

A PROGRESS REVIEW OF THE NNI NANOTECHNOLOGY SIGNATURE INITIATIVES

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Executive Summary

The National Nanotechnology Initiative (NNI), first announced by President Clinton in January 2000, is a partnership of 20 Federal agencies and departments with activities in nanotechnology research and development (R&D), policy, and regulation. In support of President Obama's priorities and innovation strategy, the Federal agencies participating in the NNI have identified focused areas of national importance that may be more rapidly advanced through enhanced interagency coordination and collaboration. These Nanotechnology Signature Initiatives (NSIs) provide a spotlight on critical areas and define the shared vision of the participating agencies for accelerating the advancement of nanoscale science and technology from research through commercialization. By combining the expertise, capabilities, and resources of appropriate Federal agencies, the NSIs accelerate research, development, and insertion, and overcome challenges to the application of nanotechnology-enabled products. The five NSIs through fiscal year 2016 are described below.

- *Nanotechnology for Solar Energy Collection and Conversion: Contributing to Energy Solutions for the Future*, launched in 2010, has spanned efforts in fundamental and applied research to improve photovoltaic and thermophotovoltaic devices and advance the development of solar fuels. These efforts have included research on understanding and characterizing essential processes in photovoltaic materials and devices; low-cost conversion of solar energy to electricity through the development of organic photovoltaic solar cells; and the development of high-efficiency photovoltaics. For example, the Intelligence Community supported the transition of quantum dot solar cell technology to a major manufacturer of commercial solar cells. This technology is essential to achieving up to 35% efficiency in space-based solar cells and greater than 40% efficiency in terrestrial solar cells. It is expected to provide up to a 23% increase in available power for U.S. satellites. Agencies participating in this NSI have also supported interdisciplinary R&D centers and provided early-stage assistance to startup companies to overcome technological barriers to commercialization. The Solar NSI has provided a valuable spotlight on critical scientific challenges facing solar technologies and on the programs within the participating agencies that address these issues. The strength of these interactions and the active community that has developed make the continued focus of a signature initiative unnecessary. Although these important activities will continue, fiscal year 2016 will be the last year they are reported under the NSI mechanism, and the NSI spotlight will transition to other high-priority areas for the NNI.
- *Nanoelectronics for 2020 and Beyond*, launched in 2010, is aimed at discovering and using novel nanoscale fabrication processes and innovative concepts to produce revolutionary materials, devices, systems, and architectures to advance the field of nanoelectronics. Federal agencies participating in this NSI have provided strong support for multidisciplinary university research through two public-private research initiatives in partnership with the semiconductor industry: the [Nanoelectronics Research Initiative](#), co-funded by the National Science Foundation (NSF), the National Institute of Standards and Technology, and the Semiconductor Research Corporation (SRC); and the [Semiconductor Technology Advanced Research Network \(STARnet\)](#), supported by the Defense Advanced Research Projects Agency and SRC. One area of rapidly growing emphasis is the development and application of novel materials for nanoelectronics. R&D efforts in

nanophotonics provide the potential for collaboration with other national efforts, such as the recently announced [Integrated Photonics Institute for Manufacturing Innovation](#) and the [National Strategic Computing Initiative](#). Work on novel devices, especially those capable of low power operation, are a focus area that supports the new [Nanotechnology-Inspired Grand Challenge for Future Computing](#). The agencies participating in the Nanoelectronics NSI have made considerable progress towards accomplishing the expected outcomes envisioned in this NSI since they were defined in the 2010 white paper, and periodically update their priorities and plans to reflect the current state of the science and incorporate new advances in nanoelectronic devices, materials, integration, and architectures.

