



Additive Manufacturing, 3D Printing, and the Coming Stock Market Boom

3rd Edition

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Dr. Alexander Elder

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Books by Dr. Alexander Elder

In chronological order:

Trading for a Living

Study Guide for Trading for a Living

Rubbles to Dollars

Come into My Trading Room

Study Guide for Come into My Trading Room

Straying from the Flock: Travels in New Zealand

Entries & Exits: Visits to 16 Trading Rooms

Study Guide for Entries & Exits

The New Sell & Sell Short (with Study Guide)

To Trade or Not to Trade: A Beginner's Guide (e-book)

Two Roads Diverged: Trading Divergences (e-book)

The New High – New Low Index (e-book), with Kerry Lovvorn

The Trading Puzzle – Book One (e-book), with Kerry Lovvorn

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Foreword to the 3rd edition

Additive manufacturing is an exploding field. So much new information is coming in, that only two months after first publishing this book in July 2012, I felt compelled to bring forth an updated second edition. In January 2013 additive manufacturing was mentioned by the President in his State of the Union speech. Now, in April 2013, I am releasing this updated edition.

I maintained the basic structure of the first book, but expanded some chapters and added several new ones. If you're a first time reader, please read the book from cover to cover. If, on the other

hand, you've read the second edition, you may want to zero in on the new and expanded parts.

The new chapters are:

- * Education
- * Fashion
- * Recycling
- * Fun & games
- * For the young

The expanded chapters are:

- * Medicine and dentistry
- * Home-building
- * The military
- * The AM stocks to watch (more stocks and all updated charts)

Many slight additions are sprinkled throughout other chapters of this book.

I also updated the cover of the book. The first edition showed a stone axe and the second a 3D jewelry design. Now I want you to see a model of a 3D-printed moon base (not science fiction but an actual project of the European Space Agency).

Many changes in this 3rd edition came about thanks to emails from readers and friends who keep sending me links to AM news. I am grateful to William Gordon, Jonathan (Jock) Gunther, Daniel Keane, Rick Lipkin, Peter Maich, Jeff Parker, Rasmus Sommerskov, Andy Webb, and John Weir. Keep those links coming for the future 4th edition! AM is a hugely exciting field, and we need to move as fast as we can to keep up with it.

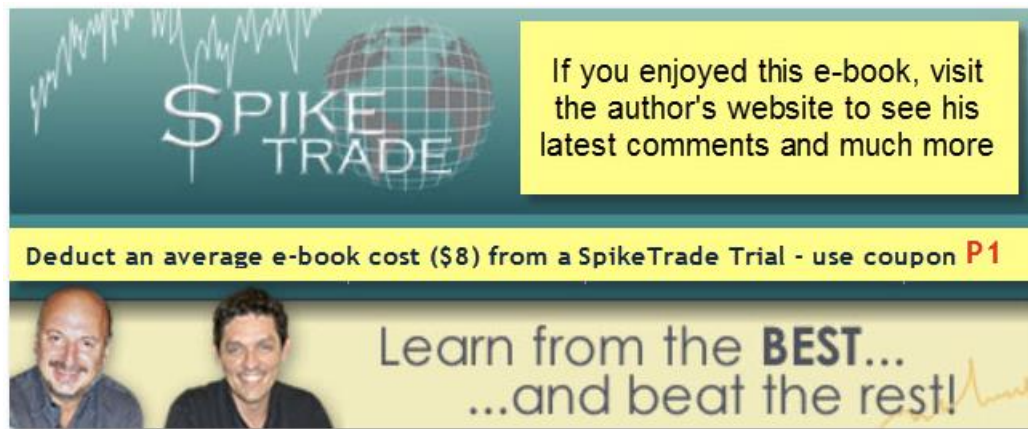
Dr. Alexander Elder

New York City, April 2013

Are you in this e-book?

We salute the pioneers of additive manufacturing – inventors and designers who shape this field, as well as journalists and videographers who publicize it. Thank you for being on the front lines of this revolution.

This e-book contains many links to websites, videos, and other resources. We aim to be scrupulous in giving credit where credit is due. If you feel we've either overlooked or misquoted you, please [contact us](#) for an immediate response and a correction if needed.



Free updates and the honor code

The field of additive manufacturing is rapidly expanding. We plan to issue updates of this e-book and send them at no charge to all purchasers. If you bought this book from Elder.com, you will automatically receive an update. If you bought it elsewhere, please [let us know](#), and we will add your email to our list for future updates. We have a strict privacy policy and will never release your information to anyone.

