

Creating the National Nanotechnology Initiative

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Distinguished colleagues, good morning!

On behalf of NSF and NNI, it is my honor to welcome you to the symposium. This is the “20-year lifetime-achievement” event of the initiative combined with perspectives into the future.

At the end of the last century, discoveries in several disciplines reached the building blocks of matter, energy, and living systems, where novel properties and functions may be exploited and efficiently changed.

This created conditions for the convergence of disciplines, and a holistic view in knowledge, technology, medicine, and philosophy — a new kind of Renaissance. *Nanotechnology affirmation is a historic pivotal development in science and society.*

From my perspective, in the 1980s I was an engineering professor doing research on nanoscience, and in 1991 I initiated a program on nanoparticles at NSF. In 1996, I formed a coalition of agencies interested in nanotechnology. Two years later, Tom Khalil in WH invited me to organize the Interagency Working Group to explore the potential of the new field. We began with bringing together fragmented activities under a unifying definition and strategy and formulating the long-term vision of nanotechnology development in the foundational report “Nanotechnology Research Directions”.

On March 10, 1999, on behalf of the interagency group, I had the opportunity to propose NNI to the WH. I had 10 minutes to make the case - “a Vision for the Next Century”, and the proposal was for half a billion dollars in the first year.

Then, we prepared the report on *broad societal implications* including ethical, environmental, and economic projections; we published a brochure for the public “*Shaping the world atom by atom*”; and an international benchmarking in 30 countries. We drafted the presidential NNI budget implementation plan with nine R&D grand challenges. It was an exciting time with extraordinary implications and multiple communities providing feedback.

After successful Congressional hearings in June 1999, where Rick Smalley was a witness, the initiative was approved by OMB and PCAST, which concluded: “*NNI...is essential, ...it will help provide for a better world*”. Then Presidential Advisor Neal Lane

recommended funding to President Clinton, who announced the NNI on January 21, 2000.

A few months later, I was asked to Chair the NSET Subcommittee to implement the NNI and Jim Murday was named Director of NNCO. A collaborative organization that currently has 33 Federal agencies and departments was set up around NSET, with five governance principles: be transformational, visionary, inclusive, responsible, and convergent.

After 2001, NNI bottom-up prepared plans received support from every Administration and every Congress that followed, but each time after diligent external and government evaluation. NNI investment increased in average by 22% per year between 2000 and 2010, reaching about \$1.9 billion in 2010.

The first draft for the long-term support of NNI was prepared in 2001 but strategy improvements and scheduling postponed the final Congressional act for two years. Senators George Allen and Ron Widen formed the Nanotechnology Caucus in 2002 which helped the preparation of the final 21st Century Nanotechnology Research and Development Act of 2003 signed by President George W. Bush on December 3, 2003.

NNI is unique as a model of scientific interdisciplinary and cross-sector collaboration, as a driver of convergence education, and as a foundation for other emerging technologies. We emphasized a strong infrastructure and partnerships such as the Nanoelectronics Research Initiative with SRC. During the first five years of NNI, about 80 countries adopted research programs aligned with its vision, making nanotechnology the first truly global scientific initiative.

The progress made in nanotechnology over the last 20 years has fundamentally changed *how we think* about nature and life, and, consequently, how *things are done* in industry, medicine, energy, environmental protection, defense, and in most sectors of the economy.

Now we do things not possible before — such as bending light with metamaterials and editing the human genes— *as well as enabling new fields* such as quantum systems and synthetic biology. Nanotechnology has become dominant in technologies such as catalysts, semiconductors, and pharmaceuticals. It supports the major industries of the future.

One longitudinal study estimated that nanotechnology was a condition for competitiveness for about *3.6% of U.S. GDP in 2020* when the corresponding annual revenues reached about \$750 billion.

In the next ten years, we envision building hierarchical systems to human scale, a new theoretical framework with increasing predictive capabilities based on nanoscale invariants, and a new generation of nano building blocks beyond those in the current periodic table. Nanotechnology is creating a *powerful synergistic foundation* for the future science and technology system able to address national challenges.

Today we celebrate the NNI progress, and we express gratitude to all nanotechnologists. I personally salute the NNI colleagues with whom I worked together for more than 20 years!

Bibliography

- Selected publications at the beginning of NNI:

- The first report formulating the motivation and vision of NNI, which was adopted as an official White House/National Science and Technology Council (NSTC) document, and then used as key report for advancing NNI support at OMB and Congress:
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Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative (2002), NASEM, Washington, DC: The National Academies Press. Available on <https://doi.org/10.17226/10395>
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- Selected publications at ~10 years of NNI:

- Retrospective and outlook of nanotechnology after one decade of NNI:
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- Selected publications at ~20 years of NNI:

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- ***A Big Bet on Nanotechnology Has Paid Off: The National Nanotechnology Initiative promised a lot. It has delivered more*** (2021). Mirkin, Chad. *Scientific American: Opinion*, Oct 9, 2021. Available on: scientificamerican.com
- ***How Nanotech Powers Precision Medicine: It's behind everything from narrowly targeted drug delivery to microchips you can swallow*** (2019). Langer, Robert (2019). *Scientific American: Observations*, June 12, 2019. scientificamerican.com
- ***National Nanotechnology Initiative at 20 years: enabling new horizons*** (2023). MC Roco, *J Nanopart Res* 25, 197 (2023). <https://doi.org/10.1007/s11051-023-05829-9>
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Bio note for the conference website:

Mihail C. Roco: Dr. Roco is the Senior Advisor for Science and Engineering at the National Science Foundation (NSF). He initiated the first Federal Government program with a focus on nanoscale science and engineering (on synthesis and processing of nanoparticles) at NSF in 1991 and formed a coalition of agencies interested in nanotechnology in 1996 that led to the creation of the interagency working group on nanotechnology. Dr. Roco later became the founding chair of the U.S. National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology (NSET), after which he has continuously served as an active member and NSF lead representative. Prior to joining NSF, he was a professor of mechanical engineering and is credited with thirteen inventions and has contributed over two hundred and fifty articles and twenty books. At NSF, Dr. Roco pioneered convergence science, identifying its underlying basic theories, principles, and methods, and applied it to various platforms such as convergence of nanotechnology with biology, cognition, information, artificial intelligence (intelligent cognitive assistants) and other fields.
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