- *Sustainable Nanomanufacturing: Creating the Industries of the Future*, launched in 2010, includes efforts focused on the development of robust nanomanufacturing methods for the cost-effective production of nanoscale materials and nanotechnology-enabled products. These efforts include the development and scaled-up production of carbon nanotube bulk materials and their demonstration in lightweight, high-strength composites and lightweight data and power cables. NNI agencies have worked together to advance scientific understanding and strengthen the community in support of the Nanomanufacturing NSI, including forming public-private partnerships to accelerate the commercialization of carbon-based and cellulose nanomaterials. Efforts supporting the advancement of carbon-based materials include a project under the [Defense Production Act Title III Program, Advanced Carbon Nanotube \(CNT\) Volume Production](#), which is providing infrastructure for the world's first industrial-scale manufacturing facility producing CNT yarn, sheet, tape, and slurry materials. In addition, these agencies, with support from the National Nanotechnology Coordination Office (NNCO), conducted two workshops in 2014 that discussed challenges to the broader adoption and commercialization of carbon nanotubes and cellulose nanomaterials. Many of the outcomes anticipated at the launch of this NSI have been achieved, allowing the agencies to now refocus this NSI on new developments in the production of nanomaterials, their use to manufacture novel products, and the invention of innovative inspection and metrology instruments.
- *Nanotechnology Knowledge Infrastructure (NKI): Enabling Leadership in Sustainable Design*, launched in 2012, is focused on providing a community-based, solutions-oriented knowledge infrastructure to accelerate nanotechnology discovery and innovation. Agencies participating in the NKI NSI recognize that the development of a robust and functional informatics infrastructure requires broad communication and collaboration among the various nanotechnology communities. These agencies collaborate with vibrant groups from the nanoinformatics community—including the [Nanotechnology Working Group](#) (supported by the National Cancer Institute's National Cancer Informatics Program), the [European NanoSafety Cluster's Databases Working Group](#), and the [U.S.–EU nanoEHS Communities of Research](#)—to build and manage the nanotechnology knowledge infrastructure. Federal agencies are building upon existing activities, such as the National Institutes of Health's [cancer Nanotechnology Laboratory \(caNanoLab\)](#) portal and the NSF-funded [nanoHUB](#), to facilitate sharing of data and models, respectively, and to promote collaboration. For example, the National Institute for Occupational Safety and Health transferred the [GoodNanoGuide](#), an Internet-based platform for good practices for safely handling nanomaterials, to nanoHUB. Other efforts being pursued under this NSI include the development of high-throughput combinatorial methods to probe nanomaterial growth and processing methods, and the development of standard procedures to validate computational techniques developed to predict the properties of engineered nanomaterials. Since its inception,

the NNI NSI has coordinated the Federal nanoinformatics community and engaged with stakeholders around the interconnected elements of collaborative modeling, the development of a cyber toolbox, and the creation of data infrastructure to shorten the time from research to new product development. These efforts aim to maintain U.S. leadership in nanoEHS research and sustainable design of engineered nanomaterials.

- *Nanotechnology for Sensors and Sensors for Nanotechnology: Improving and Protecting Health, Safety, and the Environment*, launched in 2012, is focused on the utilization of nanotechnology to develop physical, chemical, and biological sensors that have higher sensitivity and selectivity, are more portable, and have lower power demands than conventional sensors. The Sensors NSI serves as a focal point for relevant stakeholders and the public to address opportunities and barriers through the Request for Information mechanism, town hall discussions, and community meetings. Common themes for interagency collaborations continue to be identified through these inputs and interactions. Another focus of this NSI is the development of sensors for the detection of nanomaterials in biological and environmental media. In 2014, agencies participating in this NSI, with support from NNCO, sponsored the [Sensor Fabrication, Integration, and Commercialization Workshop](#) to identify key challenges faced by sensor developers and critical needs in standards development, testing and evaluation facilities, and manufacturing. The workshop highlighted the need for broader access to test beds for the evaluation of sensor performance and for fabrication facilities that address the gaps in transitioning from prototypes to large-scale commercial production. Workshop discussions guided the development of the [Sensors NSI Web Portal](#), which was introduced in a June 2015 webinar. The needs for improved awareness, communication, and collaboration at the convergence of testing and operational standards continue to be emphasized in the stakeholder interaction activities of the Sensors NSI.

Each NSI combines the focused efforts of a number of contributing Federal agencies with related missions that are committed to coordinating research and implementing strategies to achieve the goals defined for the NSIs, and to updating and prioritizing those goals as the research progresses. Individual agency-funded or mission-specific programs have benefited from improved awareness of complementary activities at other agencies and have been developed in the context of broader Federal activities. While it is challenging to describe the full impact of the NNI Signature Initiatives on nanotechnology research, development, and commercialization, the following are links to documents that provide examples of key accomplishments and highly successful collaborations that each of these initiatives have produced:

- [Nanotechnology for Solar Energy Collection and Conversion](#)
- [Nanoelectronics for 2020 and Beyond](#)
- [Sustainable Nanomanufacturing](#)
- [Nanotechnology Knowledge Infrastructure](#)