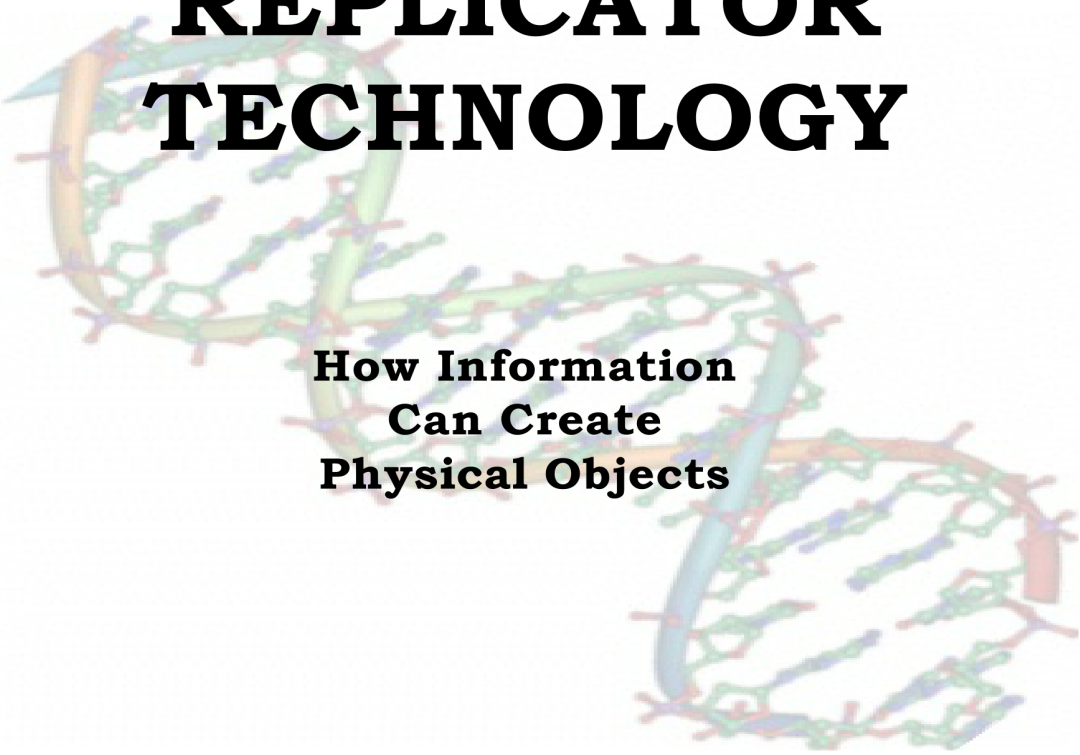
REPLICATOR TECHNOLOGY

How Information Can Create Physical Objects



Brian McMillin

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Using Information To Create Physical Objects

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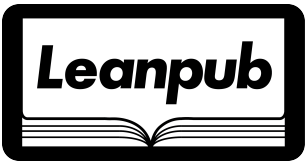

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Preface

I have based this work on a lifetime of experiences, observations and interactions too numerous and diffuse to catalog.

I have attempted to verify the accuracy of the anecdotes and statements of historical fact. Any errors that remain are purely my responsibility, and I would appreciate thoughtful comments from my readers.

I hope that any inaccuracies will not detract from the general goal of trying to outline path to a safe, sustainable, local technological future.

Brian McMillin

Watauga, TX

March, 2012

Introduction

This book is the work of a geek, toiling alone in his basement. Figuratively speaking. As I write this, I am taking a concept that I envision and converting it to data in a computer. In a moment, I will send that information to my "publisher". After a few days this physical book will be delivered to my door.

This is an example of Replicator Technology in operation today, in the real world. I have sent a (more or less) complete description of an object into a great, mysterious machine that I know almost nothing about, and the object of my desire has been delivered to me.

Now comes the best part. The information that I created is now stored in "the great computer in the sky". *You* can access that information, utter the appropriate incantations, and cause a replica of this physical book to be created and to appear at your door. This is different from just buying a book off the shelf or ordering out of some inventory in a distant land. "Publishing on demand" is actually creating the physical object only when it is needed.