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And now, let's embark on our journey.

Dr. Alexander Elder

New York City, April 2013



Figure 01 – A stone axe.

Approximately one million years old.

PART 1: THE DAWN OF A NEW ERA

Which tool have humans used the longest? Certainly not a computer, nor a screwdriver, not even a hammer. That distinction belongs to a stone axe, like the one pictured above. In *History of the World in 100 Objects*, Neil McGregor of the British Museum tells us that early humans began making such axes by striking one rock with another over a million years ago and continued to make them until about ten thousand years ago.

We are not that far from that stone axe. To this day, most manufacturing is based on the same principle: we take something big and make it useful by cutting, chiseling, drilling, polishing, and

otherwise reducing it. If you could bring a Neanderthal to a factory, he would grasp the basic principle of taking a large piece of metal and drilling it to make, say, an engine block. Our technology has changed, but the basic principle hasn't: take something big and work to make it smaller and useful. This process generates a huge amount of waste, which we accept as inevitable. We also accept severe technical limitations: for example, it may be impossible to drill an S-shaped passage through a solid piece of material.

This principle – making smaller things out of big chunks – is about to change.

After a million years of cutting, chiseling, and drilling we're stepping into a new era whose technology allows us to create objects by programming and then building or growing them layer by layer.

Think of printing a page on a dot-matrix color printer. You can draw anything on your screen, and the printer will quickly deliver a multitude of color dots to a blank page, which will coalesce into an image. Now imagine that this printer works in 3D, printing one level on top of another, building not a flat page but a three-dimensional object, layer by layer.

Such technology already exists. It is still at an early stage, but today you can already buy and use a 3D printer.



Video 01 – [The Shape of Things to Come](#), 04:54 (National Geographic).

A scientist visits a firm that scans his wrench and prints him a duplicate.

This technology is advancing very fast, getting ready to overturn the key manufacturing principle of the past million years. Our ability to create new objects will be limited only by our ability to program them. We can create objects that are as complex on the inside as they are on the outside.

Rather than driving to the hardware store to buy a wrench, we'll have a printer and buy an image file to print the tool we need. Not only will we save energy, but we will also buy less: for example, you won't have to buy a complete socket set when all you need is a single size. Manufacturing will return to the US since it will cost roughly the same to print something in Detroit as in China but the shipping cost will be lower and time will be saved.

The coming technological revolution will change our lives. It'll change the way our civilization produces things, the very way we live. Along the way it'll fuel a stock market boom. I wrote this e-book to help prepare you for the ride.

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No more bashing!

A recent cover story in *The Economist* included Additive Manufacturing (AM) in what they called "the third industrial revolution." According to that magazine, the first revolution was the mechanization of the textile industry in 18th century Britain, while the second was the introduction of the assembly line in 20th century America.



Figure 02 – AM going mainstream

The cover story of the April 21, 2012 issue of *The Economist*

I think that *The Economist*, the wonderful magazine that it is, didn't give AM enough credit. It's not the third, nor the second, but rather the first real revolution in how we make things since a prehistoric man picked up two rocks and started banging them against one other, trying to shape them into something useful.

From the days of that pre-historic man until today all manufacturing has been spending a huge amount of energy and generating mountains of waste, while struggling against harsh limits of what's possible to achieve with old methods.



Video 02 – [The new industrial revolution](#) 02:46 (Sky News)

An introduction to AM by a UK TV channel – “you are only limited by your imagination”.

Your regular ink-jet printer probably works at 300 dpi – it puts 300 droplets per one inch line. If, after printing an image, your printhead could shift a fraction of a millimeter higher and print another image, based on the next slice of the object, on top of the first one and then keep on moving higher and printing more images, one on top of the other, it would print you a three-dimensional object.

This process of 3D printing poses **two key technical challenges**. We have to figure out how to deliver printing materials in thin layers which will then become one object. We also need to write code which will enable computers to digitally slice objects into very thin layers and print those layers using 3D printers. Both challenges are well within the grasp of modern technology. One of the pioneers of the 3D industry whom you'll meet in a later chapter came to lunch with me wearing a t-shirt that said "Code or die!"

For another good illustration of additive manufacturing please view the video below from the famous TED educational series.



Video 03 - [A primer on 3D printing](#) 14:50 (TED)

Lisa Harouni is a co-founder of Digital Forming; her company allows customers to be directly involved in the design of products they wish to buy.

