Annex to the National Nanotechnology Initiative (NNI) Supplement to the President's 2021 Budget. Overview of Nanotechnology R&D by Agency[1]

Consumer Product Safety Commission (CPSC)

The CPSC staff continues to engage with Federal partners in a number of projects that are intended to quantify exposures to engineered nanomaterials, and to develop robust models to predict exposure and health effects. CPSC and NIST are developing *in vitro* test methods to determine the toxic endpoints of a variety of nanomaterials. CPSC, EPA, NIOSH, and NIST are conducting emissions testing on fused deposition modeling (FDM) 3D printers, to characterize exposure and determine best practices for product use. CPSC and NIOSH are conducting toxicity tests of 3D printer emissions. CPSC and the Army Corps of Engineers Engineer Research and Development Center (ERDC) continue their partnership along with the Duke Center for Environmental Implications of NanoTechnology (CEINT) to develop a model to predict the health effects of matrix-bound nanomaterials. This project is also using novel and advanced techniques to capture toxicity and exposure data for a range of nanomaterials. Staff and partners are engaged in voluntary standards activities to create validated methods for quantifying and characterizing exposures from products. The staff will also develop and validate *in vitro* methods to test existing and emerging nanomaterials that are used in consumer products. Similarly, staff and contractors are compiling existing toxicity data on nanomaterials that are the most utilized in consumer products. When the data are sufficient and of high quality, the reviews determine the appropriate dose metrics as well as potential acceptable daily intake (ADI) values to identify possible health hazards from specific routes of exposure.

Department of Commerce (DOC)

National Institute of Standards and Technology (NIST). An important component of NIST's mission to promote U.S. innovation and industrial competitiveness is the institute's research advancing nanoscale measurement science, standards, and technology. From leading cutting-edge research, to providing world-class facilities, to coordinating the development of standards that promote trade, NIST's intramural nanotechnology research program directly impacts the Nation's economy and well-being. The nanotechnology research conducted in NIST's laboratories results in measurements, standards, and data crucial to a wide range of industries and Federal agencies, from new measurement and fabrication methods for advanced manufacturing to reference materials and data needed to advance the use of nanotechnology. NIST further supports the U.S. nanotechnology enterprise through its user facilities, including the NIST Center for Neutron Research (NCNR) and the Center for Nanoscale Science and Technology (CNST). NIST staff members contribute unique technical expertise and leadership in nanotechnology-related standards development and international cooperation activities such as the Organisation for Economic Co-operation and Development (OECD) Working Party on Manufactured Nanomaterials, the International Organization for Standardization (ISO) Technical Committee 229, the International Electrotechnical Commission Technical Committee 113, and ASTM International Committee E56. NIST's world-class expertise in measurement, characterization, and standards development helps ensure that the resulting international standards reflect the state of technology, are unbiased, and facilitate innovation and commercialization and user confidence in the safety of nanotechnology. Interagency coordination and information sharing related to these activities is facilitated through the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the National Science and Technology Council.

U.S. Patent and Trademark Office (USPTO). The USPTO mission is to foster innovation, competitiveness, and job growth in the United States by conducting high-quality and timely patent and trademark examination and review proceedings in order to produce reliable and predictable intellectual property

[1] This document is a work of the United States Government and is in the public domain (see 17 USC §105). It may be distributed and copied, with acknowledgement to the National Nanotechnology Coordination Office.

rights; guide intellectual property policy, and improve intellectual property rights protection; and deliver intellectual property information and education worldwide. Although USPTO does not have any specific agency priorities with respect to nanotechnology R&D, it partners with other NNI participating agencies, industry, and outside technical experts to provide expert assistance and training for its examiners to ensure their ability to provide timely and informed review of patent applications in a wide variety of nanotechnology-related fields. It also provides publicly available patent data that has been used by NNI agencies, National Academies and PCAST assessments of the NNI, and other outside experts to analyze nanotechnology patent trends, both within the United States and in comparison to other countries (the latter drawing also from various international patent databases).

Department of Defense (DOD)

Recognizing the revolutionary impact that nanotechnology and nanomaterials may have on our future warfighting capabilities, the Department of Defense continues to pursue foundational research in these technologies to support the modernization of the current force. Nanotechnology shows great promise to allow the ability to design unique materials to achieve improved properties and capabilities, including novel sensing capabilities/modalities; lightweight, stronger materials for protective applications; and expanded uses in medical devices, environmental remediation, and additive manufacturing. The Department is committed to maintaining a broad base of fundamental and applied nanoscience research capabilities and expertise within its laboratories, in partnership with small businesses and academia, and continues to collaborate with other Federal agencies to develop, identify, and cultivate nanotechnology-enabled materials, sensors, devices, and advanced manufacturing technologies for transition into the defense industrial base. The Department conducts these efforts through the use of Broad Agency Announcements and Funding Opportunity Announcements—as well as through DOD Manufacturing Technology, Defense Production Act Title III, Defense Innovation Unit, Manufacturing USA, and Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) programs—to build and strengthen partnerships in support of the National Defense Strategy.

