Report

September 2016

IN BRIEF

Triennial Review of the National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI) is a coordinated, multi-agency effort that expedites the discovery, development and deployment of nanoscale science and technology to serve the public good as well as the core mission of the agencies. Established in 2001, the NNI comprises the collective activities and investments of more than two dozen participating organizations with diverse missions and a total annual investment of ~$1.5 billion related to nanotechnology. This report of the National Academies of Sciences, Engineering, and Medicine is the latest triennial review of the NNI called for by the 21st Century Nanotechnology Research and Development Act of 2003. It examines the mechanisms in use by the NNI to advance focused areas of nanotechnology and discusses the physical and human infrastructure the NNI needs to reap the benefits of nanotechnology development. The report finds that the NNI significantly contributes to the portfolio of activities across the participating agencies. Looking ahead, the NNI can increase its impact by focusing on basic and applied research that will enable progress in other priority technology areas such as advanced manufacturing. At the same time, the NNI agencies are called upon to continue investing in publicly accessible research infrastructure while taking steps to produce and share resources for educating future nanotechnology researchers, entrepreneurs, and policy makers.

FOCUSING THE NNI

The NNI currently employs two mechanisms to encourage focus on areas of national importance. Nanotechnology Signature Initiatives (NSI's) are designed to highlight technology areas that may be more rapidly advanced through enhanced interagency coordination and collaboration. Nanotechnology-Inspired Grand Challenges have ambitious but achievable goals that will harness nanotechnology to solve national or global problems and that have the potential to capture the public's imagination. Other opportunities exist for focusing the NNI on technology areas of high priority and impact.

RECOMMENDATION: The Nanoscale Science, Engineering and Technology (NSET) Subcommittee should strengthen engagement with the leadership of other high-priority

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initiatives in order to determine critical nano-enabled technological dependencies. The Subcommittee then should focus NNI efforts to address those dependencies.

An area related to advanced development that warrants particular attention is nanomanufacturing. Research on the manufacture of nanoscale materials, devices, and structures is critical for realizing the benefits of nano-enabled technologies. Nanomanufacturing research goes hand in hand with the goals of national advanced manufacturing initiatives such as the Manufacturing Innovation Institutes (MIIs) that are part of the National Network for Manufacturing Innovation (NNMI).

RECOMMENDATION: NNI-participating agencies should explicitly support the early stage (Technology Readiness Level 1-3) nanomanufacturing research needed to enable the roadmaps and goals of current advanced manufacturing programs, in particular the existing MIIs.

Federal agencies have established a number of programs aimed at pushing the ideas resulting from basic and applied research to a stage where traditional private sector investment is available. These programs, while not specifically aimed at nanotechnology, can —and in some cases already do— support the commercialization of NNI-funded research.

RECOMMENDATION: The NSET Subcommittee should form a Nanomanufacturing Working Group (NWG) to identify nanoscale research needs of advanced manufacturing, to coordinate efforts between the NNI and the Federal programs focused on advanced manufacture, and to foster greater investment by those programs in nano-enabled technologies.