Additive manufacturing is not new. A friend of mine who made a small fortune by

computerizing shoe-making told me they began using the first 3D printers some 30 years ago. Recent advances in technology have created much cheaper and effective solutions to the two challenges described above. Plus, a new highly positive factor has recently emerged.

We live in a very legalistic society, and the patents of early AM pioneers had long protected their turf. Those patents are now expiring, removing barriers to entry for new participants. The expiration of patents is throwing the field wide open for new entrants.

While basic application patents are expiring, protection is being created for AM and 3-D products. Patent 8,286,236, issued in 2012 extends the idea of digital rights management (DRM) to 3-D printers. In the future, when you load a file to print an object, your printer will be able to check whether you have the right to print that file, how many times, and out of what materials – just as with DRM for e-books or music.

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The tipping point

This term, popularized by Malcolm Gladwell, means "the moment of critical mass, the threshold, the boiling point." Today additive manufacturing is at this point – ready to explode from a state of relative obscurity into a transformative force of our society.

The December 10, 2011 issue of *The Economist* contained a report from the latest Euromold, a manufacturing trade fair in Hamburg, Germany. Titled “The Shape of Things to Come,” it reported that amidst traditional manufacturers there were some 300 exhibitors of additive manufacturing.

Some of their 3D printers could fit on a desk, others were as big as cars. All worked by building products layer by layer from powdered metal, droplets of plastic, or other materials. Many printed items looked different from their conventional counterparts: they were more elegant and less clunky, with flowing lines.

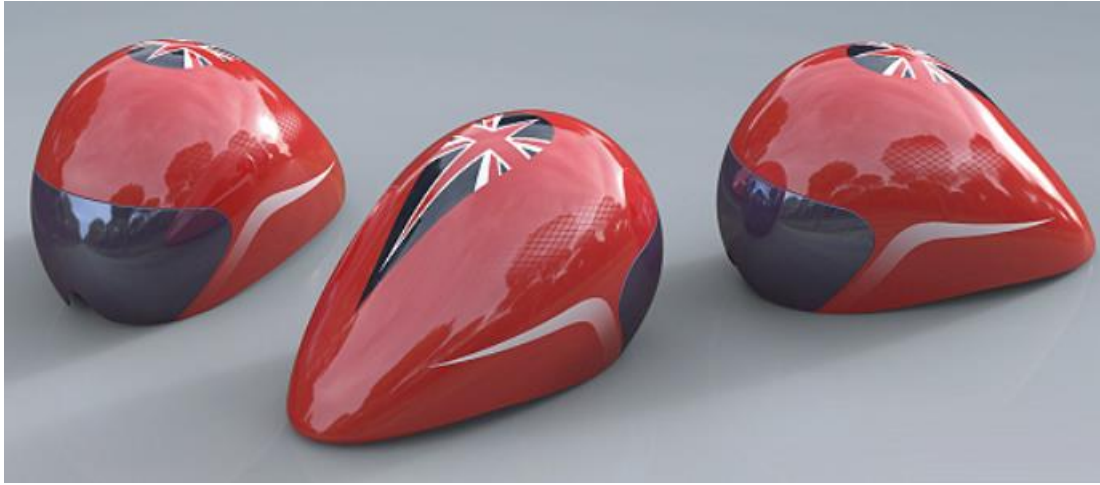


Figure 03 - bespoke cycling helmets for Team GB, created by Crux Product Design.

The UK firm took 3D laser scans of each individual athlete to ensure the best fit and used AM to turn the 3D models into prototypes overnight.

Additive manufacturing has been used for two decades in motor sports to make concept models and functional prototypes. Today a number of top racing teams have gone to the next level by using 3D printed parts for the race track. This practice has been developing for several years but only recently become widely known because early users considered direct digital manufacturing to be a closely guarded competitive advantage.



Video 04 – [Will a Printed Plane Fly?](#) 02:26 [New Scientist]

A group of British scientists prints and test-flies a radio-controlled pilotless printed aircraft

Researchers at Southampton University in Britain printed an unmanned aircraft whose body has a lattice-like structure, similar to fibrous proteins that hold a cell in shape. *The Economist* wondered whether the “...ability to create light, strong structures which have complex internal shapes may turn out to be additive manufacturing’s killer app.”

AM machines are very ‘green’ because they generate almost no waste and reduce transportation expenses: you can download a file and print a needed object in your own home. 3D printers are rapidly becoming more capable, while their prices are falling.

