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Turn on the Nanotech High Beams

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You're driving a car, very fast, on a poorly marked road, in the pitch-black darkness.

There are no streetlights, there is no moon out tonight, the only illumination you have is your car's headlights…you're in uncharted territory; you have no roadmap, no way to know for sure where you are going…but you're driving very fast, into the pitch-black darkness…

That's the state of nanotechnology today. We're advancing rapidly into uncharted territory. The changes this technology will bring may arrive sooner than we are prepared to respond effectively to them.

It's like driving a car in the darkness with only your headlights to show what's ahead. The speed you are driving exceeds your ability to react, and if something suddenly comes out of the darkness, you won't have time to respond and avoid disaster.

One other thing: you don't know it, but there is a chasm up ahead in the distance. You are driving directly toward it, very fast, and you don't even know it's there.

What's the solution? Two things:

First, turn on your high beams! Your normal headlights will illuminate only a short distance ahead, not far enough to react if you're going fast. By turning on the high beams, you can almost triple the illumination distance.

When we hear people talk about risks of nanotechnology, they often speak only of the *short-term* hazards caused by *today's* practices and products—mostly nanoparticle toxicity. But that's like driving with the low beams on. They're not looking far enough ahead, toward more serious potential dangers.

The second thing to do is activate your cell phone (it's built in to the steering wheel of your car) and call someone who might help you better understand where you are going. You could connect with someone who has a satellite view of the area, and who can warn you of the chasm in the distance. They might even be able to organize a work party to build a bridge over that chasm so you can travel in safety.

My organization, the Center for Responsible Nanotechnology, is a nonprofit think tank concerned with the major societal implications of advanced nanotechnology. We promote public awareness and education, and the crafting of responsible policy to maximize benefits and reduce dangers.

Through our research, we're creating the equivalent of a satellite picture of what's ahead. It may not be refined enough to see all the details, but we think it's clear that a chasm looms in the distance, and a bridge must be built to safely cross it. But there isn't much time. Unless we start now, we might get there before we are prepared to respond effectively and avoid disaster.

Most of the work being done today that carries the name 'nanotechnology' is *not* nanotechnology in the original meaning of the word.

Nanotechnology, in its traditional sense, means building things from the bottom up, with atomic precision. This theoretical capability was envisioned as early as 1959 by the renowned physicist Richard Feynman.

In recent years, both governments and companies have adopted a far broader definition of the word, essentially meaning any work being done on the scale of 1 to 100 nanometers. This is important work and valuable work, but in many cases, it is not fundamentally different from what has been done before. Societal impacts of this work may be significant, but they almost all will be incremental impacts—not transformative—and can be dealt with using existing systems, institutions, and solutions.

To distinguish this broad and diverse field of work from the original meaning of nanotechnology, we refer to most of what is being done today as ‘nanoscale technologies.’

Advanced nanotechnology promises the ability to build atomically precise machines and components of molecular size. Using mechanically guided chemistry, rapid prototyping, and automated convergent assembly, an integrated system of productive nanosystems—what we call a *nanofactory*—could combine these molecular components into large and complex products, including additional nanofactories.

A nanofactory should be able to provide cheap, clean, rapid manufacturing. The resulting abundance (from many nanofactories) has the potential to alleviate most shortages and enable a high standard of living for everyone who has access to it. Rapid, cheap, flexible manufacturing will allow swift development of new inventions, spurring innovation and creating further benefits.

Unfortunately, a technology this powerful could easily be misused. The rapid development cycle and massive manufacturing capability may lead to an unstable arms race between competing powers. *Excessive* restrictions that limit access to the technology or limit distribution of the benefits may lead to an inhumane gap between rich and poor, and may encourage a black market in unsafe molecular manufacturing. *Insufficient* restrictions may allow small groups and even individuals to produce undesirable products or terrorist tools. These and other dangers are the jagged rocks at the bottom of the chasm you're driving toward.

Advanced nanotechnology, along with other technologies that it will enhance or enable, will create new problems and new opportunities that require new solutions. These technologies will be more transformative than most people expect, and could develop too rapidly for *reactive* policy to succeed. We urgently need a better understanding of numerous factors related to molecular manufacturing, to prepare for its possible development sometime within the next decade.

To date, there has not been anything approaching an adequate study of these issues. In order to correct this, we have outlined a series of thirty recommended studies, covering fundamental theory, possible technological capabilities, bootstrapping potential, product capabilities, and policy questions. Preliminary conclusions to these studies have been identified, and because our understanding points to a crisis, work on all of them should begin immediately, and in parallel. That would be the equivalent of turning on our high beams.

The products of a nanofactory could have unprecedented power and efficiency. Some restrictions, implemented worldwide, probably will be necessary for sufficient control of the use of molecular manufacturing. That would be the equivalent of building a bridge to safely cross the chasm into the coming nano era.

But if the dangers are so great, why not just slow down?

That’s a good question, and it may turn out to be part of the solution. But it’s not as simple as it sounds.

For one thing, there is more than one car. In fact, it’s a drag race — in the dark — through uncharted territory.

Other countries besides the United States have active, well-funded programs to develop nanoscale technologies. These include Japan, China, Australia, Singapore, Russia, Israel, Brazil, India, and many nations within the European Union. The president of India, himself a nuclear physicist, has gone so far as to say that advanced nanotechnology must be developed by his country’s scientists because, among other things, it “would revolutionize the total concepts of future warfare.”

Just because one country or group of countries decides to slow down, that does not mean everyone will.

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Development of molecular manufacturing technology will rapidly become easier. Several technologies allow direct creation of complex structures less than 20 atoms wide, and single-atom lithography is being developed. Top-down and bottom-up approaches are meeting in the middle, and may learn to combine their efforts. Automated assembly has been used for decades; rapid 3D prototyping is quickly developing from industrial to home use.

Molecular manufacturing and assembly will be simpler and easier in many ways than normal manufacturing. Fast-track development programs, some of which may be secret, competitive, and unregulated, will be driven by powerful economic and military incentives.

General-purpose molecular manufacturing appears to be inevitable. It might become a reality by 2010, likely will by 2015, and almost certainly will by 2020. When it arrives, it will come quickly. To be prepared for the coming development of molecular manufacturing technology, we must start planning for it immediately.

Who should be concerned? Anyone whose planning horizon extends to ten years or more, including groups focused on:

- Business & Trade
- Medical Ethics & Research
- Arms Control & Geopolitics
- Intellectual Property
- Sustainable Development
- Surveillance & Privacy
- Knowledge Management
- Ecological Remediation
- Policing & Criminology
- Social Justice

Molecular manufacturing represents power: political power, military power, and financial power. Who controls that power and how widely—how *democratically*—it is distributed will make all the difference when the technology is developed. Decisions we make *before* that time will determine whether our world becomes safer or more dangerous; more just or less just; more free or more oppressive.

We need to turn our high beams on and use the cell phone. Only by taking a long view and sharing information between networked communities can we meet the test of creating wise, comprehensive, and balanced plans for an effective global response to this transformative, disruptive technology.

This essay is original and was specifically prepared for publication at Future Brief. A brief biography of Mike Treder can be found at our main Commentary page. Recent essays written by Mr. Treder can be found at the Center for Responsible Nanotechnology. He receives e-mail at mtreder@crnano.org. Other websites are welcome to link to this essay, with proper credit given to Future Brief and Mr. Treder. This page will remain posted on the Internet indefinitely at this web address to provide a stable page for those linking to it.