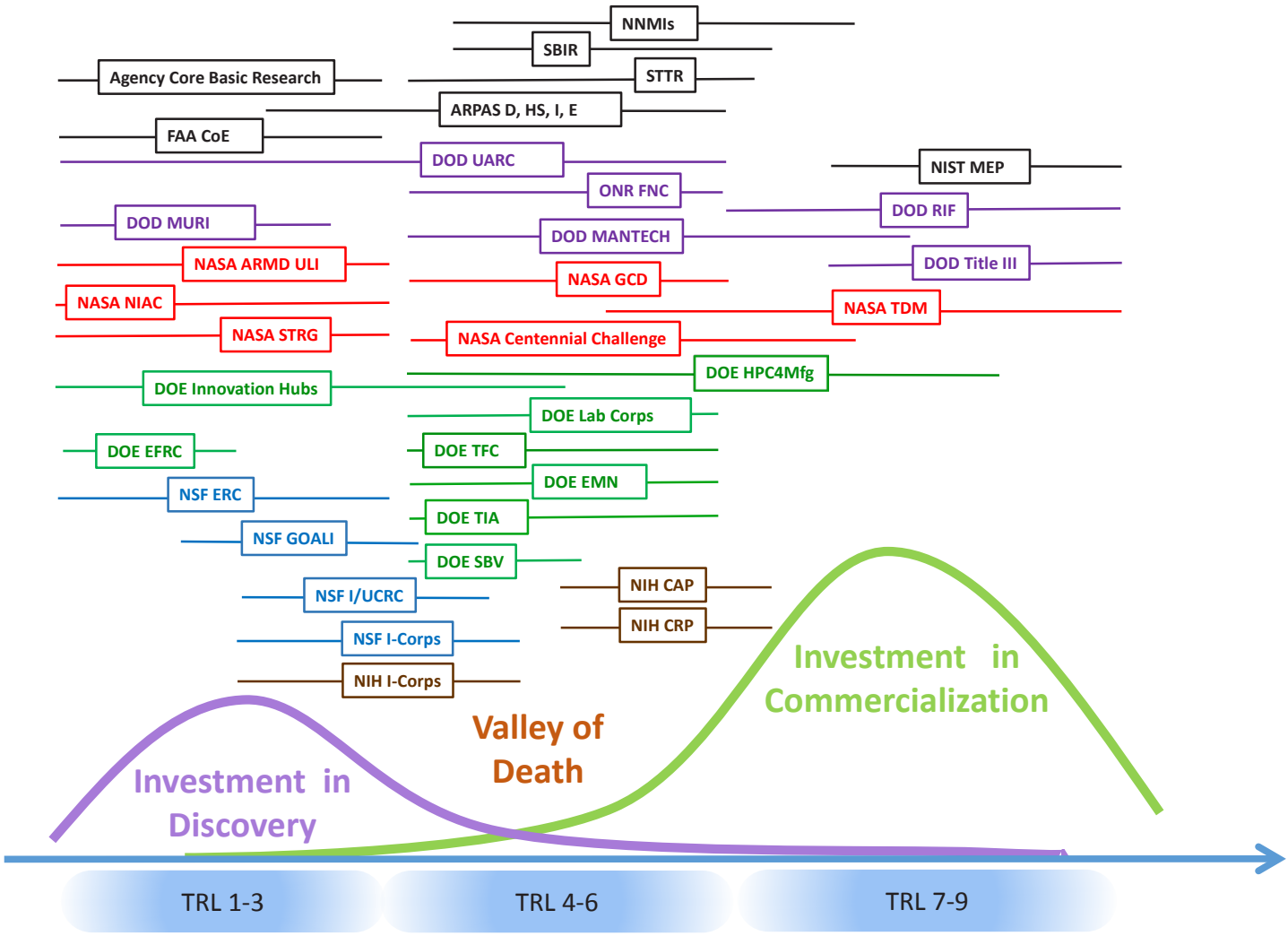
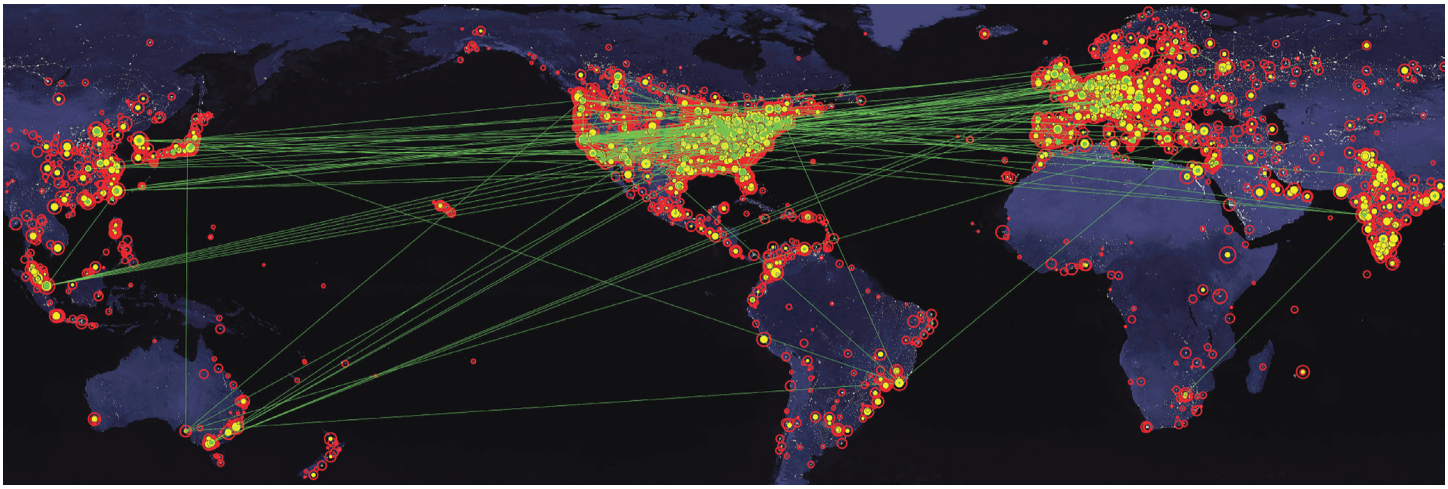


