# Shrinking the Battlefield:
## A Review of *Nanotechnology and Homeland Security*

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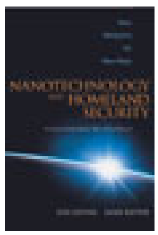


*Nanotechnology and Homeland Security:*
*New Weapons for New Wars*
By Daniel Ratner & Mark Ratner,
Upper Saddle River, NJ: Prentice Hall, 2004.
Pp 160. $24.95 (hardcover).

## I. INTRODUCTION

Though it may seem a marriage of buzzwords, *Nanotechnology and Homeland Security* is a futuristic, yet realistic vision of a more secure America. This brief, non-technical primer on military applications of nanotech research provides a wealth of ideas for policymakers and military planners seeking to upgrade our spotty defenses against terrorism. Venture capitalists should also sit up and take note of this new investment niche: as the battlefield shrinks, the demand for nanotechnology solutions is sure to grow.

While this "security through better technology" paradigm has been around ever since someone first discovered that iron was better than bronze for sword-making, nanotechnology offers radical improvements in virtually every facet of military defense. However, this book does not indulge the hyped-up sci-fi portrayals of nanotech—there are no "grey goo" swarms of self-replicating attacking nanomachines.

Instead, Mark and Daniel Ratner, a father-and-son team of a Feynman Prize-winning chemist and an entrepreneur, do an admirable job showcasing a military of tomorrow, one based on some of the most advanced research being done today. Although the authors' presentation is one-sided, and their claims are often devoid of any explanation (*how* will nanotech enable active camouflaging?), this short book is worthy of a skim by even less technically minded readers. Part II of this book review briefly summarizes the book, while Part III critiques some of the book's problematic aspects.

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In the growing field of nanotech publications, *Nanotechnology and Homeland Security* is a "second-generation" technology book. The "first generation" of technical publications seeks to describe the scien-

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tific research, and perhaps speculate on possible practical applications. The Ratners' earlier book, *Nanotechnology: A Gentle Introduction to the Next Big Thing*, is an example of this generation. The "second generation" applies the research breakthroughs to particular areas—in this case, the military and defense against terrorism.

Consequently, the authors do not try to explain the underlying mechanics of nanotechnology, having devoted an earlier easy-to-read book to that effort. The Ratners have moved on from first-generation technology books trying to educate the public to second-generation books trying to influence policy.

The Ratners envision an American military and economy that embrace nanotechnology. Soldiers would go into battle with light-weight carbon nanotube armor, surrounded by nanosensors watching out for chemical weapon attacks. If they are injured, nano-biocides (which efficiently kill bacteria on contact) would automatically be administered. But soldiers might not even be needed, thanks to autonomous military robots controlled through nanoelectronics and powered by efficient nano-solar energy collectors. On the homefront, nanotechnology allows more resilient building materials, advanced detection of chemical or biological weapons, and quick remediation efforts if necessary.

While the Ratners temper their visionary call with cautionary side notes about the environmental and social consequences of nanotech development, they believe that the predominantly "*defensive*" nature of nanotech military applications presents a compelling case for investing in and adopting nanotechnology. But perhaps the biggest failing of this otherwise praiseworthy book is that it neglects to fully inform its intended audience—U.S. policymakers—of the many "*offensive*" applications of nanotechnology that could easily become the next generation of terror weapons. As discussed later in Part III of this review, nanotechnology could also make it easier to manufacture, smuggle, and disperse biological and chemical agents among an unsuspecting populace.

Policymakers deciding how to spend their government research dollars need to know both the benefits *and* the risks of the projects they fund.

But this problem with the book highlights the important role *Nanotechnology and Homeland Security* plays for the nanotechnology research community: it provides easily digestible information for policymakers who are trying to pick among futuristic defense projects based on science they do not understand. The bulk of government research spending comes from military defense. While nanotechnology's industrial applications have attracted large public (and increasingly private) investment, this amount pales in comparison to the potential military and Homeland Security spending.

*Nanotechnology and Homeland Security* hopes to be a beacon that attracts the attention of military planners to the rapidly growing club of nanotech investors.

