be longer than Apollo with longer duration and more numerous sorties/EVAs
  - Environment is harsh – dust, radiation, temperature
  - *In situ* resource utilization, including recycling, will be needed
  - In space manufacturing will be needed to create replacement parts, effect repairs
  - Astronaut health management will be more challenging, especially for Mars
- **Nanotechnology is critical to addressing these challenges**

3D Printed Mars Habitat Challenge Winning Concept – Team Zopherus (Rogers, AR)

In Situ Resource Utillization (ISRU)

ISRU involves any hardware or operation that harnesses and utilizes 'in-situ' resources to create products and services for robotic and human exploration

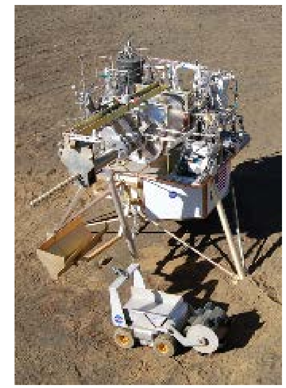
Resource Assessment (Prospecting)

sampling, sniffing, analyzing species

Resource Acquisition

abrasive environment, low-pressure gases

Resource Processing/ Consumable Production



Chemical processing plant

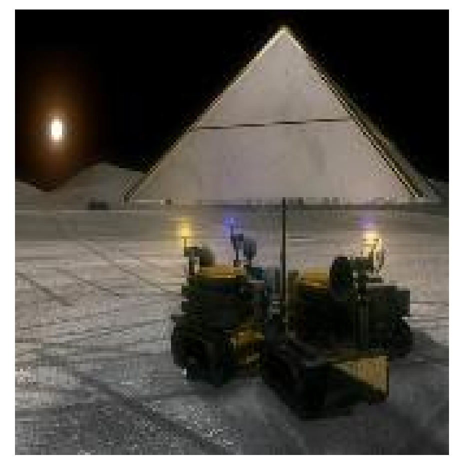
In Situ Manufacturing

Processing in-situ feedstock into parts

In Situ Construction

changing properties of loose in-situ materials into consolidated structural materials

In Situ Energy



Generation and storage of electrical, thermal, and chemical energy

Nanotechnology and ISRU?

Nanomaterial catalysts or catalyst substrates for increased active area in reactors

Sabatier catalyst material after vibration testing

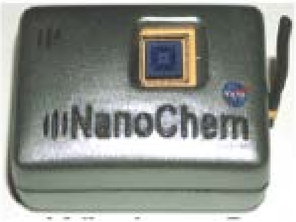
Insulation material for hot (reactors) and cold (cryo tanks) components in the not-quite-a-vacuum environment on Mars

Improved or self-healing coatings and electronics for excavation and construction equipment dealing with abrasive materials

RASSOR excavator delivering regolith

Flexible Aerogel insulation

Nanosensors for prospecting, hazard detection, and health mgmt of our chemistry plant



(L) CNT “Electronic Nose”; (R) Nanochemsensor flown on ISS

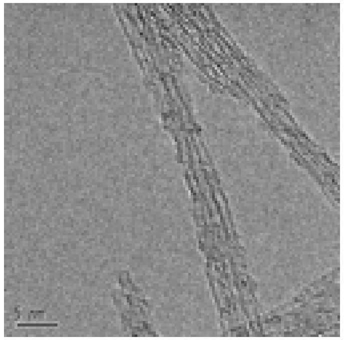
Nanomaterial sorption materials to increase mass adsorbed to mass adsorbent ratio for Mars atmosphere acquisition or during gas separation steps

Sorption pump prototype unit

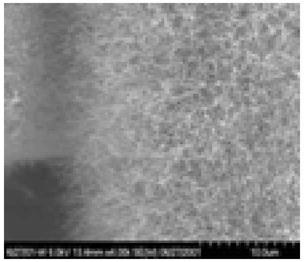
How has NASA benefited from NNI collaborations?

