Army Foresight

Searching for Sustainability

October 05: Nanotechnology

In this Edition:
How will a sustainable Army harness the potential of nanotechnology while ensuring compatibility with natural and human systems?

EDITION #1

ARMY FORESIGHT
SEARCHING FOR SUSTAINABILITY

INTRODUCTION TO FORESIGHT PROCESS

Welcome to the first edition of our new Foresight Series. In each edition, we will focus on a topic currently on the Army Environmental Policy Institute's "radar screen" and present key points from our preliminary research in a short report. We will introduce a specific topic, discuss why it is important to the Army, and present several key areas for further study.

The AEPI's mission is to assist the Secretariat in the development of proactive policies and strategies to address environmental issues that may have significant future impacts on the Army.

Foresight is the ability to look forward. We deliberately, methodically gather intelligence to follow trends and identify emerging issues. Foresight extends three years and more into the future—offering directions, not making predictions. The issues of concern have the potential affect the Army's ability to achieve its mission and warrant further study and discussion.

Foresight helps achieve sustainability by improving policy today to prevent current undesirable trends from becoming future intractable issues. It includes three components: systematically scanning trends, encouraging participation and buy-in, and building vision to improve policy. Foresight is ongoing. Topical specialists continuously track issues and offer topics for discussion, recognizing the current and creatively considering the future.

Each brief report introduces a topic, discusses its significance to the Army, and delineates key areas for further study. We don't recommend specific policy or suggest that we know the final solution. We offer these reports to interested parties to solicit comment and encourage sharing. They are designed to generate discussion and invite collaboration with our military partners, as well as potential collaborators in science, academia, industry, and other organizations. The reports summarize the topics, but they contain hyperlinks to relevant publications with the details that facilitate further research.

We invite you to join us on our journey in the search to sustain the Army mission and secure the future. To register your comments on this issue, please contact AEPI at aepi.administrator@hqda.army.mil.

The views expressed in this document do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

OCTOBER 2005

THE ISSUE: NANOTECHNOLOGY

Colonel John McGuinness, a U.S. Army War College Fellow, furnished the foundation for the concepts presented in this document.

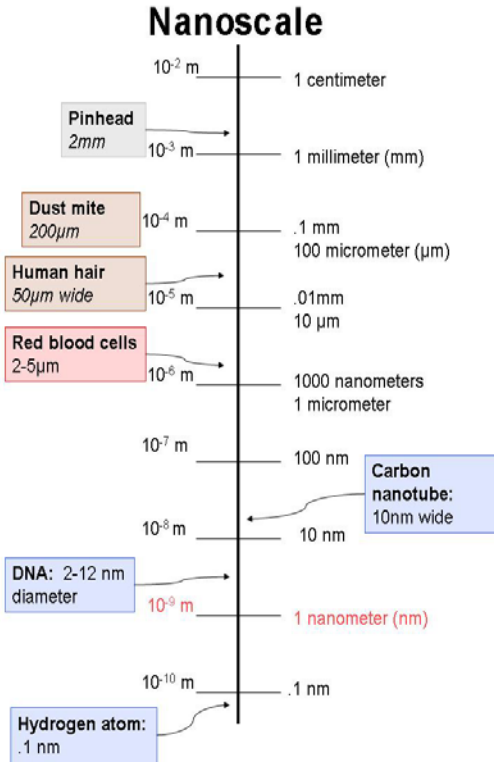
Nanotechnology is the study and manipulation of the new properties that appear when materials are reduced to the limits of the nanoscale. Because the laws of classical Newtonian physics give way to quantum mechanics at this scale, material behavior differs remarkably. Engineers and scientists can exploit these unusual material properties through nanostructured devices. Nanoscience is the convergence of chemistry, biology, and physics applied technologically to research and industry.

STRANGE NEW WORLD

Because nanotechnology operates at length scales (10^{-9} meters) where macroscopic physics breaks down, it offers engineers the potential for creating unprecedented new material properties and devices. The nanolevel world is a wildly different place where familiar materials take on new, unfamiliar properties: insulating materials become conductors, insoluble substances become soluble, and the inert becomes dangerously explosive.

TINY PRODUCTION PLANTS?

In 1959, Nobel prize-winning physicist Richard Feynman suggested that the rules of physics do not preclude molecular assembly. He urged exploration to invent new techniques that could control, manipulate, and fabricate devices with dimensions that were, at the time, unimaginable. These visions included making a machine that could operate at the biological level. Fifty years later, science has arrived at Feynman's vision.



References

McGuinness, John. *Nanotechnology: The Next Industrial Revolution—Military and Societal Implications*. AEPI, 2005. http://www.aepi.army.mil/internet/nanotech-industrial-revolution.pdf

Whitesides, George M. "The Once and Future Nanomachine." *Scientific American*, September, 2001. www.sciam.com.

Whitesides, George M., and J. Christopher Love. "The Art of Building Small." In *Understanding Nanotechnology*, edited by S. Fritz. New York: Warner Books, 2001.

ANALYSIS AND IMPACTS

Nanotechnology's maturation coincident with military transformation sets the stage for joint development by all services, which will minimize duplication of efforts and ensure interoperability. The Army has a unique opportunity to shape both the rate of development and the magnitude of the impact. We must understand nanotechnology's affect on society in general—and warfighting in particular—to shape the consequences in the soldier's environment.