In May 2012 the US federal government issued a solicitation for proposals from teams led by non-profit organizations or universities to establish an Additive Manufacturing Innovation Institute, which would serve as a pilot for their proposed National Network for Manufacturing Innovation.

Additive manufacturing grew by 29 percent in 2011, to a total market size of \$1.7 billion

worldwide, according to an industry report from Wohlers Associates Inc, a leading consultant in AM. They report that the additive manufacturing industry has grown by double digits in most years. It declined by 9 percent during the recession in 2009, but then rebounded in 2010 to grow 24.1 percent. A report released by a research company Marketsandmarkets.com in October 2012 estimates the global size of additive manufacturing at \$3.5 billion by 2017.

The shortcoming of many forecasts is that analysts tend to extrapolate an arithmetical progression, while in fact the angle of the growth curve is likely to rise. As the field goes exponential, the actual volume of AM business cannot be reliably forecast.

All revolutions have a similar dynamic: they start out slowly, almost imperceptibly, then enter a stage of gathering speed, and later explode in a parabolic move. The technology of additive manufacturing has been in development for the past 30 years. In 1986, Chuck Hill, the founder of 3D Systems (stock symbol DDD), invented a system for making three-dimensional objects which he called ‘stereolithography.’ Now there are hundreds of companies in this exploding field. We’re not yet in the parabolic stage, during which a stock market boom is likely to occur, but we’re definitely moving in that direction.

Professor [Neri Oxman](#) of MIT compares the impact of 3-D printing to a revolution launched some 500 years ago by Johannes Gutenberg who invented the movable type and began printing Bibles. Prior to that, all books were copied by hand, which made them extremely expensive, while literacy was pretty much limited to clergy and nobility. Printing democratized literacy, and now 3-D printing will democratize our society in ways that we are just starting to grasp.

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PART 2: AM TECHNOLOGIES

The basic principle of AM is simple: create a three-dimensional object out of multiple very thin layers. To view a surprisingly lively PowerPoint presentation of this concept, please click on

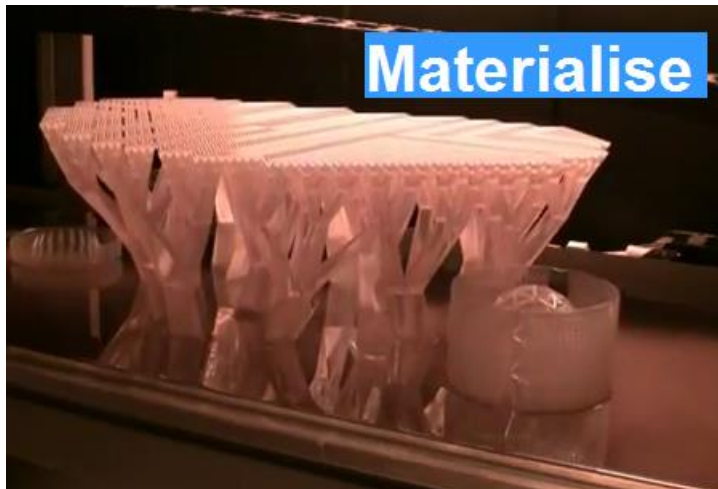
this [link](#). Give it time to load – you’ll be downloading a 5mb file. Its author – Dr. Adrian Bowyer from the UK is an AM pioneer who created the RepRap Project for 3D printing, which we’ll review in a later chapter.

While the basic concept of AM is universal, companies implement it using different technologies. Some ‘print’ with melted plastics, others with metal dust, and still others shine an ultraviolet light into a jar of liquid polymers, forcing them to harden in a controlled manner to create the shapes they want.

AM technologies include but are not limited to the following:

- Direct Metal Laser Sintering (DMLS) – can use almost any metal
- Electron Beam Melting (EBM) – uses titanium alloys
- Fused Deposition Modeling (FDM) – uses thermoplastics
- Laminated Object Manufacturing (LOM) – uses paper or plastic film
- Selective Laser Sintering (SLS) – uses thermoplastics or either ceramic or metal powder
- Stereolithography – uses photopolymers

An excellent [guide](#) to AM technologies was created and is being maintained by Travis Hessman, an editor of *IndustryWeek*. His recent review describes 16 printers made by 3D Systems – from a high-volume industrial product to a basic consumer model. A company named envision TEC produces ten various models of 3D machines using stereolithography. Since most popular 3-D printers use various plastics, a company called Vistatek produced a 3-minute [video](#) using time-lapse photography to demonstrate relative strength of eight different materials.



