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TECHNOLOGY

3D Printing as the Manufacturing Infrastructure for the Circular Economy

by Gregory Unruh

Professor Gregory Unruh describes how the Earth's biosphere could serve as a model for sustainable, efficient manufacturing processes.

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Gregory Unruh, Arison Professor of Values Leadership at George Mason University, and contributor to the upcoming *California Management Review* special issue on the circular economy, spoke with the journal to discuss the implications of additive manufacturing.

Although it's been in development for decades, additive manufacturing (3D printing) is now poised to disrupt the traditional manufacturing model in a major way. In keeping with recent trends in decentralization, the technology promises to enable consumers to print

most products locally, on-demand, by downloading design information from online marketplaces. But perhaps most importantly, additive manufacturing technology is uniquely capable of promoting environmentally sustainable product lifecycles, an essential aspect of the "circular economy."

What is a circular economy, and why is it an important concept for business leaders to understand?

A circular economy is one in which the materials with which you produce products are maintained in a circular loop. It contrasts with our current economy which is more linear — what you would call a "throughput economy."

In a throughput economy, you extract resources from an iron mine or a forest, and use them to make products. Those products are delivered to the customers, and when the customers are done with them, they dump them into the garbage.

By contrast, a circular economy is one in which the materials are maintained in a closed loop. When the customer is done with a product, instead of throwing it into the garbage, the product is recovered and its embedded materials become the inputs for the next round of new products. Instead of "cradle-to-grave," it's "cradle-to-cradle."

Historically, why has it been so hard for companies to operate more sustainably?

It's hard for executives to create a business case for sustainability because it requires changes to their existing business model, and the transition is costly in the short term — even if it pays off in the long run. Ironically, when companies do come up with a business case for sustainability, it is usually the result of business model innovation. In fact, our research has shown that the more changes to the business model, the more likely it is that the company will be able to profit from sustainability. But change is difficult. Most companies are not excited about altering the business model that they already have. Disrupting it for the purpose of sustainability is something they have long avoided.

When I first started researching the circular economy back in the early 2000s, it became pretty clear to me that we couldn't expect established companies to launch a circular economy. You can expect some experimentation and innovation on the edges, along with

incremental changes that increase efficiency or decrease waste. But what you really need is a disruptive business model transformation, and disruptive technology.

I had been looking at 3D printing as a potential disruptive technology, thinking that 3D printing could become the foundational infrastructure for a circular economy. And in the last couple years, with the emergence of inexpensive 3D printers from companies like *MakerBot*, it's really started to take off. And it's pretty clear that, if used with the right foundational principles, we now have the technological capability for a new type of manufacturing process that is based on 3D printing, running on renewable energy, and can actually recycle materials back into the system in a closed loop.

What foundational principles should guide the development of 3D printing, in order for it to become a major component of the circular economy?

Right now we already have one model of a sustainable circular economy — and that is the biosphere. **The Biosphere Rules** distill the principles that account for the circularity of the biosphere, and translate them into business rules.

One foundational principle is *materials parsimony*. If you look out the window at a forest, the amazing thing is that everything out there — 90% of it — is made up of only four elements: carbon, hydrogen, oxygen, and nitrogen. Biologists and organic chemists call that "CHON." There's over 100 naturally occurring elements, and nature has chosen to use just four. A materials engineer might say "that's crazy." They might think that we should find novel uses for all of the elements on the periodic table. But in a circular economy, using only a small range of inputs makes a lot of sense. It means that everything you make utilizes the same fundamental building blocks. Just think of building things with Legos and you get the picture.

The beauty of 3D printing, is that 3D printers use primarily one material to produce the bulk of an object. As a simple comparison, if you look at a conventionally manufactured automobile, there's 10,000 different components made from hundreds of different materials. In contrast, a company called **Local Motors** 3D prints 80% of its cars from a single material. That's radical materials parsimony. You can see that as long as the material is chosen correctly, at the end of that automobile's life you can immediately

collect 80% of that vehicle, break it down, and put it back into the manufacturing process. You can use it to print another vehicle, or some jewelry, or a kitchen table. That's where the power really comes in.

Another foundational principle is *power autonomy*. The materials can be cycled over and over again, but the cycling actually has to be powered by something. Every transformation — from raw material to finished product — requires energy. In nature, it's done with solar power. What we need to do is make sure that, whatever the infrastructure of our circular economy, it has to be able to run on renewable energy sources. The nice thing about 3D printing is that it runs on electricity, so you can connect your printer directly to your solar panel and let it run all day.

Do you have any advice for existing manufacturers, in terms of integrating 3D printing technology — or responding to its emergence?

For established companies, the history of adapting to the emergence of disruptive technologies is not very promising. The problem is, the aspects that make established companies successful today — highly developed and efficient business processes and capital assets — turn from points of competitive advantage to liabilities. This will probably be the case with 3D printing. We will no longer prioritize centralized manufacturing in high volume; manufacturing will be decentralized. We won't be doing long-distance distribution; instead of distributing your product with trucks and trains, you'll be sending a design file up to the cloud, downloading it to your printer, and printing on the spot. With recyclable materials, the supply of raw materials moves from the oil fields or open pit mine to your customer's own home or office building. Your customer can use his old table as raw materials to make a new table!

It challenges the supply chain, distribution channel, customer relationship management… *it's very, very disruptive*. It's going to be a real challenge for established companies. I would rather put my money, if I was investing, on new entrants that aren't stuck with legacy assets.

Decentralization seems to be a key feature of these new business models. Any parting thoughts on the future of technology and business?

I do think that decentralization is the future. Especially if you look at nature. As an example, the function of DNA is the capture of design information; it's a storehouse of evolutionary design data. And it also provides a mechanism for innovation, for constantly improving the design and quality — the ecological adaptiveness — of organisms. And in nature, the information that goes into producing an organism, like a tree, is open source and distributed. But the manufacturing of that tree is local. That's exactly what we're going to see in a 3D printing based circular economy. The design (the DNA) is going to be housed in the cloud, and will be available around the world. If you're in New York, and you want to download a product, you can just log on. Or if you're in a developing country, and you have access to an internet connection, a solar panel, and a 3D printer, you can download the same product just as easily as a wealthy person in New York. It's the same thing when you look at nature: a tree grows just as well in Bangladesh as it does in New York City!

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