- Carbon Nanotube Materials
- Water Purification

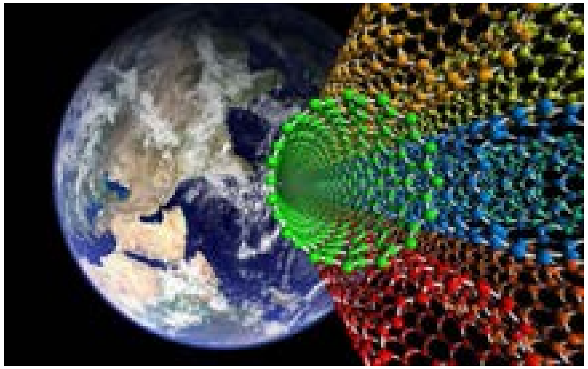
Lightweight, Multifunctional Materials- Carbon Nanotubes



Purified Single Wall Carbon Nanotubes



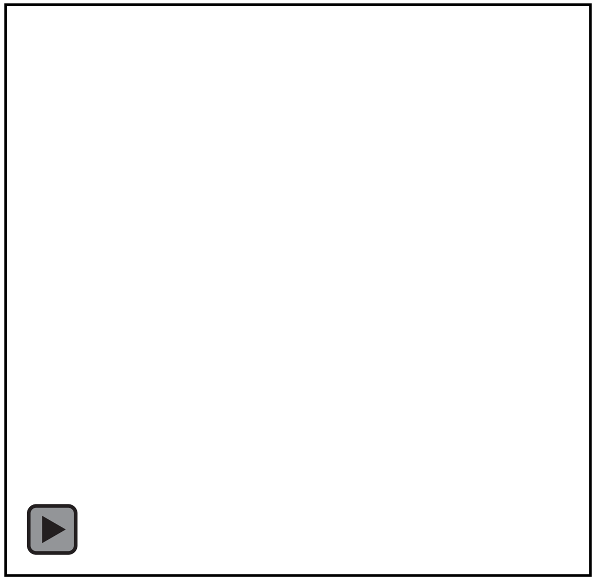
Nanotube Modified Substrates

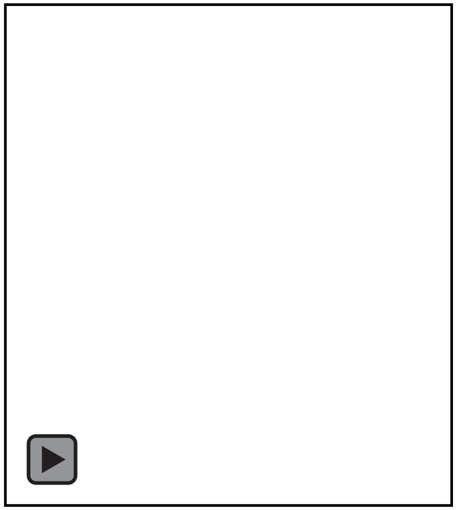


Carbon Nanotube Space Elevator

- Carbon nanotubes (CNTs) have remarkable properties-
  - ➤ Specific strength 150X that of conventional carbon fibers, 100X aluminum
  - ➤ Elongation 10X that of conventional carbon fibers
  - ➤ Electrical and thermal conductivities ~10X that of high conductivity carbon fibers
- Because of these properties, carbon nanotubes have been proposed for disruptive applications such as a space elevator cable
- Widespread use of CNTs in aerospace hampered by inability to uniformly and reliably disperse them into polymers and other host materials

Carbon Nanotube Fibers in Production





- Manufacturing technique allows for the direct production of fibers from carbon nanotubes – overcomes the dispersion problem
  - Drop-in replacement for conventional carbon fibers in polymer-based composites
  - Carbon nanotube fiber reinforced composites could reduce mass of launch vehicles by as much as 30%
- NASA is leveraging investments by DoD and NRO in the development of scale-able production of CNT reinforcements (Nanocomp Technologies)

1st Ever Demonstration of CNT Composites in Aerospace Structure

Carbon Nanotube (CNT) Fiber

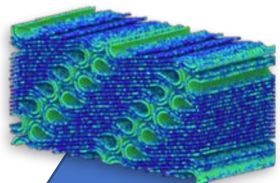
Filament Winding of Composite Overwrap Pressure Vessel (COPV)

COPV Installed in Sounding Rocket Cold Gas Thruster System

Successful Flight Test on May 16. 2017

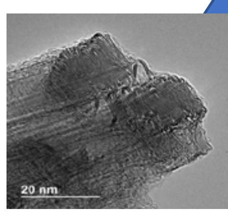
- Significantly improved the mechanical properties of CNT fibers and fiber reinforced composites – specific tensile strength on par with standard aerospace composites
- Developed flight heritage for CNT composites
- Further work is needed to develop composites that more fully exploit the unique properties of CNTs

