National Nanotechnology Initiative
Overview and Perspective:
Department of Defense

Dr. David M. Stepp

david.m.stepp@us.army.mil

(919) 549-4329, DSN 832-4329, FAX (919) 549-4399

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Outline

- Department of Defense perspective of nanotechnology & the NNI
- Overview of accomplishments toward DoD’s missions
- Budget history and distribution
- Methodology for establishing goals and metrics for DoD nanotechnology research areas
- Programmatic alignment towards the new NNI strategic goals
DoD Perspective: Nanotechnology and the NNI

“Uniquely” Department of Defense:

- Simultaneous focus on scientific merit and potential relevance to DoD:
  **Scientific Merit:** to develop understanding and control of matter at dimensions of approximately 1 to 100 nanometers, where the physical, chemical, and biological properties differ in fundamental and valuable ways from those of individual atoms, molecules, or bulk matter
  **Potential Relevance to DoD:** to discover and exploit unique phenomena at these dimensions to enable novel applications enhancing war fighter and battle systems capabilities

- History of major support for pre-“nano” nanotechnology research
- No additional or specific DoD appropriations for nanotechnology or NNI
- NNI accelerates high-potential nanotechnology-based capabilities:
  Chemical/biological defense; Information technology; Energy and energetics; Multifunctional materials and devices; Health monitoring and sensing
- “Hierarchical” coordination and collaborations
Nanostructured Decontamination

- Non-toxic nanomaterials demonstrated to treat a wide range of toxic chemicals and to destroy chemical warfare agents
  - High surface area of nanostructured materials yield greater capacity for agents and faster reactivity for increased war fighter protection
  - Proven to remove over 99.6% of VX, GD (soman) and HD (mustard gas) from surfaces in under 90 seconds, converting these agents to safer by-products
  - System of pressurized cylinders, bulk pails and shakers offers robust utility against range of scenarios with minimal training
  - Fielded in March 2004 by Supply NCAS at Cherry Point, NC, in July 2004 by RDECOM in APG, MD; dual-use for first responders
  - Joint effort between ARL-ARO, Kansas State University, NanoScale Materials, Inc., USSOCOM, USMC, and DTRA
Nanostructured Wear Resistance

With thermal spray coatings and nanomaterial processing/development research investment results as a foundation.

Develop fundamental understanding of material processes to produce uniform coatings over complex curved surfaces.

University-Industry partnerships established for manufacturing development.

University-Industry-Navy Shipyard partnerships established for evaluations of new coatings in the marine environment.

New coatings with unprecedented wear resistance and hardness.

First nanostructured coating qualified for fleet use - Large ship A/C unit reduction gear bearing surfaces.

Parts qualification continues.

>$100M/yr Maintenance Cost Avoidance.
New colloid thruster and ionic liquid propellant demonstrated to produce greater than 3,000s specific impulse ($I_{sp}$) at low specific powers

- Electric field applied to surface of a conducting liquid forms jet of accelerated charged droplets
- Electrified jet size reduced to nanodimensions by flow rate control (increasing $I_{sp}$ and decreasing required power)
- Mass spectrometry and molecular dynamics studies establish the physics governing this phenomenon
- Dual polarity operation dramatically reduces power requirements
- Colloid thrusters are discharge-free electric thrusters that will be configured in large arrays
- Activity conducted as a joint effort between AFOSR, AFRL/VS, AFRL/PR, MIT, Yale, Georgia Tech, Busek, Inc., and JPL
Bio-Molecular Nanoscale Devices

Successful Stabilization of Single Ion Channels Over Field Effect Transistors

Successfully Reproduced Stochastic Signals Using Polycarbonate Membrane with Stability ~ Weeks
Coordination and Collaborations

- Nanometer-scale materials with an optical response tunable from visible to infrared wavelengths enabled (via joint support from DOD and NIH) R&D on non-invasive destruction of tumors in mice; initial studies have shown 100% success
- Advanced simulation software developed by DoD enabled collaboration with DOE to design and fabricate nanoscale terahertz photoconductivity detectors
- Coordination of program plans and program reviews for nanomanufacturing R&D efforts (including NSF NSECs, DoD MURIIs, NIST) and development of R&D partnerships
- NSF-DoD joint nanotechnology scholarship program
# DoD Nanotechnology Research Budget History

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<td><strong>TOTAL</strong></td>
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Methodology for Establishing Nanotechnology Goals & Metrics

