Global tectonics
Part 2

Small revolution

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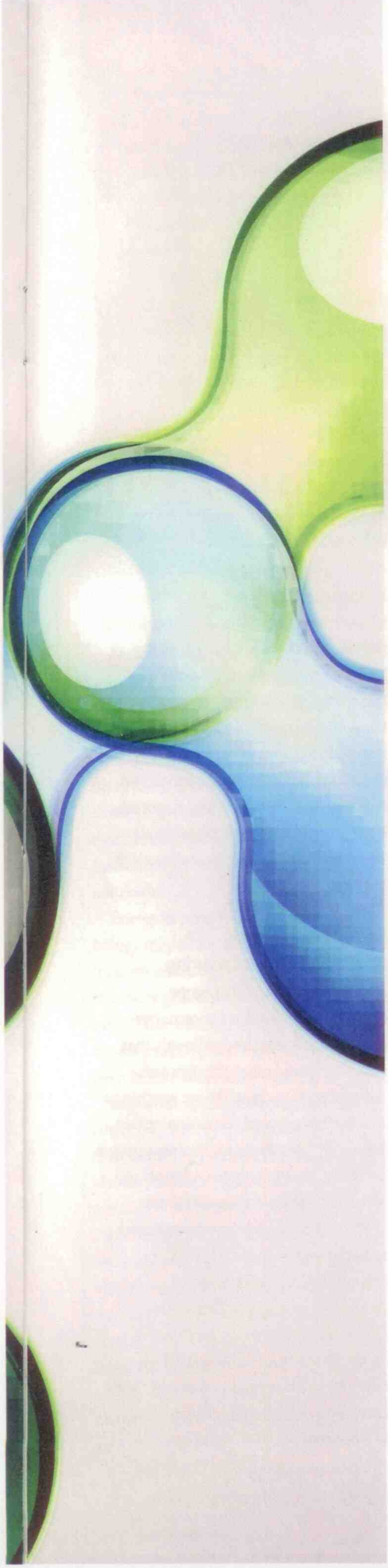
EXECUTIVE SUMMARY

Nanotechnology, the new frontier of conflict, already has attracted considerable investment by governments and private industry worldwide. When perfected, advanced nanotechnology will streamline production and reduce manufacturing costs in significant ways. It is expected that as early as 2015, the industry's global output will reach $2.4 trillion. According to a report issued by the National Science Foundation, "If nanotechnology, the manipulation of matter at the atomic level, at maturity achieves even a fraction of its promise, it will force the reassessment of global markets and economies and industries on a scale never experienced before in human history."

12 TRENDS CHANGING THE WORLD

A decade has passed since we first conducted the Global Tectonics' study that identified 12 trends that would dramatically shape the future international business environment. Though many of our predictions are coming true, certain forces – such as the growth of social media – have had a much greater impact than expected. Given the rapid change the global business climate continually experiences, we have decided to update our initial study to better equip future leaders and to revisit the trends we identified that surprisingly remain the trends that thought leaders are most concerned about today.

1. Biotechnology
2. **Nanotechnology**
3. Information technology
4. Population
5. Urbanization
6. Disease and globalization
7. Resource management
8. Environmental degradation
9. Economic integration
10. Knowledge dissemination
11. Conflict
12. Governance



While biotechnology has developed from its nascent research beginnings into incredible commercial applications and social benefits, the ramifications of the second technological global tectonic remain more difficult to predict. This next force, nanotechnology, is positioned to have major global tectonic effects – yet, ironically, what it makes use of is so small that it cannot be seen with the human eye.

One nanometer is one-billionth of a meter. Put another way, there are 1 million nanometers in 1 millimeter. For perspective, the width of a human hair is approximately 80,000 nanometers. Nanotechnology is used to rearrange molecules so that essentially every atom can be put in its most efficient place.

Ralph Merkle of the Georgia Institute of Technology explains it this way: "Manufactured products are made from atoms, and the properties of those products depend on how those atoms are arranged. If we rearrange the atoms in coal, we can make diamond. If we rearrange the atoms in sand and add a few other trace elements, we can make computer chips. If we rearrange the atoms in dirt, water and air, we can make potatoes."

New material, new properties

But nanotechnology is not just the miniaturization of products and rearranging of atoms. When moving from the micro level (1 micrometer is one-millionth of a meter) to the nano level, materials exhibit new properties. For example, "large" particles of titanium (on the micron scale) absorb sunlight; therefore they are used in some sunscreens. Unfortunately, these large particles show up white on the noses of lifeguards. The nanoscale titanium particles absorb exponentially more light due to greater surface area. As a result, they appear translucent, leaving lifeguards with more natural-looking noses. Nanotech sunblock also lasts longer on the skin.