Department of Energy (DOE)

The Department of Energy supports a broad portfolio of pioneering research and development in nanoscale science and engineering to promote scientific and technological innovation and to advance the agency's mission in energy, environment, and national security. Nanotechnology plays a vitally important role in addressing the Nation's challenges, and DOE maintains a strong commitment to the NNI. DOE supports nanoscale science and engineering research activities in academia, DOE national laboratories, and industry, including small businesses. The majority of DOE NNI funding is managed by the Office of Science (SC), with additional support from the Office of Energy Efficiency and Renewable Energy (EERE), the Office of Nuclear Energy (NE), and the Office of Fossil Energy (FE). In addition to a diverse portfolio of fundamental nanoscience research in materials and chemical sciences, geoscience, and bioscience, SC operates five Nanoscale Science Research Centers, user facilities that provide open access to leading-edge synthesis, fabrication, characterization, and computational tools and scientific expertise for interdisciplinary research at the nanoscale. EERE's nine program offices invest in a wide range of nanotechnology-related research and development in support of its energy efficiency, renewable energy, and sustainable transportation missions, including nanocrystalline metals, nanocomposite materials, and atomically precise manufacturing. NE supports research and development projects across a wide field of science and engineering associated with nuclear energy technology, including behavior and properties of nuclear-energy-related materials that have been nanostructured or nano-modified. FE supports nanoscale materials, modeling, and manufacturing projects in areas such as advanced sensors and separation membranes.

Department of Health and Human Services (HHS)

Food and Drug Administration (FDA). FDA invests in nanotechnology research to help address questions related to the safety, effectiveness, quality, and/or regulatory status of products that contain engineered nanomaterials (ENMs) or otherwise involve the use of nanotechnology; develop models for safety and efficacy assessment; and study the behavior of nanomaterials in biological systems and their effects on both human or non-human animal health. These investments continue to support FDA's mission to protect and promote public health, and to help support the responsible development of nanotechnology. The FDA Office of the Commissioner, in partnership with the FDA Nanotechnology Task Force, facilitates communication and cooperation on nanotechnology research, both within FDA and with other national and international stakeholders. FDA's nanotechnology research efforts include: (1) scientific staff development and professional training; (2) laboratory and product-testing capacity; and (3) collaborative and interdisciplinary nanotechnology research. FDA continues to foster and develop collaborative relationships with other Federal agencies through participation in the NNI and the NSET Subcommittee, as well as with regulatory agencies, healthcare professionals, industry, consumers, and other stakeholders. In 2019 FDA actively participated in an informal interagency interest group on nanoplastics, where scientists from over 20 Federal agencies shared interests, research, and resources available to advance the understanding of this emerging global issue. Recently FDA has increased its international outreach, with the goal of strengthening global regulatory research efforts aimed at the development of novel characterization/measurement tools and consensus standards. FDA co-organized the Global Summit on Regulatory Science (GSRS19) on Nanotechnology and Nanoplastics, in collaboration with the European Commission, where regulators and stakeholders from over 30 countries identified research gaps and priorities in regulatory science, to facilitate international collaboration and harmonization. These meetings allow for information to be exchanged efficiently and serve to identify research needs related to the use of ENMs in FDA-regulated products.

National Center for Environmental Health (NCEH). NCEH plans, directs, and coordinates a program to protect the American people from environmental hazards. NCEH, together with the Agency for Toxic Substances and Disease Registry (ATSDR), has formed a microplastics working group with the objective of understanding potential human health risks from exposure to nano- and microplastics.

National Institute for Occupational Safety and Health (NIOSH). NIOSH provides national and world leadership in conducting research on the causes and prevention of work-related illness and injury. NIOSH is a leader in the Federal Government research initiative on understanding the potential human health and safety implications of nanotechnology, and in addressing worker health and safety needs related to nanotechnology. NIOSH research advances the understanding of engineered-nanomaterial-related toxicology and workplace exposures, so that appropriate risk management practices can be implemented during the discovery, development, and commercialization of engineered nanomaterials along their product life cycles. Through strategic planning, research, collaborating with stakeholders, and making information widely available, NIOSH develops guidance that supports and promotes the safe and responsible development and commercialization of nanomaterials.