The term replicator was used in the television series *Star Trek: The Next Generation* to describe a mechanism on the starship Enterprise which could be verbally commanded to create almost any non-living object. This plot device allowed the story to move along without the need to explain how a (comparatively) small ship could have almost any imaginable equipment readily

available. These replicators were a more advanced version of the ubiquitous "food slots" used in the original series.

How can we move forward from today's rudimentary beginnings to a future in which Captain Picard can casually request "Tea, Earl Gray, hot."? What can we achieve in the near term, without the need for breakthrough discoveries? What are the advantages of using Replicator concepts? What are the disadvantages and dangers that we might encounter?

It is my intention to shed some light on a possible technological future by outlining some of these ideals, goals, pitfalls, and areas in need of study. This is a book of questions. I am looking forward to seeing some of the answers.

I Replicator Technology

Our global economy has reached the point that our everyday lives are fundamentally dependent on goods and services provided from great distances, sometimes ten thousand miles or more. This dependence on non-local support began when our hunter-gatherer ancestors first grouped into villages and towns. Local transportation and storage of supplies and materials expanded with trade to distant areas. This allowed mankind to exploit regional specialties, originally based on the varying abundance of natural resources.

Technological humans are those that use tools and fire, build villages and have generally stable populations. The *scope* of a population is the range over which they gather resources. Even though most individuals in a population may not travel very far they may rely on transportation of goods from great distances. Some of these exotic items may be considered luxuries, but if efficient transportation makes items abundant they may come to be viewed as necessities.

The ready availability of inexpensive goods mass produced in specialized centers located at great distances is what makes our

modern technological society possible. Exotic goods, invented mere years ago are now efficiently produced and transported from locations that are completely beyond the control of the consumer. This dependence on distant materials, manufacturing and transportation is a source of great concern. Any disruption due to economic miscalculation, terrorist acts or natural disaster could cascade into virtual collapse of society on a wide scale.

There are communities that have stable populations which use resources from a limited *scope*. Primitive tribes in isolated areas tend, for the most part, to be able to function without outside contact. Amish communities, for example, have an early twentieth-century technology and sustain their populations with minimal *scope*.

The *scope* of the average individual in the United States has grown to encompass a large part of the earth. Cheap foreign mass production and efficient, inexpensive global transportation have made local production of virtually all goods unlikely.

There are no manufacturing facilities for the most basic electronic components (resistors and capacitors) located in America. The specifications for those devices are well standardized and the production has been optimized over a long enough time that virtually all of these components come from a small number of plants in Asia. This transfer of technological competence means that the United States relies completely on foreign sources for the most basic devices. Furthermore, it is likely that there are no longer any individuals in the United States that have the knowledge of how to set up the equipment to produce these components. If it were necessary to begin domestic production it would probably take months or years to reacquire the knowledge.

Interestingly, although I believe the United States is in a dangerous situation with respect to demand for foreign resources I think China is much more vulnerable. They are depleting their resources and shifting their population in a completely non-sustainable fashion. In the quest for global trade, they are duplicating the political, regulatory and environmental mistakes that plagued the United States at the beginning of the twentieth century, with the exception that their production is not headed for domestic consumption but rather is being sold for a fraction of its worth overseas. Any major disruption of demand or transportation will lead to the collapse of their highly specialized manufacturing. This will leave huge populations without the ability to participate in commerce and may impact the availability of life-sustaining necessities to these people. The sudden loss of certain manufacturing specialties will ripple throughout the world and cause unpredictable effects on most of the population.

> The ability to produce goods as needed from simple raw materials on a local basis is the immediate goal of Replicator Technology.
>
> Producing all necessary goods on a sustainable basis without waste or depletion of local resources is the ultimate goal.

Determining the *scope* of a particular population may be trickier than it initially appears. An isolated group may be dependent on rain for agriculture which comes from seasonal weather systems

that cover thousands of miles. *Scope* determination becomes easier in a high-tech environment where virtually all resources flow through a known transportation system. Submarines at sea, the International Space Station and research bases in the Antarctic allow a careful examination of resource utilization, but none have truly closed environments or sustainable populations.