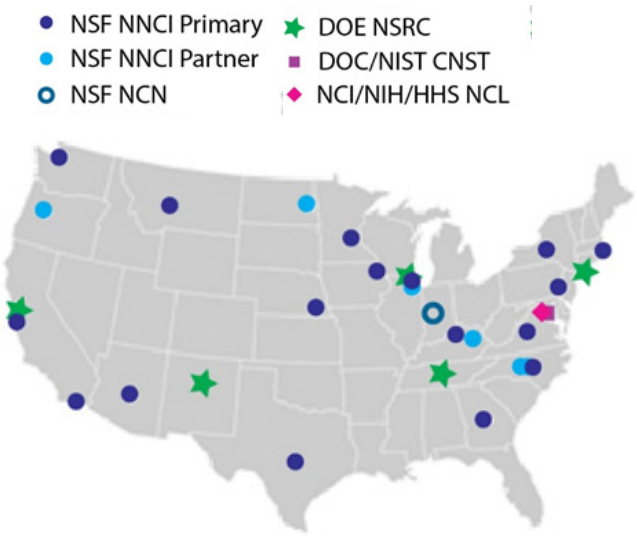
Illustration of the many Federal programs specifically addressing technology transition as part of the Manufacturing-Innovation Process. At the bottom of the Figure are the Technology Readiness Levels (TRLs). The lower center of image depicts the "valley of death" between the principal government research funding in grey and the principal industry funding in green. In the upper center there is a suite of color coded (blue—NSF; red—NASA; purple—DOD; green—DOE; black—others) Federal programs designed to bridge that gap and their approximate position on the TRL scale. Image from committee and staff.



nanoHUB user map in the year 2011 superposed on NASA's world at night. Red circles designate users viewing lectures, tutorials, or homework assignments. Yellow dots are users of simulation. Green dots indicate authors of publications citing nanoHUB. Dot size corresponds to the number of users, and lines show author-to-author connections proving intense research collaboration networks.

PHYSICAL INFRASTRUCTURE FOR NANOTECHNOLOGY

The NNI agencies have built a substantial publically accessible infrastructure for nanoscale research and development. The existence and quality of these infrastructure resources are key factors in reducing barriers to discovery and technological innovation, and in developing and retaining the nation's science and engineering talent pool. However, because there is a lack of identified funds for the development of new instrumentation at NNI-sponsored user facilities, there is a real risk of obsolescence for the physical and computation infrastructure available to the research enterprise. The agencies managing these resources need to plan for renewal of instrumentation and equipment in future years.



Locations of major nanoscience and technology user facilities operated by NNI participants as of October, 2015.

RECOMMENDATION: NSF and DOE, in concert with other NNI agencies with instrumentation programs, should identify funding mechanisms for acquiring and maintaining state-of-the-art equipment and computational resources to sustain leading-edge capabilities at their nanoscale science and engineering user facilities.

The Nanotechnology Characterization Lab (NCL) serves as a trusted source of information on the safety of nanomaterials being developed for cancer treatment while helping facilitate FDA assessment. However, there is a lack of centralized facilities for addressing other areas of nanomedicine and nanobiotechnology. As increasing numbers of nanomaterials are developed for medical and other applications that involve contact with the body or the environment, there will be a need to establish standards and guidelines for assessing and managing risks to the environment, health, and safety.

RECOMMENDATION: NIH should assess what areas, in addition to cancer diagnostics and treatment, there are emerging medical applications that rely upon engineered nanomaterials. NIH should expand the NCL to address nanomaterials being developed for those other medical applications.

RECOMMENDATION: The National Institute for Occupation Safety and Health, NIST, and the Environmental Protection Agency should join with the Consumer Product Safety Commission and the National Institute of Environmental Health Sciences to support development of centralized nanobiotechnological characterization facilities, at NCL or elsewhere, to serve as a trusted source of information on potential environmental, health and safety implications of nanomaterials.

HUMAN INFRASTRUCTURE FOR NANOTECHNOLOGY

Human capital, and the infrastructure required to produce it, is essential to realizing the full value of nanotechnology advances. The nanoscale science and engineering education ecosystem must address not only the education of future researchers, but also the education of future business and government leaders who can accelerate the adoption of nano-enabled technologies and future workers with skills needed for nanomanufacturing. The NNI has funded the development of diverse formal and informal educational materials suitable for various levels and ages. The Network for Computational Nanotechnology nanoHUB is becoming an increasingly widely used online platform for disseminating tools for nanoscale computer modeling and simulation. The site also allows users to share educational resources such as online presentations, courses, podcasts, and videos that are geared towards post-secondary education as well as K-12 students and teachers.

RECOMMENDATION: NNI-funded researchers and others who have developed educational materials should be required to deposit the information content on the nanoHUB website, and to explore affordable commercial availability for laboratory and classroom demonstration materials.

In summary, the NNI continues to add value to the portfolio of activities across the participating agencies. The NNI can significantly increase that value by focusing on basic and applied research that will enable progress and success in other advanced technology areas of priority, especially advanced manufacturing. The NNI agencies also are called upon to sustain investment in and facilitate access to physical infrastructure and to take steps to realize the full value of educational materials and programs. In the course of identifying areas in which to focus, it is an opportunity to consider the goals of the initiative and the criteria for continuing to invest resources in its coordination and management.

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