SUSTAINABLE TECHNOLOGY

Sustainable technology requires four conditions:

- **It does not rely, to the extent possible, on substances extracted from the ground.** Nanotechnology uses established stockpiles of materials for production. As the technology matures, individual molecules will be used repeatedly as the need arises, making the constant acquisition of new raw materials from the ground unnecessary.
- **It does not promote an increase in waste products released into the environment.** Within the limits imposed by the second law of thermodynamics, nanotechnology will minimize environmental contamination—recycling on a molecular basis. Waste products less visible to the eye will be minimized as well: the amount of heat generated by processes on a nanoscale is an order of magnitude less than that of current processes.
- **It does not physically degrade the environment.** Nanotechnology emphasizes product assembly molecule by molecule, so environmental degradation is minimal.
- **It meets human needs worldwide.** Nanotechnology certainly holds this potential, offering a sustainable process for new industries.

OTHER IMPLICATIONS

The notion of resources will change. For example, because an atom can be recycled again and again, removing raw materials from the soil is unnecessary; this property of nanotechnology allows enormous strides toward a sustainable economy.

National wealth will become less a function of location and conventional natural resources and more a reflection of the technological sophistication of an educated population.

The technology has widespread application to military logistics and maintenance. For example, new coatings will offer better environmental protection and chemical agent resistance. Superior nanolubricants will extend the useful life of machinery.

References

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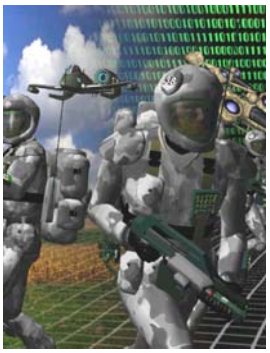
Loder, Natasha. "Small wonders, a survey of nanotechnology." *The Economist* 374, no. 8407, January 2005.
Nattrass, Brian, and Mary Altomare. *Dancing with the Tiger*. Gabriola Island, BC: New Society Publishers, 2002.

WHAT NEXT?

Nanotechnology could be used to create new materials for use in a variety of combat environments. For example, individual molecules could be manipulated to



change their orientation when exposed to a magnetic field or electrical current—from brittle to bullet-proof, porous to water-repellent, and insulating to conducting. Imagine a combat uniform on the battlefield of the future with a surface that changes colors to camouflage a soldier according to varying terrain.

INSTANT ARMOR

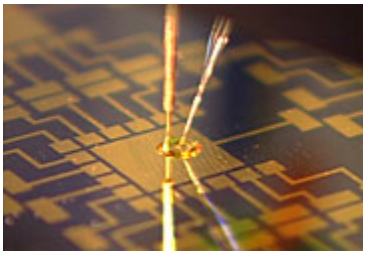
Soldiers could also wear uniforms that turn from soft, comfortable fabric to light, flexible, durable armor with a flip of a switch. The photo below shows iron fluid for instant armor that has turned solid after exposure to a magnetic field. The liquid-solid transformation (which happens in 0.02 second) takes place on the molecular level. When the magnetic field is removed, the material returns to the liquid state.

NANOSENSING

Other nanoscale processes could develop sensors, actuators, and similar devices to change the uniform fabric, reacting in milliseconds to increase defense and protection for the soldier. This technology could also be used for detecting chemical or biological agents and monitoring physiological conditions. Tiny chips (smaller than one square centimeter) could carry microsensing capabilities and nanoengineered surfaces to detect specific compounds such as viruses, proteins, and antibodies.

NANOWIRES AND NANOASSEMBLY

Instant armor will require integrated electronic circuitry. Nanotechnology can also be used to create and manufacture these materials with magnetic or optical properties on an incredibly small scale so that they can be integrated into fabric.



Research websites

http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-5
http://www.sciencentral.com/articles/view.php3?language=english&type=&article_id=218392121&PHPSESSID=c703877f46a6fe36f7245115e496a49c5SQWN?OpenDocument
http://web.mit.edu/isn/newsandevents/isnnews/isnnews504.pdf

FURTHER STUDY AND INVESTIGATION

The Army has a historical opportunity to anticipate an emerging environmental issue and shape the technology. Federal investment in nanotechnology research across 10 agencies is approaching $1 billion in FY05. The Army has invested millions in university nanotechnology partnerships to benefit American soldiers in combat. Sustainability is crucial to future uses of the technology for advances in warfare, soldier safety and welfare, and general military operations. The key to Army leadership in the development of nanotechnology lies in the funding, research, and acquisition process.

RISKS AND BENEFITS

Research and policy direction is required to measure the degradation process of nanomaterials, gauge their effects on the environment—including the air, soil, and water—and analyze risks and benefits.

PRODUCT DEVELOPMENT

Through its purchasing power, the Army can leverage sustainable nanomaterial development to benefit the civilian and military populations.

SAFETY ADVOCATE

A key component of the leadership role in nanotechnology is protecting the work force, civilian and military, from the unintended consequences of nanotechnology processes and materials. The Army should take an active role in drafting environmental, safety, and occupational health guidelines for nanomaterials to ensure contractors follow best environmental practices in the development, manufacture, and application of the new technology.

LAST WORD

New technologies periodically reshape the world, and the impact of a technology on human history is determined by the manner in which it is designed and applied. Just as gunpowder spelled the end of feudalism and better navigational instruments ushered in the age of exploration, nanotechnology will effect a revolution in industrial processes and military hardware. Our challenge is to prepare for the revolution to ensure the influence of our nation and the superiority of our soldiers.

Agencies Funding Nanotechnology Research

Department of Agriculture
Department of Defense
Department of Energy
Department of Homeland Security
Department of Justice
Environmental Protection Agency
National Aeronautics and Space Administration
National Institutes of Health
National Science Foundation
National Institute of Standards and Technology

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