PROGRESS AND PLANS OF NATIONAL NANOTECHNOLOGY INITIATIVE (NNI) AGENCIES

February 2018

National Aeronautics and Space Administration (NASA)

Summary

The National Aeronautics and Space Administration is supporting research and development in nanotechnology to address NASA mission needs in aeronautics and space exploration. Nanotechnology R&D efforts include a combination of in-house activities, grants, and contracts that are focused in areas such as the development of advanced lightweight and multifunctional materials to reduce vehicle mass and improve performance; new materials to improve the performance of power generation and storage systems; advanced catalysts and membranes for more efficient air and water purification systems for long-duration human exploration missions; and new materials and manufacturing methods to produce low-power and compact sensors to detect chemical and biological species for astronaut health management and robotic exploration. Such efforts include a combination of theoretical and experimental research. NASA also supports the education and training of the next generation of scientists and engineers through a variety of programs ranging from internships for undergraduates and high school students, graduate fellowships such as the Space Technology Research Fellowships, and postdoctoral fellowships, as well as the continued development of faculty through Space Technology Early Career Awards and other activities.

Key Technical Accomplishments by NNI Goal

Goal 1. Advance a World-Class Nanotechnology Research and Development Program

In late fiscal year (FY) 2017, NASA announced the establishment of a multi-university Space Technology Research Institute (NSTRI) focused on the development of computational tools, carbon nanotube material synthesis techniques, and composite processing and testing methods to produce carbon nanotube composites with mechanical properties that exceed those of today's carbon fiber reinforced composites. The Ultra-Strong Composites by Design (US-COMP) NSTRI is a five-year, $15 million collaboration between investigators at eleven universities, industry, and Government labs. Computational tools developed under this institute will be made publically available to promote impact that benefits the broader nanotechnology and aerospace communities and the public. NASA is also funding a companion in-house effort to develop approaches to enhance the load transfer between carbon nanotube bundles to improve the load-carrying capability of carbon nanotube composites. (This work is in support of the Nanomanufacturing Nanotechnology Signature Initiative.)

Previous work by the Department of Defense and industry has shown that substitution of carbon nanotubes in place of metallic conductors in data cables can reduce cable mass by between 30 and 70 percent. NASA researchers have been working on the utilization of polymer aerogel-based nanoporous dielectrics to replace conventional fluoropolymer dielectrics in data cables in order to further reduce cable mass. Recently these researchers have developed a class of thermally reversible polymer gels and utilized them in a

continuous process to coat carbon nanotube wires. NASA is currently working with Aerogel Technologies to transfer this technology.

Goal 2. Foster the Transfer of New Technologies into Products for Commercial and Public Benefit

NASA has been working with a small U.S. business, Aerogel Technologies, to commercialize polymer aerogels for use in high-volume applications. Aerogels are lightweight, nanoporous materials with outstanding electrical, thermal, and acoustic insulation properties, as well as ultra-low dielectric constants. A major barrier to widespread commercialization of aerogels is their poor mechanical durability. NASA researchers have developed a family of polymer aerogels that are mechanically robust, have electrical and thermal insulation capabilities equivalent to those of conventional aerogels, and are very flame resistant. Thin films processed from these aerogels can be folded and creased and do not tear or crack. Aerogel Technologies has licensed this technology, has recently developed a cost-effective method to produce these aerogels at production scale, and is working with several end users to pursue their use in commercial applications such as aircraft interiors and automotive components.

Plans and Priorities by Program Component Area (PCA)

PCA 1. Nanotechnology Signature Initiatives and Grand Challenges

Under a Space Technology Mission Directorate Tipping Point Project, NASA is collaborating with Orbital ATK to investigate the vibration-damping capability of carbon nanotube composites in aerospace structures. Application of these composites in self-damping structures would eliminate or reduce the need for added vibration damping systems to protect spacecraft during launch and would significantly reduce the parasitic weight associated with these systems.

NASA has funded several SBIR grants in support of efforts in long-duration human spaceflight, including the development of antimicrobial and self-cleaning coatings, sensors for the detection of ethylene, and sensor array platforms for the detection of calcium and pH in urine.

PCA 2. Foundational Research

The Space Technology Mission Directorate recently awarded two grants under the Early Stage Innovation Program to develop mesoscale computational models to enhance the understanding of load-carrying mechanisms in carbon nanotube composites, and provide insight into how these composites can be designed to more fully exploit the superior mechanical properties of carbon nanotubes on the macro-scale.

PCA 3. Nanotechnology-Enabled Applications, Devices, and Systems

Under the Convergent Aeronautical Solution's Conformal Lightweight Antenna Systems for Aeronautical Communications Technologies (CLAS-ACT) sub-project, NASA researchers are working on developing polymer-aerogel-based conformal antennas for use in beyond-line-of-sight communication for unmanned aerial vehicles (UAVs). Use of polymer aerogels as low-dielectric substrates for patch antennas was demonstrated in 2016 and shown to enable significant reductions in antenna mass and improvements in performance. Under the present project, a reconfigurable antenna array fabricated on a flexible polyimide aerogel substrate will be flight tested on the NASA Ikhana UAV in late FY 2019.

As NASA and the U.S. aircraft industry continue to pursue hybrid electric propulsion for use in future commercial aviation, a major technology need is in the development of lighter-weight and more robust wiring for use in power distribution lines and electric motors. Under an Advanced Air Transport Technology project, NASA scientists are working on the development of carbon nanoconductor-based wiring and boron

nitride nanocomposite thermally conductive electrical insulation to reduce the mass and improve heat dissipation in electric motors for use in propulsion systems. Nanocomposite-based multifunctional multilayer insulation is also under development by NASA under a project funded by the Aeronautics Research Mission Directorate (ARMD) Transformational Tools and Technologies Program.

NASA continues to explore the development of nanosensors for use in astronaut health management, for detection of chemical and biological species on other planets, and for aerospace vehicle health monitoring. Carbon nanotube and graphene-based nanosensors were fabricated in a three-dimensional (3D) printer as embedded strain sensors for use in future aircraft. These sensors will be flight tested in FY 2018 as part of the ARMD Advanced Air Transport Technology Program.

In collaboration with MIT, NASA is developing an ultra-compact, low-mass, and low-cost multispectral imager based upon a quantum dot array (QDA). The QDA acts as an adsorptive filter array and replaces prisms and gratings that require a long pathlength to achieve high spectral resolution. Due to its small size, this instrument will be suitable for small satellite missions for a wide range of science applications, including auroral imaging, mapping of water and hydroxyl in lunar regolith, spectroscopy of the atmosphere or surface of planetary bodies such as Venus and Mars, studying volatiles in comet comae, glaciological mapping, and imaging ocean color to understand its biogeochemistry.