## II. BOOK SUMMARY

It would be hard to capture and describe the stylistic flair that the Ratners use in *Nanotechnology and Homeland Security*. The book's virtual catalogue of pop culture references to nanotech (ranging from TV shows like *Star Trek* and *X-Files* to books like Michael Crichton's *Prey*) and occasional whiffs of humor go a long way to making the text friendly to the layman. The authors make it clear that this is not intended to be a scholarly book, and there are few citations for readers to learn more or to contest the seemingly fanciful ideas. However, the book does start with a basic description of the nuts-and-bolts of nanoscience.

## 1. A Brief Primer on Nanotechnology

The science of nanotechnology actually spans several diverse fields; the unifying theme is that the research occurs at the nanoscale level—one-billionth of a meter. Excitement about nanotechnology boils down to two things: materials at the nanoscale level behave differently than they normally do, and it is cheaper and easier to build useful larger structures starting at the smallest level.

The Ratners identify seven major areas of research that have already developed potential nanoscale applications. *Material science* has developed remarkable structures such as nanotubes ("the strongest, most conductive and stiffest materials ever made"), molecular coatings, and nanoscale sieves. Researchers working with *nanoscale sensors* have developed tiny devices that respond to molecules such as anthrax toxin. *Biomedical* researchers are using some nanomaterials as novel drug delivery devices, while *energy* researchers are testing other nanomaterials in building better batteries. *Electronics* and *optics* research are turning to smaller and smaller materials to build computers and light emitting diodes (LEDs), yielding options such as "pervasive computing" and "all-optical computers." Finally, more general *fabrication* research uses nano-sized building blocks of molecules to fabricate much bigger objects.

Together, these research areas create new options for military planners, as the bulk of the text describes.

## 2. Nanotechnology in the Battlefield

The Ratners envision the "new battlespace" of the 21st century, where wars are waged under the constant threat of imminent attack from chemical and biological weapons ("CBWs"). Under these conditions, soldiers must be protected, or even better, taken out of harm's way altogether.

Nanotechnology already allows "lab-on-a-chip" devices that can continually survey the battlefield for lethal toxins such as anthrax. Nanoscale structures of gold (called nanodots) and DNA strands can be designed to bind to anthrax spores in the air, triggering a molecular color change that can be quickly detected. Future lab-on-a-chip devices could attach to a wide variety of other toxins, allowing a single tiny device to guard a soldier from most CBWs.

Given how small and cheap these labs-on-a-chip could become, they could be woven into a soldier's uniform. More dramatically, the Ratners suggest that these sensors could be injected into the soldier's bloodstream, so that they could detect CBW agents throughout the body while monitoring the soldier's health.

After the initial detection of CBWs, smart nanomaterials in the uniform would react to form an air-tight bodysuit to protect the soldier from exposure—although a filtered oxygen mask would still be necessary. Improved filters could be created using nanotubes, which would allow oxygen molecules to pass, but not the larger deadly CBW compounds. (A caveat: most chemical weapons, such as cyanide gas (HCN), are not much bigger than an oxygen molecule.)

The nanotech smart material could also act as stronger and lighter body armor. For example, research being done by Ray Baughman's group at the University of Texas in Dallas uses interwoven nanotube fibers to produce a cloth 17 times tougher than Kevlar.

Even more exciting possibilities for soldier gear involve active camouflage (automatically changing color to match the environment) and automatic deployment of antiseptics, antibiotics, and anesthetics as soon as a soldier is injured. Best of all, these technologies can be combined into a suit that is much lighter than the bulky and cumbersome gear soldiers currently use.

A more intriguing strategy for protecting soldiers is to take them out of harms way by using autonomous or remote-controlled military vehicles, such as the Predator drone (currently being used to hunt terrorists in Afghanistan and the Middle East). To be successful enough to replace soldiers, these machines will need better image recognition and computer processing power, sturdier material to survive counterattacks, and better batteries and lighter construction to allow longer missions. The seven areas of nanotechnology research described above can all contribute, whether through nanoelectronics that quickly respond to military battleground conditions, or nanomaterials that provide lightweight armor and more efficient fuel cells.

The battleground, never a safe place to begin with, has become much more dangerous with the threat of CBWs. However, nanotechnology would allow future American soldiers to complete their missions with fewer worries about these unseen threats.