Video 05 – [Would Queen Victoria be impressed?](#) 01:24 [Materialise Group]

AM gives creative freedom to artists who make three-dimensional objects.

One of the largest players in AM is a Belgian company called Materialise. Its 3D products are even exhibited in London's fabled Albert & Victoria Museum (watch a snazzy video above). A German company named EOS, with six machines to its name is considered a world leader in AM technology called **laser sintering**.



Figure 04 – Art and design.

A lamp created using AM.

If you're interested in the nuts and bolts of AM, consider visiting one of the growing numbers of

trade shows that feature AM technologies. Some are run by the Society of Manufacturing Engineers (SME), which offers this [link](#) to a brief presentation on AM (it includes a link to RepRap, mentioned above). Even if you are not an engineer, educating yourself about AM today will prepare you to be a more confident investor when a mass of additive manufacturing IPOs start coming to market in the years ahead.

Still, it's easy for a non-techie person to become overwhelmed by an avalanche of technological terms, descriptions, abbreviations, and claims to superiority. As the field of AM grows, you can expect to hear the deafening volume of competing claims.

What's a non-techie to do?

Stock market investors and traders can do very well without becoming technology experts. Once masses of AM companies start getting listed and the boom gets going, the rising tide will lift all the boats. Every cat and dog will have its day in the sun. In the long run, key technologies will emerge, while others will fade away, but this will take years. In the more realistic short run, we want to spread our bets.

Remember the internet bubble? Today the Internet is an integral part of our lives, but in the late 1990s it was huge news. Almost every stock that added a dot-com to its name went through the roof. Furniture.com, Pets.com, Amazon.com, and countless others exploded on the charts. In due time survivors, such as Amazon.com, emerged, while many dot-com companies eventually went bust. The key thing to remember is that early on in that boom all dot-com stocks went up.

Today we're in a pre-boom stage. Don't give yourself a headache trying to sort out competing claims of various AM technologies – just wait for a wave of listings to emerge. We will review suggested investing and trading approaches in a later section of this e-book.

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What's AM good for?

In a phrase – almost everything. Let's go on a whirlwind tour of industries that are starting to use AM. Without a doubt, this chapter will be expanded in future editions of this e-book.



Figure 05 – Objects created using AM.

From a TED presentation by Lisa Harouni.

Rapid prototyping

In the beginning, the main use of AM was rapid prototyping – quickly fabricating scale models of physical parts or even assemblies of parts. An engineer with a 3D printer can model anything from shoes (which is what my friend did, mentioned above) to airplane parts for testing in wind tunnels. To this day, rapid prototyping remains one of the main uses of AM.

A friend recently invited me to visit Avon's AM department to see how this consumer goods company uses 3D machines to create prototypes of their famously flash packaging. I was not allowed to take photos of any products because they were in development and had to settle on having my own photo taken next to an industrial strength 3D printer. It was made by an Israeli company called Objet which recently merged with a listed US company called Stratasys – we will re-visit them later in this book. In 2013 Objet 3D printers won Design World's Leadership

in Engineering program.

The small, elaborately detailed bottles coming out of the printer were gorgeous – I kept admiring their details and did not want to put them down. ‘Why do you print them?’ – I asked. ‘To make one by hand would take me more than two days, but I can design and print one in two hours – an engineer answered – and my time is worth \$120/hour.’ I quickly calculated that it cost \$240 for a 3D printed bottle prototype vs. \$2,400 for a hand-made one. And of course 3D gives him the ability to tweak any design, which would be impossible if he had to carve everything by hand.

‘These 3D machines, printing in plastic, are essentially glorified glue guns’ – the engineer said. The magic is in their software and the metal parts that move the nozzles on the tool paths. The thickness of a layer can be set between 64 and 32 microns (31 to 62 layers per millimeter).’ The final product is ‘cured’ with ultraviolet light.

I asked about the differences between his \$350,000 machine and an under \$2,000 unit for home use. It was due primarily to the thinness of layers, the maximum size of printed objects, the number of objects that can be printed at the same time, and the speed of the machine.

In the final part of this e-book we’ll review a listed company that specializes in rapid prototyping and short print runs. We will examine its stock chart and discuss how to handle it.