In addition to having a larger surface area, "nanoparticles in the three-to-five nanometer range behave a lot like gas particles," said Peter Dobson, a professor of engineering science at Oxford and the founder of several nanotechnology startups. Nano-enhanced materials offer new combinations of material characteristics. Scientists can use nanotechnology to produce materials that are both hard and tough, whereas hard materials are usually brittle and tough materials usually soft. And these are just some of the many different characteristics and possibilities nanotechnology presents.

Though Richard Feynman, who received the Nobel Prize in physics in 1965, conceptualized the idea behind nanotechnology more than half a century ago, we are beginning to see wide uses for these emerging nanotechnologies in this century. A decade ago, Jack Uldrich and Deb Newberry wrote in their book *The Next Big Thing is Really Small: How Nanotechnology Will Change the Future of Your Business* that nanotechnology was not a far-off, fuzzy, futuristic technology:

> Companies, universities and governments around the world have invested billions in nanotech research.

"It has already established a beachhead in the economy. The clothing industry is starting to feel the effects of nanotech. Eddie Bauer, for example, is currently using embedded nanoparticles to create stain-repellent khakis. This seemingly simple innovation will impact not only khaki-wearers, but dry cleaners, who will find their business declining; detergent makers, who will find less of their product moving off the shelf; and stain-removal makers, who will experience a sharp decrease in customers. This modest, fairly low-tech application of nanotechnology is just the small tip of a vast iceberg – an iceberg that threatens to sink even the 'unsinkable' companies."

Within the past decade, advancements in new instruments and technologies that provide scientists and researchers with the ability to better examine and manipulate matter now allow for a foreseeable future nanotechnology revolution. Since nanotechnology's beginnings, companies, universities and governments around the world have invested billions in nanotech research. According to M.C. Roco and his co-editors in *Nanotechnology Research Directions for Societal Needs in*

2020, between 1990 and 2008, 17,600 companies from 87 countries were involved in nanotechnology publications and patent applications. Further, in 2009, the market included $254 billion worth of products that used nanotechnology.

Though the nanotechnology industry started solely with large corporations and countries investing, that landscape is changing. According to Georgia Institute of Technology researcher Jan Youtie, smaller concerns are beginning to jump on board: "A lot of small companies are involved in novel nanomaterial development. Large companies often focus on integrating those nanomaterials into existing products or processes."

Thanks to the investment on the part of small and large companies, global nanotech industry output is predicted to reach $2.4 trillion as early as 2015. Its future impact beyond next year, however, is incredibly challenging to forecast, for nanotechnology has the potential to affect and fundamentally change multiple industries. Many, such as the Pew Charitable Trusts, even speculate that it will usher "in the next technologically driven Industrial Revolution."

Patenting activity also has risen. In fact, the U.S. patent office published a record number of more than 4,000 patents in 2012, which is an increase of more than 2,000 patents from just three years before. Unfortunately, though, this "patent feeding frenzy" may have detrimental effects on the industry at large. Last year, *Chemistry World* reported in the article "Nanotech Patent Jungle Set to Become Denser in 2013" that "hyperactive nanotechnology patenting is increasing costs for innovators, slowing technological development and locking away fundamental knowledge from use." As a result, some have called for a reprieve on patents for publicly funded research.

'Invisible' materials, self-propelled cancer fighters

Despite some of these research barriers, progress in the field is still being made. For example, new drugs and diagnostic tools already have been developed with nanotechnology.

Moreover, through metamaterials, we have almost achieved invisibility. A metamaterial is an artificially created matter that bends light around it, and to the human eye, an object covered in a metamaterial appears invisible. In June 2013, Stanford University made a breakthrough in creating invisibility through the use of optical metamaterials. Previous efforts only allowed invisibility within a limited range of optical wavelengths and, therefore, colors. The Stanford research team, however, has designed a material that can bend nearly all wavelengths of light visible to the human eye.

Other nanotech breakthroughs include the discovery of graphene, the best heat conducting material known to man, new cancer treatments and energy-generating shirts. Penn State researcher John Badding and his team have developed the first fiber-optic solar cell. The fibers are thinner than human hair and can produce electricity. The U.S. military already has begun to invest in the fiber, which can power small electronics for soldiers in the field.

In the longer term, nanotechnology will continue to impact the world in which we live. Nanotechnology researchers and developers can be broken into two camps of thought. The scientists in one camp create the products we see in the market today, such as wrinkleless shirts and high storage computer chips. They miniaturize products and take advantage of the properties of elements at the nanoscale. The scientists in the other camp believe that one day we will be able to build things from the bottom up, atom by atom. They imagine personal desktop nanofactories that build objects from the most basic raw materials.