## 3. Nanotechnology in Homeland Security

The authors turn away from the battlefield to discuss using nanotechnology to defend against CBW attacks at home. Many of the possibilities raised are unsurprising based on the earlier chapter: cheap, ubiquitous nanosensors in buildings' air systems, and super-strong, flame retardant nanocomposite materials in the walls. Police, firefighters, and other emergency responders would be protected from CBWs much the same way as soldiers would.

The more interesting (and controversial) possibilities are those in human repair and surveillance. The Ratners showcase the self-assembly research by Sam Stupp's group at Northwestern University, who injected rodcoil molecules at the site of a bone fracture. In seconds, the molecules self-assembled into bone-like fibers to bridge the fracture, speeding up the healing. (It is a little odd that the Ratners do not further discuss the implications of developing nanotechnology that can easily manipulate human tissue, and instead just sanguinely ask, "Wouldn't it be nice to be able to walk out of a hospital just days after being wheeled in with a broken leg?" But more on this later. . .)

The best way to defend against a terrorist attack is to use intelligence to prevent an attack from occurring in the first place. The Ratners' answer to this challenge is to invoke the powerful computers enabled by nanotechnology. They describe DNA computing, molecular computing, and quantum computing as new computing architectures that could process massive amounts of data (such as a database of faces) or quickly crack encrypted communications.

At least the Ratners have not forgotten that one of the initial responses to the September 11 attacks was the proposed "Total Information Awareness" project, a massive computer database of travel, financial, and medical records. Smaller and smaller computers raise the danger of Bigger and Bigger Brother. But the authors consider threats to privacy an inevitable risk of the continual advances in nanoscience and information technology—one not within their province to try to resolve.

## 4. Environmental and Economic Considerations

Although the focus of the book is clearly on military and defense applications, some of the most exciting applications of nanotechnology show up in the civil sector. The Ratners tie these industrial applications to the rest of the book by characterizing them as addressing the "economic motivations" behind terrorism. The availability of cheap, abundant, and ecologically friendly energy would completely transform our thinking about security.

Perhaps the most interesting possibility described in this chapter is efficient solar power. Photosynthesis occurs in plants and bacteria through a complex set of nanostructures. Scientists are currently trying to replicate those structures, while start-ups like Nanosolar are already making flexible solar cells only 300 nanometers thick.

Of course, cheap energy would still need to be transported and stored. Under certain conditions, nanotubes conduct electricity without resistance, offering a significant improvement over copper wires that dissipate as much as 30% of the energy they carry. Other nanomaterial research is being done to improve batteries and fuel cells, while biological nanoscience offers some possibilities for tackling the elusive challenge of storing hydrogen, a cheap but very volatile energy source. More immediately, nanotechnology is already being used in catalysts for refining higher-octane gasoline.

But any benefit posed by non-polluting energy production must be weighed against the potential for serious environmental harm. Daniel and Mark Ratner, advocates for embracing nanotechnology, do not emphasize the environmental concerns of activists like the ETC Group (although they are briefly mentioned). Since nanoparticles can be easily absorbed by cell membranes—the same reason they make for effective medicinal drug delivery—some nanoparticles may act much like asbestos and other toxic materials.

Even more startling, DuPont researchers found that when nanotubes fibers were injected into the lungs of rats, the clumping of the fibers caused the animals to immediately begin gasping for air, and 15% of the sample quickly died.[1] This is not to say nanotechnology should be rejected, but policymakers need to hear the full story if they are considering funding the Ratners' visions.

### 5. Social Consequences

The Ratners have laudably focused on the social implications of this new technology. Their first book, *A Gentle Introduction*, concluded with a "nano ethics" section that urged a public multidisciplinary debate on potential negative uses of nanotechnology. While those negative uses get downplayed in this book, the Ratners again conclude with a section on "nano ethics."

This time around, the Ratners are more concerned about privacy and international inequality. As discussed earlier, the authors fear that a collision between privacy and technology advancement is inevitable. They suggest that a constitutional amendment directly stating a right to privacy is a necessary solution.

The chapter also contains a somewhat misguided discussion of intellectual property (IP) law as a barrier to sharing nanotechnology benefits with poorer nations. The authors criticize recent copyright controversies regarding Mickey Mouse and Harry Potter (yet more pop-culture allusions), suggesting they foreshadow restrictive patent law policies. While there is much truth behind these concerns, the reality is more complex, due to the differences between copyright and patent law. While copyright treaties effectively give automatic worldwide protection to books and movies, a nanotechnology patent would generally have to be registered in each country to be enforced there—and patent enforcement varies widely country to country.

