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# 3D Printing

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## **Learn to:**

- Use 3D printing software, hardware, and tools
- Work with the different types of 3D printing processes and services
- Follow best practices for 3D printing
- Create your own RepRap 3D printer

**Kalani Kirk Hausman  
Richard Horne**



***3D Printing***

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**DUMMIES®**  
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**by Kalani Kirk Hausman  
and  
Richard Horne**

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## **3D Printing For Dummies®**

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# Introduction

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Unlike traditional manufacturing which involves injecting material into a pre-formed mold or removing material from base material objects, additive manufacturing (3D printing) starts with a virtual 3D model that is transformed into solid form one layer at a time. Each layer is built on top of the layer before, creating a solid form representing the virtual 3D model in all of its complexity and detail without requiring additional forms of machining and treatment necessary in traditional forms of manufacturing.

Although 3D printers have been available for years, only recently have they become available at a price most home users can afford. Because they are becoming more widespread, and because innovations in this technology now permit the creation of products in a much wider array of materials — and even combinations of materials — 3D printing is poised to make an impact on average consumers in a big way. *3D Printing For Dummies* was written with the average reader in mind. It's a survey of the existing capabilities of additive manufacturing, for both private and commercial purposes, and a consideration of the possibilities of its future.

## ***About This Book***

In this book, we review many different technologies currently available for additive manufacturing. These are early-generation technologies with numerous limitations and caveats to their use and the selection of materials available for use in 3D printers in both commercial-scale and consumer-grade options. We also explore the

process by which you can build your own 3D printer using the open-source self-REplicating RAPid-prototyping (RepRap) family of designs. This will not make you an expert in all aspects of 3D printing, but will provide you with an opportunity to explore the many types of additive manufacturing systems. Hopefully, you will be excited by the amazing potential of 3D printers – excited enough to build your own printer and start sharing your own creativity with friends and family!

## ***Foolish Assumptions***

You might find it difficult to believe that we have assumed anything about you — after all, we haven't even met you yet! Although most assumptions are indeed foolish, I made these assumptions to provide a starting point for the book.

It is important to understand that the current level of sophistication in 3D printers is close to the first automated looms that found their way into factory settings in the early 1700's. Commercial 3D printers have less variance, but for consumer-grade equipment a certain amount of “tinkering” will be needed from time to time to keep things running. Working with 3D printers is very rewarding, but you should learn how to adjust and tune your home or office printer so that when things go awry you will be able to fix them yourself. It is not necessary to be a do-it-yourself handyman, but a certain familiarity with basic tools will help you when you build, assemble, or use your own 3D printer.

The book assumes you will have the ability to download or access programs in a web browser if you want to try out some of the applications we review, such as TinkerCAD. However, it is not necessary to have a computer of your own to enjoy this book — all you need

is an open mind and enthusiasm about the future and what additive manufacturing can produce!

## *Icons Used in This Book*

As you read this book, you'll see icons in the margins that indicate material of interest (or not, as the case may be). This section briefly describes each icon in this book.



Tips are nice because they help you save time or perform some task without a lot of extra work. The tips in this book give you timesaving techniques or pointers to resources that you should check out to get the maximum benefit from 3D printing.



I don't want to sound like an angry parent or some kind of maniac, but you should avoid doing anything marked with a Warning icon.



Whenever you see this icon, think *advanced* tip or technique. You might find these tidbits of useful information just too boring for words, or they could contain the solution you need. Skip these bits of information whenever you like.



If you don't get anything else out of a particular chapter or section, remember the material marked by this icon. This text usually contains an essential process or a bit of information that you must know.

# ***How This Book Is Organized***

We divide this book into several parts based on topic. The following sections describe what you can expect to find in each part.

## ***Part I: Getting Started with 3D Printing***

Part I explores fundamental 3D printing technologies and options for additive manufacturing within the current state of the art. It is intended to provide you with a general overview of what additive manufacturing provides today.

## ***Part II: Outlining 3D Printing Resources***

Part II expands your exploration of additive manufacturing to include different materials that can be used in current and near-future 3D printing technologies, and examines options available to create new virtual 3D object models to be printed.