Institute for Ultra-strong Composites by Design (US-COMP)



Computational Tools
- Multiscale Modeling
- Topology Optimization

MGI



Experimental Tools
- Multiscale Characterization
- Panel Level Mechanical Tests

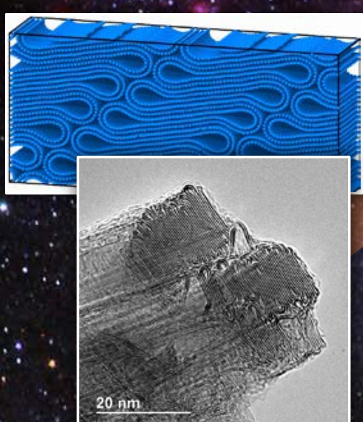
Digital Data for Design
- Structure/Property Relationships
- Mechanical Property Database

Develop integrated multiscale modeling and simulation, experimental tools, and design methods to enable the development of CNT reinforced composites with:

✓300% increase in tensile properties
✓50% increase in fracture toughness

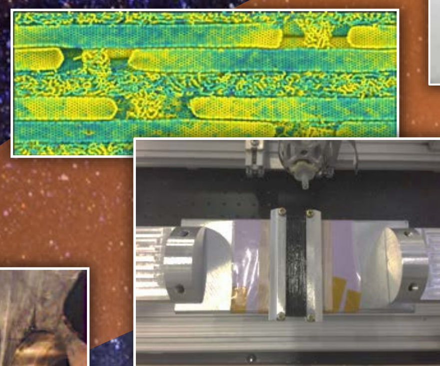
Technical Monitor: Emilie Siochi, NASA Langley

NASA Carbon Nanotube Structural Materials R&D



Computationally Guided CNT Reinforcement Optimization – STRI, ESI, GCD
(US-COMP STRI, NASA, Nanocomp, U of Minnesota, U of Virginia)

CNT Reinforcement Scale-up - GCD
(Nanocomp)



Computationally Guided CNT Composite Development – STRI, GCD
(NASA, US-COMP STRI)

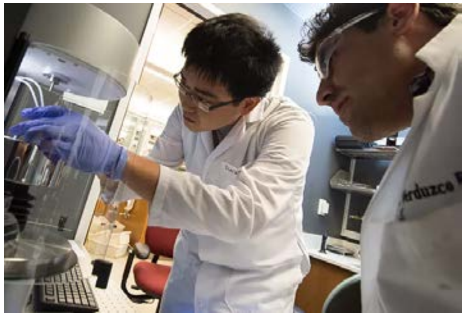
CNT Component Prototyping and Testing - GCD
(NASA + Industry)

Component Demo - TBD
(NASA + Industry)

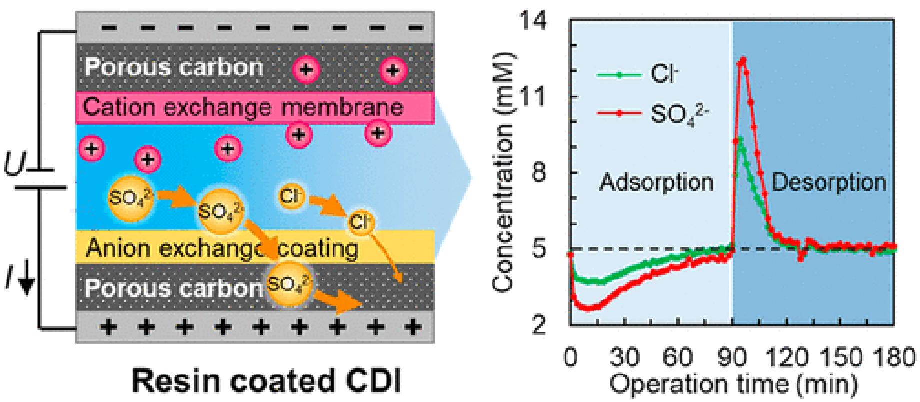
NASA/Rice Collaborate on Water Purification

- Long duration human space exploration requires compact, low power demand, reliable water purification systems
- NASA Johnson Space Center and the NSF's Nanotechnology-Enabled Water Treatment Center at Rice University are collaborating to:
  - Evaluate water purification developed for terrestrial applications for use in space exploration
  - Provide opportunities for students to be involved in NASA technology development