In general, this is not the most cohesive chapter in the book, and might be skipped by less patient readers.

## III. SPOTLIGHT & CRITIQUE

### 1. Intellectual Property Legal Issues

The Ratners are right to be concerned that IP restrictions may hinder the spread of nanotechnology benefits. The Trade-Related Aspects of Intellectual Property Rights Agreement (TRIPS) and the World Trade Organization (WTO) have begun to enforce patent rights under the gun of economic sanction.

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1 *See* Barnaby J. Feder, *As Uses Grow, Tiny Materials' Safety Is Hard to Pin Down*, N.Y. TIMES, Nov. 3, 2003, at C1.

However, the IP problem may be more immediate than they realize. Nanotechnology patents are so muddled and overlapping that rigorous patent enforcement may prevent any of these exciting applications from being developed. For example, a developer of a bio-toxin sensor may have to get multiple licenses for overlapping patents covering nanodots, biosensors, DNA-binding, and nanoelectronics. Unless some sort of patent coordination occurs, it may be hard to profitably develop such a biotoxin sensor or other useful nanotechnology applications.

### 2. "Nanotechnology Plus": A Book About Interdisciplinary Research

For most of the book, the Ratners are not talking about nanotechnology; but rather *nanotechnology plus*. Many of the fantastic applications they describe require significant advances in non-nanotechnology fields of research. For example, the new computing architectures the authors propose (all-optical computing, bio-electronic computing, DNA computing, quantum computing, and molecular electronics) are as dependant on computer science, genetics, and quantum theory as nanoscience.

This has implications for policymakers deciding where to spend their military research dollar. Nanotechnology offers a lot of potential, as outlined in this book, but in the end it needs development in other technologies to fully achieve the vision.

Still, this interdisciplinary aspect should make the book appeal to venture capitalists focusing in non-nanoscience fields. By showcasing the results of combining nanotechnology with other technologies, this book may encourage investors in divergent fields to explore unusual joint projects.

### 3. A Double-Edged Sword for Fighting Terrorism

Finally, we turn to the most egregious problem with the book. Although the Ratners acknowledge that nanotechnology could be a "double-edged sword," they avoid discussing the possibilities of nanotechnology as terrorist weapons *anywhere* in the book. This omission is unfortunate, since military planners need to be aware that the defensive technologies they may fund today to combat terrorism could easy be turned into the next generation of terror weapons.

For example, super-strong carbon nanotubes could create knives that render airport metal detectors virtually worthless. This idea is not particularly original; the Ratners themselves suggest it in their "nano ethics" chapter in *A Gentle Introduction*.

More serious, nanoparticles that can penetrate cell membranes or manipulate human tissue could easily be adapted to kill rather than heal. These new classes of "nano-poisons" would have no antidote, could be easily dispersed through the air or water, and would be extremely difficult to detect. Even more chilling, nano-poisons could be engineered to respond to certain DNA triggers (much as the lab-on-a-chip binds to a certain kind of DNA). This would allow targeting a group of people with a certain genetic characteristic.

But why design new toxins, when anthrax and sarin nerve gas are enough to inspire crippling terror? While these agents are currently difficult to mass-produce, nanotechnology would allow building toxins molecule-by-molecule from scratch. Currently, governments have tried to address CBW threats by limiting the source material. In the future, this will no longer be an effective strategy.

Again, these points are not to suggest that U.S. policymakers should reject nanotechnology. As a practical matter, that is not an option—the Ratners point out that Russia, China, and other nations have plunged ahead with nanotechnology initiatives. Ignoring the military benefits of nanotechnology could affect the future balance of power.

But policymakers can be selective about which military projects they fund, and devote resources to preparing for or even preventing any subversion of defensive technology for terrorist uses.

## IV. CONCLUSION

*Nanotechnology and Homeland Security* is short, easy-to-read, informative, and visionary while keeping mostly within the bounds of contemporary research. While the book has flaws, on balance, the authors do a credible job of advocating their vision. The book is something policymakers should skim briefly to pick up new ideas, rather than keep as reference material. While new ideas cannot take us back to the time when no one had ever heard the phrase "Homeland Security," they may lead us to a time when we hear it far less often.