## ***Part III: Exploring the Business Side of 3D Printing***

Part III examines the potential for disruption in existing businesses and new business opportunities that becomes possible through new additive manufacturing capabilities. We also explore current lines of research, building new options to the current state of the art.

## ***Part IV: Employing Personal 3D Printing Devices***

Part IV explores consumer-level 3D printer options including both commercial and open-source alternatives available for home and small business uses in fabricating creative and artistic designs exploring this magnificent new capability. We discuss considerations you should take into account when building your own RepRap-style 3D printer.

## ***Part V: Creating a RepRap 3D Printer***

Part V walks you through the creation, assembly, and calibration of a RepRap style printer.

## ***Part VI: Part of Tens***

Part VI offers lists of ten interesting, disruptive, or impossible (in traditional manufacturing) applications of additive manufacturing.

## ***Beyond the Book***

A lot of extra content that you won't find in this book is available at [www.dummies.com](http://www.dummies.com). Go online to find the following:

✓ **Online articles covering additional topics at**

[www.dummies.com/extras/3dprinting](http://www.dummies.com/extras/3dprinting)

Here you'll find examples of how to use available software to design and prepare 3D models for printing and to set up your own personal digital storefront using free services already in place.

✓ **The Cheat Sheet for this book is at**

[www.dummies.com/cheatsheet/3dprinting](http://www.dummies.com/cheatsheet/3dprinting)

Here you'll find a roadmap to additive manufacturing and the construction of your own RepRap-style 3D printer.

✓ **Updates to this book, if we have any, are also available at**

[www.dummies.com/extras/3dprinting](http://www.dummies.com/extras/3dprinting)

## ***Where to Go from Here***

The goal of this book is to get you thinking about 3D printing and the potential it offers in your own life, home, or work. We stand at the start of a new Industrial Age, where traditional mass manufacturing will give way to personalized, individualized, ecologically-friendly and on-demand manufacturing close to home. You do not have to read this book cover-to-cover, although I think you will find interesting and amazing items on each page. In any event, we hope you walk away with dozens of ideas for improvements, uses and new capabilities made possible by the emerging capabilities of 3D printers.



# Part I

## Getting Started with 3D Printing



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## ***In this part...***

- ✓ Explore the world of 3D printing, including many of the different types of additive manufacturing and their applications.
- ✓ Discover current uses for the ever-growing spectrum of 3D-printing alternatives available today.
- ✓ Examine alternatives currently in existence for 3D printing.
- ✓ Discover ways that you may be able to use additive manufacturing in personal and professional settings.

# Chapter 1

## Seeing How 3D Printers Fit into Modern Manufacturing

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### ***In This Chapter***

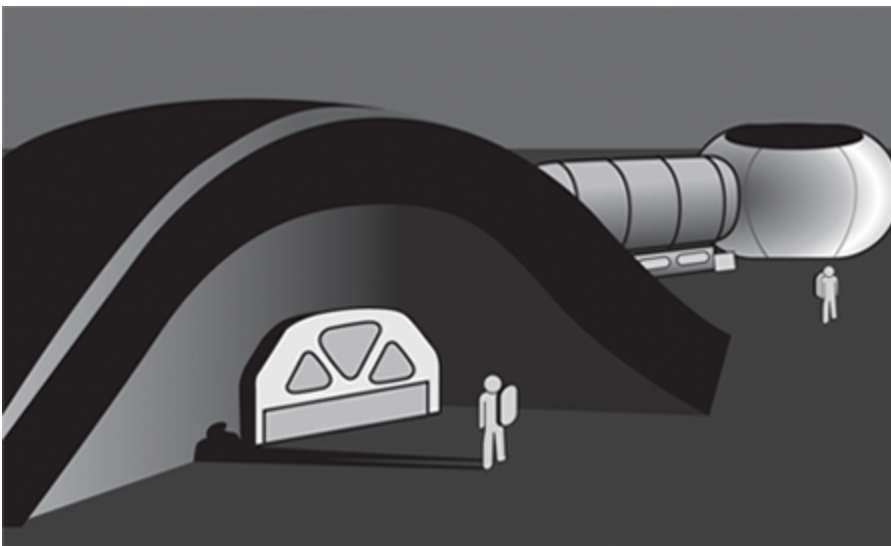
- ▶ Embracing additive manufacturing
  - ▶ Defining additive manufacturing
  - ▶ Contrasting traditional manufacturing
  - ▶ Recycling and planned obsolescence
  - ▶ Exploring the application of 3D printing
- 