2018 NEWT/NASA summer intern group



Professor Rafael Verduzco served as host & mentor for the 2018 NASA/NEWT summer students



Capacitive Deionization Process Developed for Descaling of Boiler Water Being Evaluated for Urine Processing

Space Technology Pipeline

Space Technology Research Grants
Opportunities to Propose

Engage Academia*: tap into* ***spectrum*** *of academic researchers, from graduate students to senior faculty members, to examine the theoretical feasibility of ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable.*

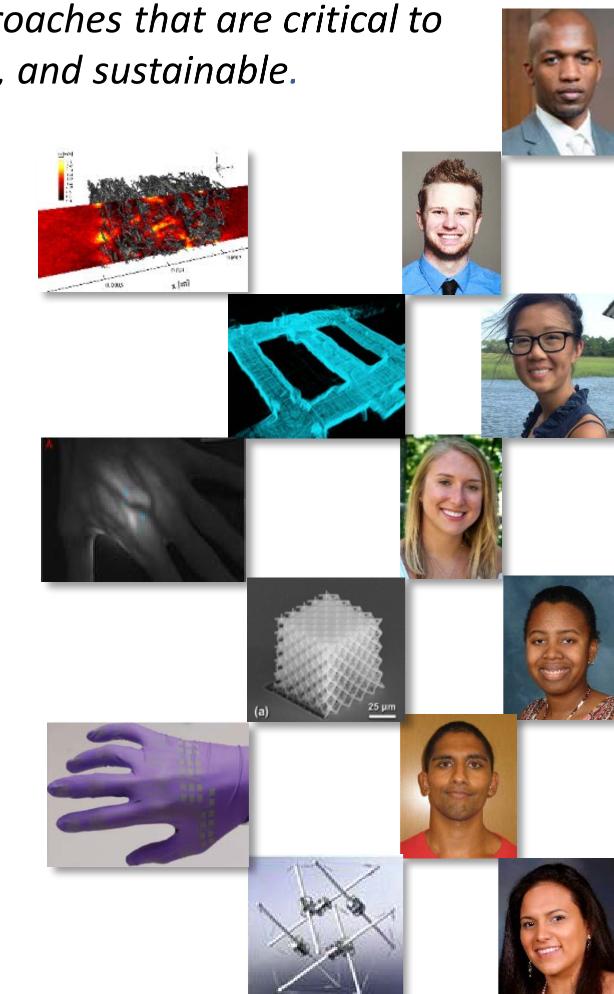
NASA Space Technology Research Fellowships
- Graduate student research in space technology; research conducted on campuses and at NASA Centers and not-for-profit R&D labs

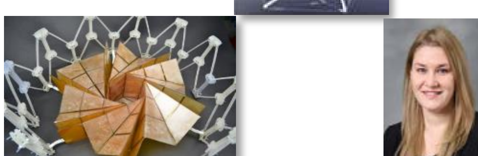
Early Career Faculty
- Focused on supporting outstanding faculty researchers early in their careers as they conduct space technology research of high priority to NASA's Mission Directorates

Early Stage Innovations
- University-led, possibly multiple investigator, efforts on early-stage space technology research of high priority to NASA's Mission Directorates
- Paid teaming with other universities, industry and non-profits permitted

