EXECUTIVE SUMMARY

Nanotechnology has potential applications in many sectors of the American economy, including consumer products, health care, transportation, energy and agriculture. In addition, nanotechnology presents new opportunities to improve how we measure, monitor, manage, and minimize contaminants in the environment. While the U.S. Environmental Protection Agency (EPA, or "the Agency") is interested in researching and developing the possible benefits of nanotechnology, EPA also has the obligation and mandate to protect human health and safeguard the environment by better understanding and addressing potential risks from exposure to nanoscale materials and products containing nanoscale materials (both referred to here as "nanomaterials").

Since 2001, EPA has played a leading role in funding research and setting research directions to develop environmental applications for, and understand the potential human health and environmental implications of, nanotechnology. That research has already borne fruit, particularly in the use of nanomaterials for environmental clean-up and in beginning to understand the disposition of nanomaterials in biological systems. Some environmental applications using nanotechnology have progressed beyond the research stage. Also, a number of specific nanomaterials have come to the Agency's attention, whether as novel products intended to promote the reduction or remediation of pollution or because they have entered one of EPA's regulatory review processes. For EPA, nanotechnology has evolved from a futuristic idea to watch, to a current issue to address.

In December 2004, EPA's Science Policy Council created a cross-Agency workgroup charged with describing key science issues EPA should consider to ensure that society accrues the important benefits to environmental protection that nanotechnology may offer, as well as to better understand any potential risks from exposure to nanomaterials in the environment. This paper is the product of that workgroup.

The purpose of this paper is to inform EPA management of the science needs associated with nanotechnology, to support related EPA program office needs, and to communicate these nanotechnology science issues to stakeholders and the public. The paper begins with an introduction that describes what nanotechnology is, why EPA is interested in it, and what opportunities and challenges exist regarding nanotechnology and the environment. It then moves to a discussion of the potential environmental benefits of nanotechnology, describing environmental technologies as well as other applications that can foster sustainable use of resources. The paper next provides an overview of existing information on nanomaterials regarding components needed to conduct a risk assessment. Following that there is a brief section on responsible development and the Agency's statutory mandates. The paper then provides an extensive review of research needs for both environmental applications and implications of nanotechnology. To help EPA focus on priorities for the near term, the paper concludes with staff recommendations for addressing science issues and research needs, and includes prioritized research needs within most risk assessment topic areas (e.g., human health effects research, fate and transport research). In a separate follow-up effort to this White Paper,

EPA's Nanotechnology Research Framework, attached in Appendix C of this paper, was developed by EPA's Office of Research and Development (ORD) Nanotechnology Research Strategy Team. This team is composed of representatives from across ORD. The Nanotechnology Research Framework outlines how EPA will strategically focus its own research program to provide key information on potential environmental impacts from human or ecological exposure to nanomaterials in a manner that complements other federal, academic, and private-sector research activities. Additional supplemental information is provided in a number of other appendices.

Key Nanotechnology White Paper recommendations include:

- **Environmental Applications Research.** The Agency should continue to undertake, collaborate on, and support research to better understand and apply information regarding environmental applications of nanomaterials.

- **Risk Assessment Research.** The Agency should continue to undertake, collaborate on, and support research to better understand and apply information regarding nanomaterials':
  - chemical and physical identification and characterization,
  - environmental fate,
  - environmental detection and analysis,
  - potential releases and human exposures,
  - human health effects assessment, and
  - ecological effects assessment.

  To ensure that research best supports Agency decision making, EPA should conduct case studies to further identify unique risk assessment considerations for nanomaterials.

- **Pollution Prevention, Stewardship, and Sustainability.** The Agency should engage resources and expertise to encourage, support, and develop approaches that promote pollution prevention, sustainable resource use, and good product stewardship in the production, use and end of life management of nanomaterials. Additionally, the Agency should draw on new, "next generation" nanotechnologies to identify ways to support environmentally beneficial approaches such as green energy, green design, green chemistry, and green manufacturing.

- **Collaboration and Leadership.** The Agency should continue and expand its collaborations regarding nanomaterial applications and potential human health and environmental implications.

- **Intra-Agency Workgroup.** The Agency should convene a standing intra-Agency group to foster information sharing on nanotechnology science and policy issues.

- **Training.** The Agency should continue and expand its nanotechnology training activities for scientists and managers.

Nanotechnology has emerged as a growing and rapidly changing field. New generations of nanomaterials will evolve, and with them new and possibly unforeseen environmental issues. It will be crucial that the Agency's approaches to leveraging the benefits and assessing the impacts of nanomaterials continue to evolve in parallel with the expansion of and advances in these new technologies.