An amazing transformation is currently under way in manufacturing, across nearly all types of products — a transformation that promises to remake the future into a sustainable and personally customized environment. In this fast-approaching future, everything we need — from products to food, and even our bodies themselves — can be replaced or reconstructed rapidly and with very minimal waste. This is not the slow change of progress from one generation of iPhone to the next, but instead a true revolution, mirroring the changes that introduced the world to the Industrial Age and then brought light and electricity to our homes and businesses.

This will not be a “bloodless coup” by any means; any truly fundamental change that spans all aspects of the global economy will, by its nature, be disruptive. But traditional inefficient ways of producing the next year's

model will surely give way to entirely new opportunities impossible to imagine before. The technology behind this transformation is referred to as *additive manufacturing*, *3D printing*, or *direct digital manufacturing*.

By whatever name, in the coming decade this technology will be used to construct everything from houses to jet engines, airplanes, food, and even replacement tissues and organs made from your own cells! Every day new applications of 3D printing are being discovered and developed all over the world. And even in space: NASA is testing designs that will function in zero gravity, on the airless moon, and even to support human exploration of other planets like Mars. (See Figure [1-1](#) for a glimpse.) Hold on tight, because in the chapters ahead we cover a lot of incredibly new and fantastic technologies — and before the end, we show you how you can get involved in this amazing transformation yourself by building and using a 3D printer at home.



**Figure 1-1:** A line drawing of NASA's planned 3D-printed lunar construction.

# *Embracing Additive Manufacturing*

So, what is “additive manufacturing,” you might ask? Additive manufacturing is a little like the “replicators” in the *Star Trek* universe, which allow the captain to order “Tea, Earl Grey, hot” and have a cup filled with liquid appear fully formed and ready for consumption. We are not quite to that level, but today's 3D printers perform additive manufacturing by taking a 3D model of a object stored in a computer, translating it into a series of very thin layers, and then building the object one layer at a time, stacking up material until the object is ready for use.



3D printers are much like the familiar desktop printer you already use at work or in your home to create copies of documents transmitted electronically or created on your computer, except that a 3D printer creates a solid three-dimensional object out of a variety of materials, not just a simple paper document.

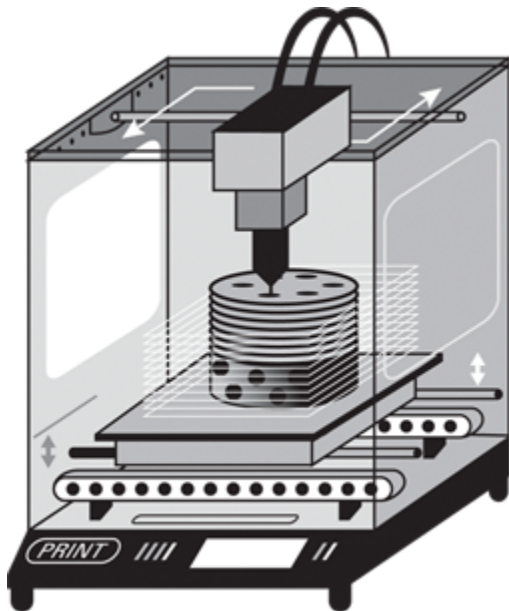
Since the time of Johannes Gutenberg, creating multiple printed documents has brought literacy to the world. Today, when you click the Print button in a word processor application, you merge the functions of writers, stenographers, editors (spellcheck), layout, illumination (coloring and adding in images), and press reproduction all into a single task, and with the click of a few more buttons, you can post the document you create onto the Internet and allow it to be shared, downloaded, and printed out by others all over the world.

3D printing does the exact same thing for objects: Designs and virtual 3D models for physical objects can be shared, downloaded, and then printed out into physical form. It's hard to imagine what Johannes Gutenberg would have made of that.

## ***Defining additive manufacturing***

Why is additive manufacturing called “additive?”