National Institutes of Health (NIH). NIH advances creative, fundamental discoveries and translational nanotechnology research and development to ultimately enhance health, lengthen life, and reduce illness and disability through a variety of mechanisms and approaches. The NIH nanotechnology investment portfolio encompasses both basic and clinical research funded primarily through grants. Current research efforts focus on advancing new medical diagnostics, therapeutics, and vaccines; supporting nanotechnology-related environmental, health, and safety research; developing nanotechnology information resources; and training a new generation of nanotechnology researchers. Due to the successful integration of nanotechnology-based R&D into broad areas of biomedical applications, scientists can propose ideas via non-nanotechnology-specific funding opportunity announcements supported by a large number of NIH institutes.

Department of Homeland Security (DHS)

DHS interest in nanoscience is primarily focused on the application of nanoscale materials and devices that provide enhancements in component technology performance for homeland security applications. Applications of interest include threat detection for enhanced security for aviation, mass transit, and first responders. R&D topics include nanomaterials for novel sensing structures and arrays, high-performance nanoscale preconcentrators for use in next-generation detection systems, and development of manufacturing techniques for low-cost nanoscale sensor platforms and wearable sensing technologies.

Department of the Interior (DOI)

U.S. Geological Survey (USGS). USGS nanotechnology R&D is primarily focused on developing improved methods for estimating organic, metal, and biogenic chemicals (including nanomaterials) in the field in natural systems. Future methods for sensing contaminants may include adapting alternative animal bioassays (cell, invertebrate) to rapidly assess contaminants in field-collected samples, which could provide information on unknown contaminant stressors, mixtures, and site-specific data.

Bureau of Safety and Environmental Enforcement (BSEE). The Bureau of Safety and Environmental Enforcement Oil Spill Preparedness Division (OSPD) Response Research Branch (RRB) focuses on advancing methods and technologies for oil spill response. RRB currently supports research developing a continuous oil/seawater separation technology deployable in arctic conditions aboard oil-skimming vessels. The technology would enable the recovery of skimmed oil while producing a safely discharged oil-free water stream. This separation technology involves coupling electrically conducting ultrafiltration membranes with ferromagnetic nanoparticle-stabilized oil droplets, therefore permitting the efficient collection and separation of oil from water. This (nano) technology reduces the need to store large volumes of contaminated water.

Department of Justice (DOJ)

National Institute of Justice (NIJ). The NIJ investment in nanotechnology furthers DOJ's mission through the sponsorship of research that provides objective, independent, evidence-based knowledge and tools to meet the challenges of crime and justice. New projects are awarded on a competitive basis; therefore, total investment may change each fiscal year. However, NIJ continues to view nanotechnology as an integral component of its R&D portfolio as applicable to criminal justice needs.

Department of Transportation (DOT)

Federal Highway Administration (FHWA). FHWA is pursuing nanotechnology-enabled solutions to improve the safety and performance of the Nation's transportation system. Innovative technologies and approaches to modernizing and renewing U.S. transportation infrastructure are paramount to ensuring mobility, accessibility, and economic productivity for all Americans. Development and deployment of high-performance nanomaterials shows great promise for improving the durability, resilience, and long-term performance of extant and future transportation infrastructure.

Environmental Protection Agency (EPA)

EPA's engineered nanomaterials research is conducted as part of the Chemical Safety for Sustainability National Research Program within the Office of Research and Development (ORD). This research is focused on developing, collating, mining, and applying information on engineered nanomaterials to inform both exposure and hazard assessments and support risk-based decisions related to the agency's implementation of the Toxic Substances Control Act (TSCA) and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). EPA's research activities have two objectives: (1) evaluate the environmental release of, and assess human and ecological exposures to, engineered nanomaterials; and (2) integrate information and develop

a user interface for ORD's existing nanomaterials database, NaKnowBase, which captures the chemical and physical parameters of materials tested by EPA, the assays in which they were tested, and measured results.