Eventually mankind will try to establish self-sustaining colonies in space or on the Moon or Mars. It will be necessary to use local manufacturing to produce many of the goods that will be needed in such colonies. There will not be adequate transportation or storage area to bring along every commodity that might be required. The population will (initially) be too small to allow skilled artisans to manufacture rarely needed goods.

All of the assumptions that make mass production and transportation on a planetary scale so efficient will not be applicable in tiny, truly isolated colonies. Determining the minimum sustainable population on Mars (for example) is a completely different matter than on Earth. Specialists will be required for maintaining the habitat, obtaining energy and raw materials from the environment, managing health care and reproduction and training young replacements for aging individuals. Each of these tasks will need sufficient redundancy so that accidents or time will not leave the colony short of critical skills.

For the foreseeable future, certain strategic goods will need to be shipped from Earth. But a just-in-time manufacturing facility will be required in any case. With a population of only 250 adults, even carefully screened, one would expect more than 25 cases of diabetes to develop. It would be unreasonable to rely on timely shipments of simple pharmaceuticals from Earth. Deriving insulin from pig pancreases is simple, early twentieth-

century technology. Of course, this presumes that the colony has plenty of pigs.

An important aspect of Replicator technology is that it allows one to focus on defining goals clearly and devising ways of achieving them. Cultural biases and current technologies tend to confine our thinking about both the problems and the solutions.

1 What is a Replicator?

Let's begin by defining what I mean by a Replicator. There is the ideal concept and then there are compromises and simplifications that we need to make to fit into the real world. In the ideal case:

This is a very idealized concept which implies the creation of matter from pure energy. This is certainly possible and is being done today in the real world. A visit to your local particle accelerator might allow you to see for yourself. The amount of matter that can be created is, however, very, very, very tiny. You would probably have to take somebody's word that matter had actually been created at all. And the amount of energy that it takes is prodigious. That bit about waste heat is not really a joke, either. Making the particle accelerator be able to operate without melting is a major consideration.

So, maybe we need to compromise a little and allow some type of raw materials to be used. What we mean by raw materials, where we get them, and how they are delivered to the Replicator are all interesting questions which will require further exploration. Now we have:

This has radically simplified things and moved more into the realm of what we might be able to do practically.

Allowing our Replicator to accept raw materials leaves open the possibility that we could process previously replicated objects into new, completely different objects. This recycling ability forms the heart of a sustainable technology.

Now, what do I mean by information? In this case I am talking about a description of the object in sufficient detail to allow an acceptable copy to be created. It is expected that the Replicator itself will contain a library of detailed information that can be accessed by using nice, user-friendly names. We do not intend to require an atom-by-atom description when all I really need is "Make me a chair".

The Replicator may contain patterns for 10,000 different chairs, but we expect a suitable user interface to allow the most popular or most appropriate version to be selected. Think of it as Googling the Replicator's pattern database. You get a kind of catalog to choose from.

Even though the Replicator contains 10,000 chair patterns, it goes without saying that the one you *really* want is not there. So, the user interface should allow easy customization of objects and some level of error-checking and visualization of the object prior to creation. Thus, "Make me a chair like this, only paisley" would allow you to see if the pattern really matches the decor. And "Make me a chair like this out of mercury" might elicit a cautionary response that the object would instantly melt at room temperature. You could then correct your request to "Make me a chair like this out of titanium."

Where might this Pattern information come from? For simple objects it could be built from manually created Computer Aided Design (CAD) drawings. For complex objects, an entire library of these detailed descriptions would be needed. The information applicable to each different manufacturing process uses its own

set of standards and has certain hidden assumptions that need to be included as part of the Pattern.

For many objects, both simple and wildly complex, it would be very nice if the Replicator could simply duplicate an existing object. This would require a (presumably non-destructive) scanning process, coupled with an ability to identify materials, plan processes and actually derive a Pattern. This Pattern would then be used to duplicate the object.

I argue later that a proper Replicator Pattern must include disassembly and recycling instructions, and that this is at least as important as the object-creation part itself.