- Opportunity-driven and needs-driven research to enhance war fighter and battle systems capabilities
- **Agency Working Groups**
  - DoD Agency Reliance Panels
  - OSD Nanoscience Strategic Research Area (SRA) Committee
    (Chair: Dr. Dr. Gernot Pomrenke, Air Force Office of Scientific Research)
  - Army RDECOM Nanotechnology Integrated Product Team
    (Chair: Dr. Michael Sennett, Natick Soldier Center)
  - Naval Working Group on Nanoscience
    (Chair: Dr. James Murday, Naval Research Laboratory)
  - Air Force NanoScience and Technology Working Group
    (Chair: Dr. Daniel Miracle, Air Force Research Laboratory)
- **Subcommittee on Nanoscale Science, Engineering, And Technology (NSET)**
Programmatic Alignment towards NNI Strategic Goals

- **NNI Goals (NNI Strategic Plan, December 2004):**
  - Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology
  - Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit
  - Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology
  - Support responsible development of nanotechnology

- **Program Component Areas (PCAs):**
  - Fundamental Nanoscale Phenomena and Processes
  - Nanomaterials
  - Nanoscale Devices and Systems
  - Instrumentation Research, Metrology, and Standards for Nanotechnology
  - Nanomanufacturing
  - Major Research Facilities and Instrumentation Acquisition
  - Societal Dimensions
Fundamental Nanoscale Phenomena and Processes

DoD Program Goals include:

- To discover new phenomena and processes to enable breakthrough advantages for war fighter and battle systems capabilities
- To develop robust strategies for synthesis, characterization, and assembly of individual nanostructures
- To explore applications of nanostructures for revolutionary catalysts, scavengers, taggants and sensors
- To elucidate fundamental aspects of phonon and electron transport in individual nanowires and two and three dimensional nanostructures as they relate to the development of high performance thermoelectric, thermionic, and photovoltaic devices for advanced solid state power generation, cooling, and thermal management
Nanomaterials

DoD Program Goals include:

- To develop precision nanostructure synthesis techniques required to provide process control over quantum transport characteristics of devices utilizing nanostructured materials
- To harness biological processes for low-cost synthesis and templating of designed nanostructures
- To control and exploit interactions between synthetic and naturally-occurring (biological) materials
- To develop nanoscale architectures to enhance local diffusion behavior, reaction kinetics, optical properties, and electrical properties
Nanoscale Devices and Systems

DoD Program Goals include:

- To utilize breakthroughs in nanotechnology to provide revolutionary devices and systems to advance war fighter and battle systems capabilities
- To establish a detailed understanding of nanoscale behavior related to electrochemical power source applications (batteries with enhanced discharge rate and energy density, high energy density capacitors, etc.), fuel cell catalysts, and electrode structures
- To engage the DoD applied research and development communities to accelerate the transition of science discovery into DoD relevant technologies
- To work with the Director, Defense Research and Engineering (DDR&E) Advisory Group on Electron Devices (AGED), US Navy groups developing technology plans for Navy Carrier Technology (CARTECH), Navy Submarine Technology (SUBTECH), and Navy Surface Technology (SURFTECH) programs, the Air Force Future Technology Branch, and the U.S. Army Research, Development and Engineering Command (RDECOM) Nanotechnology Working Group to examine future platform opportunities and requirements
DoD Program Goals include:

- To develop breakthrough next-generation instrumentation for developing advanced nanotechnology-based materials and devices
- To extend magnetic force microscopy and enable robust single spin measurement devices
- To extend new measurement capabilities into innovative sensors for use in defense missions
Nanomanufacturing

DoD Program Goals include:

- To guide and monitor the introduction of nanotechnology into military hardware
- To identify appropriate opportunities to introduce nanomanufacturing into the DoD Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR) and Manufacturing Technology (MANTECH) programs
- To enable the synthesis, generation, and assembly of individual nanostructures using lessons drawn from biology, including use of viruses and related structures as templates for nanowires and for arrays of inorganic materials of particular interest
- To develop affordable manufacturing approaches to nanostructured bulk materials
DoD Program Goals include:

- To provide advanced nanoscience instrumentation via the Defense University Research Instrumentation Program (DURIP)
- To provide DoD facilities and instrumentation capable of contributing to nanoscience research
Societal Dimensions

DoD Program Goals include:

- To assure health and safety of war fighters utilizing future nanotechnology-based applications
- To enable physicochemical characterization and toxicology for water, air and space environments
- To sustain an investment strategy to enable a multidisciplinary education system capable of sustaining the skilled workforce needed to meet future defense needs
- To assess, avoid and abate any adverse environmental or health impact from defense utilization of nanotechnology