National Aeronautics and Space Administration (NASA)

The National Aeronautics and Space Administration supports research and development in nanotechnology to advance space exploration and aeronautics research. Successful integration of nanomaterials into various aspects of NASA's missions may be essential to enable humans to maintain a permanent and sustainable presence in space. Agency activities where nanomaterials are used for space exploration include: lightweight, high-strength structural nanocomposites for lower payload weight, chemical and biological sensors to support astronaut health or detect signs of potential habitable planets, novel membranes and catalysts for air and water purification, nanoelectronics and damage-tolerant materials for extreme environments, and novel materials for communication devices, power, and energy. Nanotechnology is also advancing aeronautics research through rapid manufacturing of lightweight aircraft structures and the design of advanced propulsion technologies to make flight safer and more efficient. Commercialization of nanotechnologies is being accomplished through NASA's SBIR and STTR programs. NASA also invests in cutting edge, university-led nanotechnology research by training the next generation of scientists and engineers through student fellowships and faculty awards, most of which are funded by the Space Technology Research Grants (STRG) Program in the Space Technology Mission Directorate, in addition to University Leadership Institute (ULI) awards, which are funded through the Aeronautics Research Mission Directorate.

National Science Foundation (NSF)

NSF supports fundamental nanoscale science and engineering in and across all disciplines. NSF's nanotechnology research is supported primarily through grants to individuals, teams, and centers at U.S. academic and small-business institutions. The team and center projects are particularly fruitful because nanoscale research and education are inherently interdisciplinary and increasingly translational pursuits, often combining elements of materials science, engineering, chemistry, physics, biology, and neuroscience. Several new directions planned for 2021 are nanotechnology using artificial intelligence for smart materials and systems, quantum systems, the human-technology frontier, nanoplastics, and sustainability in the urban environment. The 2021 investments continue to include research on highly energy-efficient systems and intelligent cognitive assistants; nanobiomanufacturing and nanobiomedicine, including cell technology; chromatin and epigenetic engineering and its nanoscale environment; semiconductor synthetic biology for information processing and storage technologies; food-energy-water processes such as nanostructured membranes and point-of-use nanofiltration; nanomodular materials and systems by design, including hierarchical 3D nanoscale materials; and emerging aspects of nanoelectronics, photonics, and neuroscience. In 2021 NSF will increase its focus on convergence research and education activities in confluence with other interagency initiatives and NSF priority areas (e.g., the Networking and Information Technology R&D Program, the National Quantum Initiative, artificial intelligence, the Materials Genome Initiative, and NSF's Big Ideas). NSF will continue its sponsorship of student contests (e.g., the Generation NANO competition for high school students and the Quantum Matters communication competition for undergraduate and graduate students), and its support for the National Nanotechnology Coordinated Infrastructure and the Network for Computational Nanotechnology. Contributions to nanotechnology innovation and translation will continue through programs such as Grant Opportunities for Academic Liaison with Industry (GOALI); Industry-University Cooperative Research Centers (IUCRC); Innovation Corps (I-Corps™); Partnerships for Innovation, and SBIR, and by strengthening industry and small business partnerships with the Nanosystems Engineering Research Centers. An emerging technologies industrial internship program, INTERN, will be expanded. The 2021 budget reflects the fact that NSF has mainstreamed nanotechnology-related research, education, and infrastructure in core programs in several directorates.

U.S. Department of Agriculture (USDA)

Agricultural Research Service (ARS). The USDA Agriculture Research Service has a limited research program in nanotechnology. However, examples of nanotechnology accomplishment for 2019 include: (1) nanodetectors to detect as few as 10 enteric bacterial cells in food samples, (2) nanoparticle formulations to supplement human gut microbiota composition, (3) nanoscale formulations of catfish by-product proteins that generate high solid and protein recovery from processing waste, (4) nanobiosensors for detecting fungal neurotoxins in corn and dairy-based foods, (5) nanoscale particles of starch-oleic acid inclusion complexes in films to enhance their biodegradability, and (6) nano-modification of cotton fiber for improved mechanical and thermal properties.

Forest Service (FS). Forest Service nanotechnology research supports departmental and agency priorities of facilitating rural prosperity and economic development, ensuring productive and sustainable use of National Forest System lands, and strengthening the stewardship of private lands through research and development. The primary focus of Forest Service nanotechnology research is on producing cellulose nanomaterials from wood, and on developing the science and technology for the application of cellulose nanomaterials in a broad range of products. Other nanotechnology research in the Forest Service includes understanding the nanostructure of wood and wood properties and wood-water interactions with nanotechnology techniques.

National Institute of Food and Agriculture (NIFA). The NIFA nanotechnology portfolio will continue providing national leadership and investments in research, education, and extension activities through its extramural funding instruments. NIFA advances nanoscience and nanotechnology for addressing significant societal issues such as sustainable agricultural production, food and nutrition security, food safety and biosecurity, the bio-based economy, water and other natural resources, and environmental and ecological systems. The program also supports risk assessment and management, public engagement, and communication about nanotechnology and nanotechnology-enabled products.