We have gone to great lengths to have the information input to the Replicator accurately describe the desired physical object to be produced. The Replicator is expected to produce exactly that object and nothing else. We do not want more than one of the object. We do not want a bunch of left-over, scrap object-pieces, sawdust, used tools, solvents, or radioactive waste. Just one chair.

Right now we are simply trying to define the problem. Actually *achieving* all this is what the future is for. Even getting close in the near term is going to be a challenge for a lot of people to work on. But I think it is a worthy goal to start toward.

Brian's Dictum

Never teach a child to swim.

Teach him to dive. Once he has jumped in he will have to figure out how to get back to the side of the pool. Maybe with a little help the first few times. But if it isn't a big deal to you, it will not be a big deal to him.

Set the goal high. The little things will tend to take care of themselves. And if one of the spinoffs happens to be what you wanted in the first place, so much the better.

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2 What Do We Want To Replicate?

At the least we would probably wish to replicate solid, three-dimensional objects composed of a single material. I refer to such a device as a Simple Replicator.

> **A Simple Replicator is a Replicator which creates solid, three-dimensional objects from a single material.**

Much of this book will concern replicating complex objects, creating exotic materials and assembling structures with replicated objects. But we must not overlook the advantages of being able to simply and reliably obtain objects made of a single material. I refer to these as solid, three-dimensional objects. For now, I want to defer dealing with liquids and gasses, I want the raw materials to be easily handled, I do not want to have to address the internal environment of the Replicator, and I want to deal with essentially one processing step.

We can get many useful objects by choosing the right raw material and shaping it into a three-dimensional object. Shaping raw materials into objects involves one of three processes: *adding* material, *removing* material, or *deforming* the material. Modern manufacturing processes are generally grouped into (1) casting, (2) molding, (3) forming, (4) machining, (5) joining, or (6) finishing.

Michelangelo was a master of using simple tools to create useful objects out of solid marble. His tools were capable only of

removing material. It seems reasonable to want to design a Simple Replicator capable of delivering, for example, the Statute of David on command.

Purists will complain that marble is not really a single material, but rather a mosaic of crystal polymorphs of calcium carbonate, often with inclusions of other minerals. I will deal with the question of the purity of raw materials later. Marble is a metamorphic rock formed from limestone, dolostone or older marble under heat and pressure. Interestingly, this presents a route for recycling manufacturing waste and used statutes. Given an initial supply of marble, we can presumably reuse it continuously.

Once we have a Simple Replicator for marble objects we can begin to explore the things that can be done with just this single building material. I leave this as an exercise for the reader to list the everyday objects that could be made from marble, presuming the material was essentially free and disposable, and to contemplate the change in philosophy this would bring to our society.

Why would I want to Replicate food instead of just growing it?

1. I don't know how to grow food. I am not a farmer.
2. I don't have the space for a farm or garden.
3. I don't have the materials: soil, water, seeds, etc.
4. I don't have the time. Dinner is at 5:00
5. I don't need much. The recipe calls for a pinch of saffron.
6. I need a lot. The locusts ate the crops.

Why would I want to Replicate fuel instead of just storing it?

1. The Replicator might be the best device for converting an energy source to physical fuel to be stored for later use.
2. The Replicator might be fast enough to convert an energy source to physical fuel as needed.
3. Stockpiling physical fuel might be too dangerous.
4. The desired physical fuel might need exotic structure, such as a solid fuel rocket core.

Maybe we just replicate materials that are destined to be used by a factory outside the Replicator.

If we replicate a liquid or gas we need a container.

Do we want to Replicate a state (hot or cold)?

How do we Replicate an object with significant potential energy such as a cylinder of pressurized gas or a compressed spring?

How big an object? Maybe big things come out in chunks for external assembly.

Maybe really small objects like cells, bacteria, viruses, molecules (buckyballs or insulin).

Maybe long, skinny objects come out on a spool (fiber-optic cable).

3 What DON'T We Want to Replicate?

Presumably it would be reasonable to put some limits on the objects that we want a Replicator to produce. Our definition of a replicator means that it will not produce hazardous waste or pollution other than heat, and that it is capable of recycling any object that it does produce.