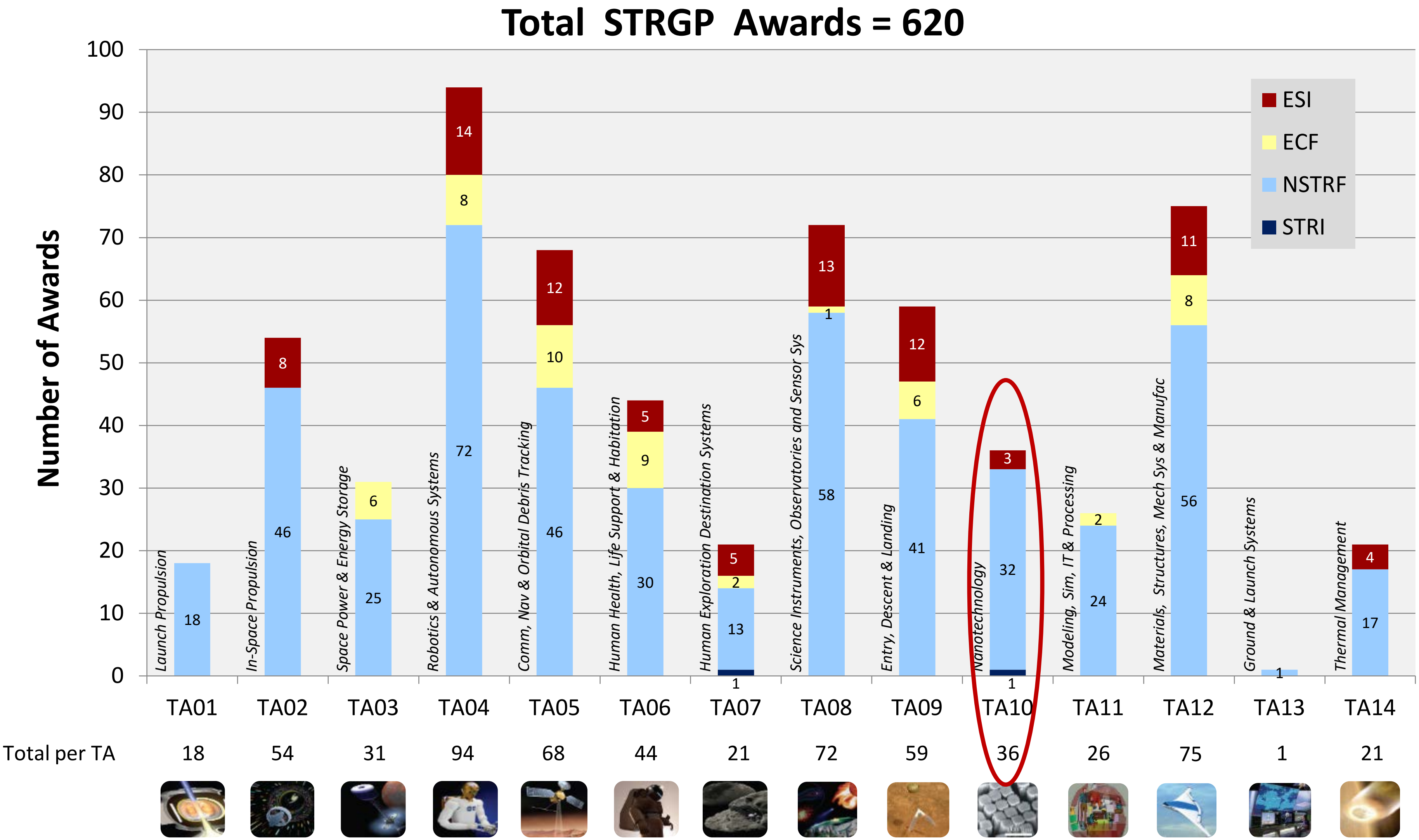
Space Technology Research Institutes
- University-led, integrated, multidisciplinary teams focused on high-priority early-stage space technology research for several years

Accelerate development of groundbreaking high-risk/high-payoff low-TRL space technologies





STRG Portfolio - Awards To-Date
Awards by Technology Area since 2011



https://www.nasa.gov/offices/oct/home/roadmaps/index.html#.VT1OZmNTd20

Perspective on the NNCO as Former NNCO Director

- Performs statutory responsibilities outlined in the 21st Century Nanotechnology R&D Act
- Works with NSET agencies to serve the broader goals of the NNI in ways that individual agencies can't
  - Act as a central point of contact for information of US efforts in nanotechnology research, development, commercialization, and education
  - Highlighting overall successes of the NNI to decision makers, the public (including students), and other stakeholders
  - Outreach to the broader nanotechnology community including professional societies, trade groups, and international organizations
  - Promote educational efforts to stimulate interest in STEM and develop the next generation of scientists and engineers
- All of this is critical to ensuring that the NNI remains a viable initiative

Conclusions

- Nanotechnology is an important tool in meeting future NASA mission needs
- NASA has had a rich and fruitful history with the NNI
  - Member of Interagency Working Group on Nanotechnology, founding member of NNI
  - NNI has and continues to facilitate NASA's ability to leverage resources and investments of other agencies and adapt to meet unique mission needs – critical for agencies with limited resources
- NNCO has a critical role within the NNI
  - Uniquely supports the broader goals of the NNI
  - Adapting to meet the changing needs of the Initiative, member agenices, and the broader nanotechnology community