Developments made in the first camp certainly will shake the business world. A breakthrough in the second camp would transform the business world. Perhaps one day there really will be tiny, self-propelling structures that seek out and destroy cancer cells inside the human body. Nanotech eventually could change the nature of healthcare – moving us from what General Electric had called a "see and treat" world to a "predict and prevent" world. Treating the human body at the cellular level could allow doctors to develop new methods to correct a number of cellular disorders, including many types of cancer.

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Although it perhaps sounds a bit futuristic, nanotechnology also increases the medical community's understanding of brain function. A nanostructured data storage device the size of a typical human liver cell could hold information amounting to what the entire Library of Congress can store. Implanted in the human brain and equipped with appropriate interface mechanisms, this device could provide insights into brain function and artificial intelligence (AI) – the technology used to create intelligent robotic machines.

Besides commercial products and healthcare, nanotechnology also has the potential to effect change in industries ranging from energy and the environment to communications and computing to more. In time, nanotechnology could change all of materials science, all of computing, and much of biology.

Safety worries and streamlined manufacturing

A transformation of that scope could generate serious concerns over nanoethics. It is unlikely, though, that anything would cause the nanotechnology baton to drop. We are watching a classic technological revolution unfold. The critical questions for business people are where we are in that revolution and where we will be in the near future.

When perfected, advanced nanotechnology, also known as "molecular manufacturing," is expected to streamline production and reduce manufacturing costs so that they do not greatly exceed the cost of the required raw materials and energy. With every molecule in order, production will generate less waste and be more efficient, producing low-cost, high-quality, nanoengineered products.

These products, cheaper to buy and to produce, have the potential to raise living standards around the world.

Nanotechnological developments also could lead to a cleaner environment. The ability to create filtration systems at a molecularly precise level would improve purification of wastewater and gas from fossil fuels. Research is being done to develop nanotechnological components that break down toxic waste and to come up with catalysts that decompose pollutants.

Energy experts think that nanotechnology might help to reduce transmission losses by equipping the electricity grid with superconducting cable. More efficient light-emitting diodes could replace wasteful incandescent and fluorescent lighting.

Engineering materials that consume large quantities of energy during the manufacturing process, such as steel, aluminum and titanium, could be replaced by resilient nanocomposites and carbon nanotubes. Scientists also hope that advances in molecular manufacturing will develop solar power into a cost-effective energy solution. Already, nanowires are having a dramatic impact on the efficiency of solar energy.

Without a doubt, the next two decades will see more sophisticated uses of nanotechnology and better integration. While it's hard to predict the commercial impacts of nanotechnology, consumer products, health products, chemicals and electronics will be among the most affected. And despite many challenges, nanotechnology's eventual wide spread into materials seems inevitable. Scientists will learn how to assemble atoms with stable structures predictably and profitably, and nanotech applications will take off. They will turn it over to engineers who will develop prototypes and expertise that can be transferred to the manufacturing foremen and the marketers.

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Properly calibrating the risks

Yet, as with all new technologies, nanotechnology must be developed and implemented with proper risk assessment and regulation. Despite significant breakthroughs in nanotechnology and its much-touted potential application in biomedical and materials sciences, questions still remain in the scientific community about whether nanotechnology will present unique health and environmental dangers. In fact, the U.S. Environmental Protection Agency's National Center for Environmental Research funded $4 million to 12 universities for the purpose of investigating potential health and environmental impacts of nanomaterials.

The incredible diversity of nanoparticles complicates the data-gathering process. Essentially, anything can be made nanoscale, and all materials will not be as safe as water. Determination of safe and not safe will need to be made on the specific basis of the material and the application. Like all brand new technologies, there are potential negative repercussions that have to be analyzed carefully. At the forefront of this will, of course, be the insurance companies that want to make sure certain elements of nanotechnology do not become the next crisis.

Nonetheless, accidents caused by careless research and development can be avoided through the implementation of appropriate safety guidelines in both the public and private sectors. Public education and government-sponsored discourse remain critical to the successful emergence of new nanotech applications. Such dialogue will result in improved regulation, safety enforcement and wider public support for new products and processes utilizing the technology.

Given the potential for nanotechnology to improve the manufacture, sale and transport of goods and services, business leaders should spearhead efforts to mainstream and employ this technology as it develops. But before investors get out their checkbooks, they need to be aware that it could be years before we see the full effects of the industry and resolve many of its complications. And, as with most new technologies, the resolutions will owe much to trial, error and a good dose of luck. ❖