The Norse fairy tale *Why the Sea is Salt*, collected by Peter Christen Asbjørnsen and Jørgen Moe, is a cautionary tale that would be applicable to any Replicator technology. The premise that an untrained operator might accidentally command the creation of a dangerous amount of an otherwise innocuous substance is only one of the possibilities that should be guarded against.

The moral aspects of Replication. Creating life.

Maybe cloning an army is bad.

What about yeast? It is needed as a processing step for bread and beer. And we already kill it in the end, anyway.

What about viruses? Is it better to store bio-hazards or to create them on demand for research?

What about explosives? Rocket fuel?

> In 1942, Dr. Isaac Asimov published the short story *Runaround* in which he first posited the Three Laws of Robotics:

> 1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
> 2. A robot must obey orders given to it by human beings, except where such orders would conflict with the First Law.
> 3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Should we have a paraphrased version of Isaac Asimov's Three Laws of Robotics?

> (3) A Replicator shall preserve its own existence unless doing so conflicts with the first or second law.

This is probably a very bad idea. The Replicator should probably have severe restrictions on doing anything that would damage itself, to the point of elevating this above the level of the First Law. Even then, children, terrorists, and the misguided would probably attempt to cause spectacular consequences that the Replicator's safety systems would be unable to anticipate.

Robust systems are designed to anticipate random failures and to function safely even in the presence of single-point failures. A

traffic control system that relies on everyone obeying a law that says "Do not run a red light" is not robust. A single person failing to obey the law can lead to immediate death and destruction. The system needs to be redesigned with inherent safety features that allow safe operation.

An example of a twenty-first century solution would be to eliminate traffic signals altogether. Assigning time slices to intersecting roadways would allow vehicles to cross by simply modulating their speed. No one would ever stop near an intersection. This would be vastly more efficient, especially for cargo vehicles, than the current start-and-stop approach.

This would lead to what is known as *platooning*, where you have groups of cars bunched together and moving in lock-step. Any failed vehicle would simply leave the platoon, and platoons would "see and avoid" obstacles (defective vehicles, construction, etc.) by changing lanes and speed modulation. Think of it like a computer-assisted figure-eight race.

A good first step forward would be to simply standardize road intersections. This was attempted when the interstate highway system was envisioned in the mid-twentieth century, but there were far too many horse-and-buggy concessions left in the design.

Understand that I am opposed to manual operation of automobiles. The height of luxury for the wealthy has always been chauffeur-driven travel. Henry Ford made inexpensive vehicles available to the masses and set in motion an automotive industry

geared toward convincing the public that they actually *wanted* to drive. And had to have a new car every two years.

I do not like to drive. It is a waste of my time. I do not want to be reduced to the level of a collision-avoidance robot. I cannot work on anything else while I am driving. I cannot even enjoy the scenery. Glancing at the drivers of the vehicles around me leads me to believe that they do not want to be driving, either. They are talking on the phone, eating, playing with their children, and enjoying the effects of liquid refreshment and burning agricultural products.

I think that the "car of the future" should have no windows. There will be a large flat-panel display and controls in the traditional driver's position. You don't have to sit in the driver's seat if you don't want - the car is going to chauffeur you from home to work, all by itself. Really want to drive? OK. You have controls and a screen. You can be Mario Andretti racing through the Swiss Alps. Work up a sweat. Enjoy yourself. The physical car is still stuck in traffic on I-35.

Eliminating the windows would allow many new engineering opportunities. The decisions about the frame, safety structures, air conditioning, and seating could all be revisited. Psychological aspects such as claustrophobia could be handled creatively. Early elevators had metal grates or windows in the doors. Modern elevators do not seem to need such features, and most people find them acceptable.

There is also the question of whether I would actually own the vehicle or not. Maybe I just summon one on demand, like an efficient taxi or limousine service. I do not want to have to take care of maintenance. I do not want to pay for an extra vehicle and insurance that I use infrequently. I might not even need a

vehicle sized for shopping, because, in this future, I would order the goods I need and they would be delivered to my doorstep in specialized vehicles.