Additive manufacturing works by bringing the design of an object — its shape — into a computer model, then dividing that model into separate layers that can stack atop another to form the final object. It reimagines a three-dimensional object as a series of stackable layers that, when added together, forms the finished object. (See Figure [1-2](#).) Whether this object is a tea cup or a house, the process starts with the base layer and then builds up each additional layer until the full object has been completed.



**Figure 1-2:** A line drawing of how 3D printing works.

My children did this before they ever saw my first 3D printer. They discovered they could use crackers and

cheese spray for more than just a snack — they could build towers and grand designs simply by layering crackers and cheese on top of each other. These edible structures show the potential in additive manufacturing. Each cracker was given a personalized application of cheese to spell out names, draw designs, and even to build shapes and support tiny pyramids. The resulting snacks were both unique and also customized to exactly the design each child wanted.

3D printers build up layers of material in a few different ways: Either they fuse liquid polymers with a laser, bind small granular particles using a laser or a liquid binding material, or they extrude melted materials out like a tube of toothpaste squeezed onto a toothbrush. However, 3D printers perform their additive manufacturing using many more materials than just toothpaste or cheese spray. They can fabricate items using photo-curable plastic polymers, melted plastic filament, metal powders, concrete, and many other types of material — including biological cells that can form amazingly complex structures to replace, repair, and even augment our own bodies.

Just as the rings of a tree show the additive layers of growth to the tree each year, additive manufacturing builds up objects one layer at a time. In this way we can create a small plastic toy, a whole car, and very soon an entire house (with all of its furnishings), or even complete airplanes with interlocking parts. Research today on conductive materials suggests that wires will soon become just another part of the additive manufacturing process, by allowing them to be printed directly into an object itself instead of having to be installed later.

## ***Contrasting traditional manufacturing***

How does this additive manufacturing compare to the traditional methods of production that have worked just fine since the First Industrial Revolution in the 1700's transformed manufacturing from hand production to automated production, using water and steam to drive machine tools? Why do we need to take up another disruptive technological shift after the Second Industrial Revolution in the 1800's transformed the world through the increased use of steam-powered vehicles and the factories that made mass manufacturing possible? Today, we stand at the opening moment of the next transformation, a Third Industrial Revolution, where mass manufacturing and global transfer of bulk goods will be set aside in favor of locally-produced and highly personalized individual production fitting society's transition to a truly global phase of continuous self-upgrade and incremental local innovation.

The First Industrial Revolution's disruption of society was so fundamental that governments had to pass laws to protect domestic wool textile production in England against new power-woven cotton textiles being imported from the East Indies. The spinning jenny and automated flyer-and-bobbin looms allowed a small number of people to weave hundreds of yards of fabric every week, whereas hand weavers took months to card plant fibers or shorn hair, spin the material into thread, and then weave many spools of thread into a few yards' worth of fabric. Suddenly, these new industrial technologies like the automated loom shown in Figure [1-3](#) were putting weavers out of work, sparking the formation of the Luddite movement that tried to resist this transformation. Fortunately, the capability for the new



technologies to provide clothes to families eventually won that argument and the world was transformed.