Industry & manufacturing

Making parts using current methods requires several employees running multiple machines and using hundreds of tools. Most machines require specialized training; they also tend to be loud, expensive and potentially dangerous. AM eliminates these problems, plus, quoting a price to a customer becomes simpler since processing time is based on the amount of material deposited at a certain density.

Today, companies have to make tools (dies) for making tens of thousands and even millions of parts. Frequently, the design and development of a die can take 12 weeks or more. Using AM to

create the die could reduce the time and cost of this process, offering an enormous competitive advantage. This could be a reasonable intermediate step on the way to complete additive manufacturing.

A recent article in *USA Today* was headlined [3D printing could remake U.S. manufacturing](#).

“About 20 miles east of Pittsburgh, the former heart of the nation's steel industry, a small company called ExOne is churning out a new generation of stainless steel boat propellers, oil pump parts and door knobs. But there are no clanging hammers, wheezing presses or even computer-controlled milling machines. Instead, a dozen 3D printers quietly stitch together industrial parts by meticulously spreading hundreds or thousands of layers of powdered metal onto a canvas until they form three-dimensional shapes.” In 2013 ExOne sold its shares in an IPO – it is now a publicly traded company, reviewed in the AM Stocks to Watch chapter of this e-book.

The article continued: “Since just a few employees run dozens of printers — vs. several hundred or thousands of workers in traditional factories — some experts say the technology can neutralize the low-cost labor advantage that countries such as China and India enjoy over the U.S. That, along with 3D printing's ability to accommodate quick product launches, is expected to accelerate a trend that has seen a growing number of manufacturers bring some production back to the U.S.” It quotes Christine Furstoss, the head of General Electric's manufacturing and materials technology group, who says that in 10 years up to half of the parts in GE's energy turbines and aircraft engines could be 3D printed. A few months after the 2nd edition of this e-book appeared, GE Aviation acquired Morris Technologies, a precision-engineering firm involved in printing aircraft engine parts using aerospace-grade titanium.

The spread of AM will restructure entire supply chains. The need for transportation will be reduced and many distribution networks eliminated. Retail shops will become not just transaction centers, but production areas, capable of delivering huge choices of inventory from relatively limited spaces.

Marcel Rosenbach and Thomas Schulz write in *Der Spiegel*: “Changing a product's design no longer means the entire assembly line must be reworked as well. This shortens product cycles considerably and makes it possible to introduce improvements more quickly.”

A good model is the progress of printing on paper. A generation ago, if you wanted a quality print, you'd need to hire several experts. An artist would prepare a drawing, a specialist would create mechanicals and an expert in printing would make high quality prints with the help of several assistants. Today all of the above can be done using a low-power laptop and a \$100 printer. The quality of your printed output is limited only by your imagination. AM will follow a similar course towards automation and bringing everything in-house.

Personalize your product design

While rapid prototyping was the main focus of AM during its early stages, the technology is now evolving in the direction of ‘mass customization.’ Historically, designing and producing a single object has been very expensive, but production costs fell sharply with mass production. Such economies of scale do not matter much with AM because every single object in a production line can be easily individualized with a few clicks of a mouse.

A UK company called Digital Forming has created a system that allows the general public to become involved in the design process. You can choose not only colors and textures of the products you order, but also modify their shapes, as long as your changes are within safety limits set by the manufacturer.

Medicine and Dentistry

A friend of mine was told by his doctors that he needs a hip replacement. The old way would have been to find a titanium hip of approximately his size and chisel it down a bit. Not any longer – now my friend is looking for an AM company that will “print” a perfectly sized titanium bone for him. AM’s ability to create very complex shapes is becoming increasingly popular for making prosthetics.



Figure 06 – A patient-specific knee implant by Stryker Orthopaedics.

Created using an EOS machine for direct metal laser sintering with bio-compatible cobalt-chrome alloy.

In 2013 Oxford Performance Materials (OPM), a company in Connecticut, received FDA clearance for its 3D printed “OsteoFab” Patient Specific Cranial Device. These are used to fill in holes in the skull due to trauma or disease.



Figure 07 – a replacement plate for the human skull: printed using PEKK polymer.

Some injured construction workers and wounded soldiers remain in danger of medical complications due to damage to their skull. An OPM implant is made from polymer which is biocompatible and translucent to X-rays. Its microstructure encourages bone cells to invade it and deposit bone tissue, blending the printed implant with the patient's own body. Other users of this polymer are dentists who can implant in a patient's jaw to replace lost bone.

