Published by the Council on Foreign Relations

Design Within Reach

Preparing for the 4-D Printing Revolution

By Nayef Al-Rodhan

Andreas Kroker looks at a 3D-printed figure of himself in Berlin, December 2013. (Thomas Peter/ Courtesy Reuters)

Two years ago, the physicist Neil Gershenfeld argued that the next great digital revolution would come not in computing or communication but in fabrication. Today, 3-D printing, which uses digital data to rapidly construct physical objects, is more accessible than ever. Automakers are placing the latest printing devices on factory floors, design students are learning they can make virtually anything out of plastic, and scientists are experimenting with human tissue. Last year, Australian biologists at the University of Queensland created a functioning kidney from scratch, albeit in miniature; they are now working on printing such organs by layering tiny sheets of living cells.

Yet just as the world is beginning to grasp the implications of the 3-D revolution, researchers are proposing an upgrade. Their work suggests that the true promise of digital fabrication lies with a fourth dimension -- in printing objects programmed to change over time. Whereas 3-D objects are static and require human control, 4-D objects can react to their environment autonomously, assembling, repairing, or transforming themselves. Advances in this realm will rely less on printing technology than on materials themselves. At MIT, the architect Skylar Tibbits combined a 3-D printer with a novel combination of materials to create a wirelike object that when dropped in water changed its shape to form the letters “MIT.” It was the pairing of a water-absorbing polymer material with a basic plastic that made the effect possible.

The potential applications, of course, are endless. And they could prove especially significant on large scales. Consider underground pipe systems, long troubled by fixed capacities and costly maintenance. With programmable materials, individual pipes could adapt to shifting conditions, expanding or contracting to adjust capacity and flow rates. They might even repair themselves when damaged or disintegrate once out of use.

Or think of the possibilities for the defense industry. The U.S. Army has already started using 3-D printing, deploying a team to develop new gear on the frontlines in Afghanistan. And in an effort to create better camouflage -- its own invisibility cloak -- the army has funded research into so-called metamaterials, composites that refract light waves off camouflage textiles, obscuring a covered object from view. Four-D printing technology could allow the military to chart similar territory, building vehicles with coatings that adapt to varied terrains or uniforms that can detect the presence of poisonous gas.

To be sure, 4-D printing won’t be without dangers or downsides. Many of the same concerns that already surround 3-D printing will carry over. The possibility of criminal exploitation will remain. (Consumers have used 3-D printers to build guns and handcuff keys.) Producers will have even more ways to customize products, further shortening the supply chain and endangering skilled jobs. Questions of liability will grow only more complicated, as printers and suppliers fight over who should bear responsibility for a product if something goes wrong. So, too, will issues of intellectual property. U.S. copyright laws, like those of other countries, already contain numerous loopholes, and existing legislation is ill equipped to regulate 4-D products. Tracing the origins of continuously transforming products will be particularly difficult, for example. Issues of irreproducibility and patenting promise to be problematic as well.

As with many other emerging technologies, 4-D printing is a clear example of convergence, bringing together diverse technologies, approaches, and disciplines. The most alarming risks, however, will most likely arise in the field of biology, where the potential for progress and danger go hand in hand. Scientists are already using bioengineering to combat life-threatening diseases; at Harvard University, researchers have used the principles of 4-D printing to construct a cancer-fighting nanorobot from DNA strands. Here, as always, dual use remains a real concern. A range of actors could use such techniques to create new biological weapons, aided by easy access to the necessary tools. In the absence of regulation, startups such as Project Cyborg are offering average consumers design tools that make it possible to program cells.

Moreover, the potential dangers could take on unexpected forms that governments are unprepared to deal with. Cancer-fighting nanorobots, for example, could be reprogrammed to regulate neurotransmitters, such as serotonin, dopamine, or oxytocin -- all of which can alter human behavior. Some caution that even commonly prescribed medication, such as the antidepressant Prozac, can permanently alter an individual's long-standing cognitive and personality traits. With 4-D printing, more people than ever before will be able to experiment with that sort of chemistry.

Given such risks, leaders in every field have some hard thinking to do. It's already clear that programming matter -- living and nonliving -- will have far-reaching effects that are impossible to predict. That makes regulation and oversight crucial. All disruptive technologies inevitably require new governance structures and institutions, but advances in 4-D printing could easily spiral out of control if governments don't act in time. Only within carefully guarded boundaries can innovation remain beneficial.

Nayef Al-Rodhan is a philosopher, neuroscientist and geostrategist. He is an Honorary Fellow of St. Antony's College, University of Oxford, UK, and Senior Fellow and Director of the Centre for the Geopolitics of Globalization and Transnational Security at the Geneva Centre for Security Policy, Geneva, Switzerland. He is the author of Sustainable History and the Dignity of Man: A Philosophy of History and Civilisational Triumph (Zürich: LIT VERLAG GmbH & Co. KG Wien, 2009).

This article was originally published on *Foreign Affairs* website on October 8, 2014.
http://www.foreignaffairs.com/articles/142171/nayef-al-rodhan/design-within-reach