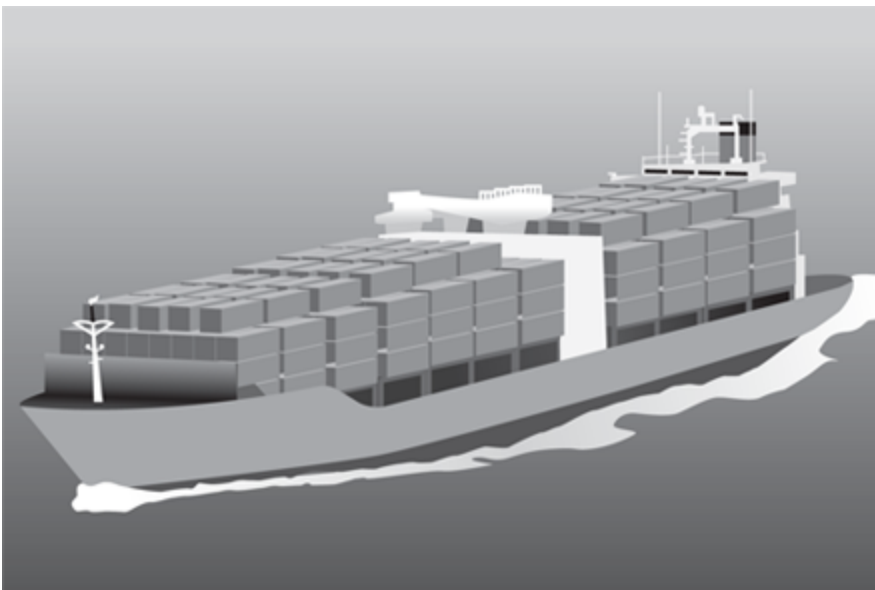


**Figure 1-3:** An example from past industrial revolutions.

A few years later, the Second Industrial Revolution's disruption of society was even more pronounced, because automation provided alternatives not limited by the power of a man or horse, and steam power freed even massive industrial applications from their existence alongside rivers and water wheels, and allowed them to become mobile. The difficulties traditional workers faced with these new technologies are embodied in the tale of folk hero John Henry, chronicled in the powerful folk song "The Ballad of John Henry," who proved his worth by outdigging a steam-driven hammer by a few inches' depth before dying from the effort. This song and many like it were heralded as proof of mankind's value in the face of automation, and yet the simple fact that the steam hammer could go on day after day without need for food or rest, long after John Henry was dead and

gone, tells the tale of why that disruption has been adopted as the standard in the years since.

Here at the edge of the transformation that may one day be known as the Third Industrial Revolution, the disruptive potential of additive manufacturing is obvious. Traditional ways of mass manufacturing, which makes products by milling, machining, or molding raw materials; shipping these materials all over the world; refining the materials into components; assembling the components into the final products in tremendous numbers to bring per-unit costs down; shipping those products from faraway locations with lower production costs (and more lenient workers' rights laws); storing vast numbers of products in huge warehouses; and finally shipping the products to big-box stores and other distributors so they can reach actual consumers, is comparatively inefficient in the extreme. (See Figure [1-4](#).)



**Figure 1-4:** Cargo transportation required for traditional mass-manufactured goods.

Because of the costs involved, traditional manufacturing favors products that appeal to as many people as possible, preferring one-size-fits-most over customization and personalization. This limits flexibility, because it is impossible to predict what the actual consumption of products will look like by the time next year's model is available in stores. This process is also incredibly time-consuming and wasteful of key resources like oil, and the pollution resulting from the transportation of mass manufactured goods is costly to the planet.

### ***Machining/subtractive fabrication***

Because additive manufacturing can produce completed products — even items with interlocking moving parts such as bearings within wheels or linked chains — 3D-printed items require much less finishing and processing than traditionally manufactured items. The traditional approach uses *subtractive* fabrication procedures, such as milling, machining, drilling, folding, and polishing to prepare even the initial components of a product. The traditional approach must account for every step of the manufacturing process, even a step as minor as drilling a hole, folding a piece of sheet metal, or polishing a milled edge, because such steps require human intervention and management of the assembly-line process — which therefore adds cost to the end product.



Yes, this means that fewer machining techs will be needed after the Third Industrial Revolution occurs, but it also means that products can be produced very quickly, using far fewer materials. It's much cheaper to put down materials only where they're needed, rather than to start with blocks of raw materials and mill away unnecessary material until you achieve the final form. Ideally the additive process will allow you to reimagine 3D-printed products from the ground up, perhaps even allowing you to use complex open interior spaces that reduce materials and weight while retaining strength. And additive manufactured products are formed with all necessary holes, cavities, flat planes, and outer shells already in place, removing the need for many of the steps in traditional fabrication.

### ***Molding/injection molding***

Traditional durable goods, such as the components for automobiles, aircraft, and skyscrapers, are fabricated by pouring molten metal into molds or through tooled dies at a foundry. This same technology was adapted to create plastic goods: Melted plastic is forced into injection molds to produce the desired end product. Molding materials such as glass made it possible for every house to have windows, and for magnificent towers of glass and steel to surmount every major city in the world.

However, traditional mold-making involves the complex creation of master molds, which are used to fashion products as precisely alike as possible. To create a second type of product, a new mold is needed, which can in turn be used to create only that individual design over and over. This can be a time-consuming process. 3D printers, however, allow new molds to be created rapidly