Center for Responsible Nanotechnology

Scenario Project: Introduction

Let's begin by clarifying the specific definition of 'nanotechnology' as it is used in our scenarios, as compared to the broad and diverse field of 'nanotechnology' that exists today. Current nanoscale technologies can and do include everything from lithography to optics to metrology, encompassing materials science, semiconductor manufacture, and even ranging into biotechnology.

At the Center for Responsible Nanotechnology, we've tried to narrow the definition a bit by describing nanotechnology as "the engineering of functional systems at the molecular scale." This covers both current work and concepts that are more advanced.

Within the scenarios you're about to read, the focus is on a particular advanced form of nanotechnology, often referred to as 'molecular manufacturing'. Future generations of nanotechnology will use sophisticated nanoscale machinery to construct powerful products with molecular precision. Molecular construction will lead to revolutionary capacities, including tabletop fully automated factories capable of constructing duplicate factories in less than a day.

The economic, security, military, and environmental implications of molecular manufacturing are extreme. Unfortunately, conflicting definitions of nanotechnology and blurry distinctions between significantly different fields have complicated the effort to understand those differences and to develop sensible, effective policy for each.

The risks of today's nanoscale technologies cannot be treated the same as the risks of longer-term molecular manufacturing. It is a mistake to put them together in one basket for policy consideration—each is important to address, but they offer different problems and will require far different solutions. As used today, the term nanotechnology usually refers to a broad collection of mostly disconnected fields. Essentially, anything sufficiently small and interesting can be called nanotechnology. Much of it is harmless. For the rest, much of the harm is of familiar and limited quality. Molecular manufacturing, by contrast, will bring unfamiliar risks and new classes of problems.

Desktop nanofactories will use vast arrays of tiny machines to fasten single molecules together quickly and precisely, allowing engineers, designers, and potentially anyone else to make powerful products at the touch of a button. Although such a contraption has been envisioned in some detail for almost two decades, and although the basic concept goes back to 1959, when the physicist Richard Feynman first articulated it, it's only in the last few years that technology has advanced to the point where we can begin to see the practical steps that might bring it into reality.

Recently, for example, the first version of a "Technology Roadmap for Productive Nanosystems" was published. This event marks the completion of a broad, years-long, multidisciplinary effort to explore how current laboratory techniques for atomically precise fabrication can be extended, step by step, toward increasingly advanced products and capabilities. Before that, as part of a study released in December 2006, the U.S. National Research Council reviewed the technical analysis originally presented in Eric Drexler's *Nanosystems: Molecular Machinery, Manufacturing, and Computation* (1992) and called for experimental research in support of molecular manufacturing. Subsequently, DARPA issued a request for proposals for developing tip-based nanofabrication at the threshold of atomic precision, and the U.K. government announced grants to research teams developing nanomachines that can build materials molecule by molecule.

Taken together, what these developments mean is that warnings, from CRN and others, about the possibly disruptive impacts of a mature molecular manufacturing technology should be taken seriously. We advocate the prompt and thorough investigation of both potential benefits and anticipated risks to see what might be done now and in the next few years to mitigate the dangers and increase the likelihood of beneficial outcomes. Along those lines, we initiated a project earlier this year to create a series of professional-quality scenarios of a near-future world in which exponential general-purpose molecular manufacturing might be developed and deployed.

In pursuing this project, CRN pulled together more than 50 people from six continents, with a range of backgrounds and points of view, as potential collaborators. Over the course of several months, we conducted a unique series of “virtual workshops,” using a combination of teleconferencing, Internet chat, and online shared documents, and in the end produced eight very different scenarios. Workshop participants were given the sole guideline that nanofactory technology should be expected to arrive no later than 2022—everything else came from the collective knowledge and imaginations of the scenario working group (see participant list below).

The development of molecular manufacturing over the course of the next 15 years is in many ways the paradigmatic example of what scenario specialists refer to as a “critical uncertainty.” When nanotechnology-enabled molecular manufacturing appears, few observers doubt that it will fundamentally reshape everything from transportation, energy, and information networks, to how we do business, to how we make war.

A technological or social development that affects so many disparate realms in such profound ways is the classic definition of a “critical” driver. The “uncertainty” aspect is a bit less obvious. While a 15-year time frame for the development of molecular manufacturing is arguably optimistic, it is by no means outrageous, and, as noted above, recent events indicate that this transformative technology can be expected to arrive relatively soon. What's uncertain is precisely how it will emerge.

The scenario process offers a tool for the examination of internally consistent possibilities regarding a particular topic as a way to test and reconsider strategies. The scenarios we’ve produced examine possible outcomes of different nanotechnology developmental pathways across a variety of nations. These scenarios are not predictions, and do not represent outcomes desired by the Center for Responsible Nanotechnology. CRN intends these scenarios to provide a springboard for discussions of molecular manufacturing policies and societal responses.

While each scenario can be understood individually, the real value of the process comes from the comparison of multiple scenarios. A strategic response that appears robust in one scenario may be dangerous in another; an organization, community, or polity using these scenarios to consider how to handle the emergence of molecular manufacturing should strive for responses that are viable across multiple scenarios. Such strategies would stand a higher chance of success in the face of how molecular manufacturing really does emerge.

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