A recent article on a website called BioMed Central stated: “The design of foot and ankle orthoses is currently limited by the methods used to fabricate the devices, particularly in terms of geometric freedom and potential to include innovative new features. AM technologies, where objects are constructed via a series of sub-millimeter layers of a substrate material, may present

the opportunity to overcome these limitations and allow novel devices to be produced that are highly personalized for the individual, both in terms of fit and functionality.”



Video 06 – a 3D [printed exoskeleton](#)

Returning the use of her arms to a child whose inborn condition makes her arms extremely weak.

Physicians and biomedical scientists can use 3D technologies to help normalize the lives of disabled people. Their 3D printed devices help restore some of the abilities taken away by illnesses. The use of such devices improves not only the patients’ physical abilities, but also their mental health.

At a molecular level, scientists are designing programs that will drive 3-D printers to print patient-specific medicines. You can watch a [TED Talk](#) by Dr. Lee Cronin, a professor of chemistry in Edinburgh. He describes how chemical inks can be used to create medicines as printed output.



Figure 08 – Custom-printed orthodontic aligners by ClearCorrect, LLC

The company uses Objet printers for both rapid prototyping and additive manufacturing.

Imagine going to a dentist to have a bridge made. Most dentists today use soft plastic to take an imprint of your teeth and send it to a lab. Some 10 days later an unfinished model of your bridge arrives – metal only, no porcelain. You return to the office, and your dentist tests it in your mouth, makes a few adjustments, and sends the model back to a lab. In another 10 days the lab delivers a finished bridge, and if everything goes smoothly, the dentist will fit it into your mouth after a few minor final adjustments.

In the future, he'll simply stick the wand of a scanner into your mouth, and then print a perfect bridge right there in his office, while you wait. Customization is relatively inexpensive when it comes to AM. In the months since the first edition of this book, a Danish firm [3Shape](#), a pioneer in intraoral scans, integrated its scans with Stratasys' (SSYS) dental 3D printers.

One of the most exciting new uses of AM is 'bioprinting' – printing human tissue and even entire organs. An article in the November 16, 2012 issue of *Science* explains that the key to growing cells is 3-D printing of a microscopic scaffold on which cells donated by a patient can thrive and multiply. It becomes possible to control the distribution of cells by printing surfaces and structures in desired shapes.

In 2013 Cornell University researchers created a replacement ear using a 3-D printer and injections of living cells. After scanning an ear, a 3-D printer produced its soft mold into which scientists injected cow cells that produce cartilage. After three months they had a flexible and workable outer ear. While the printing of organs, such as kidneys and hearts is still in the future, we will return to this revolutionary idea in the final part of this e-book when we review a company called Organovo, the makers of a bioprinter.

Fun & Games

AM is not only serious business – it allows people to exercise their playfulness and creativity. Some projects are sheer fun, while others may translate into serious business down the road.



Figure 09 – Up a creek in a printed boat

The November 3, 2012 issue of *The Economist* reported of an unusual entry in Seattle's annual Milk Carton Derby. Entries have to be made from old plastic milk bottles; they compete for speed in crossing a lake in one of the city's parks. Three local college students had shredded and

melted their bottles, then used a 3D printer to print themselves a plastic boat.

These students intend to use their prize money to bring 3D printing to poor countries – beginning with printing rainwater collectors and composting toilets. A trial is being planned for Mexico, and while printers have to be bought, the raw materials will be old plastic bottles that fill garbage dumps around the globe – turning junk into construction materials at virtually no cost.

Recycling

Organic Connections newsletter writes tongue-in-cheek: “Suppose you could replace “Made in China” with “Made in my garage.” Suppose also that every time you polished off a jug of two percent, you would be stocking up on raw material to make anything from a cell phone case and golf tees to a toy castle and a garlic press.”

Joshua Pearce, an associate professor of materials science at Michigan Technological University, is working to reduce the cost of filament for 3D printing. He and his group are tinkering with a RecycleBot – a device that shreds milk jugs, melts the plastic, and then extrudes it as a filament that can be used for 3-D printing. Their unit is open-source and free for anyone to download from Thingiverse.com (described in a later chapter).

Milk jugs are made from high-density polypropylene (HDPE), which is not the most ideal material for 3-D printing, but Prof. Pearce says it is only a question of time before he solves this engineering challenge. “Three billion people live in rural areas that have lots of plastic junk. They could use it to make useful consumer goods for themselves. Or imagine people living by a landfill in Brazil, recycling plastic and making useful products or even just ‘fair trade filament’ to sell. Twenty milk jugs get you about 1 kilogram of plastic filament, which currently costs \$30 to \$50 online.”

Other people are working to turn plastic trash into 3-D treasure. Tyler McNaney, a college student, is developing a machine for turning plastic household waste into plastic for 3D printers. His [Filabot](#) is being built using funds raised on Kickstarter and he plans to release machine drawings to the public. This way hobbyists will be able to download his plans and build their

own Filabots.

‘The Internet of things’

Computer chips can be printed as part of almost any AM object. A company named Kovio in San Jose, CA is already shipping printed radio-frequency identification (RFID) tags for tracking products as they move through a supply chain; they cost less than half of those made from silicon. A Norwegian company named Thinfilm is working to supply toy companies with trading cards for board games that include printed memory chips; those cards can even keep game scores.

Some shippers attach strips to packages that change color if exposed to excessive heat. Thinfilm plans to print digital sensors at a comparable price that will tell at what time heat exposure occurred and how long it lasted. Similar strips can be used to track the timing of many other processes, including the wetting of diapers.

Household use

While industrial-strength 3D machines may cost tens and even hundreds of thousands of dollars, 3D printers for home use can be had for under \$2,000. We will review some of the popular ones in the next chapter. The raw plastics from which home AM machines make things cost about \$20 per pound.

Brian Guptill is an American engineering executive who divides his time between homes in China and Florida. He owns a Makerbot 3D printer. He told me how one evening he needed a bottle opener; he went to the Makerbot website, found an opener he liked, downloaded and printed it. Another time he discovered a mouse in his house. He went to the same website, found several mousetraps, and downloaded one of them. Soon he caught a mouse that apparently had never before encountered a 3D-printed mousetrap.

Art

Creative artists as well as copyists are discovering the unique possibilities of AM. At its most basic level, 3D can be used to create replicas of three-dimensional art objects.



Figure 10 – Getty Museum through a scanner, by Bruce Sterling

A 3D user scans and prints famous sculptures.

As photo-stitching software, including Autodesk's [123D Catch](#) becomes more powerful, you need to take only a few photos to capture and print a sculpture. In 2012, New York's venerable Metropolitan Museum of Art – the Met – held what they called a Hackathon, with folks photographing and printing their sculptures and creating derivative works.



Figure 11 - Moon Pi by [Bathsheba Grossman](#)

This sculptor used a composite material made from sintering powder to create a puzzle-sculpture made of three interlocking parts.

As the second edition of this e-book was being published, 3D Systems Corporation (DDD) entered into a major multi-year agreement with the Smithsonian Institution to provide 3D printing services and technology. The Smithsonian is the world's largest museum and research complex, consisting of 19 museums and galleries and nine research facilities.

Fashion

Modern designers are starting to adapt AM technology. Dutch designer Iris van Herpen prints her collections on Stratasys and Materialise machines.



Figure 12 – Stratasys printed cape and skirt from a 2013 collection by Iris van Herpen

The technology allows to combine both hard and soft elements within the same print. According to van Herpen, “it is only a matter of time before we see the clothing we wear produced with this technology.”



Figure 13 – Materialise printed dress from a 2013 collection by Iris van Herpen

The outfits shown above are not quite ready for the production lines – or rather, the production lines are not yet ready for them. After the fashion shows end, these outfits will be going to MIT Media Lab, which helped to design them.

Jewelry

Modern jewelers can create one-of-a-kind pieces without spending days bent over magnifying glasses and fine tools. Some print jewelry directly, while others print plastic molds and use them to create pieces of jewelry.



Figure 14 – Gold jewelry by [Cookson Precious Metals](#) (UK)

The company uses EOS laser sintering machines to create unique pieces.

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Home-building



Video 07 – How to use [3D printing to build homes](#) (TED TV)

With a big enough machine on a sturdy foundation one can 3D print a house.

Contour Crafting is a layered fabrication technology invented by Dr. Behrokh Khoshnevis of the University of Southern California. His projections indicate that a 2,000 sq foot (200 sq meter) two story house can be built in less than 24 hours at a 20% cost of traditional construction. An

architect's CAD/CAM design can be directly printed, with electric and plumbing installed. As additional benefits, such methods of construction will reduce waste and workplace accidents.



Video 08 – [Rooms from trash](#) (2:03, DUS Architects)

Other companies are picking up this idea. DUS Architects of Amsterdam is rolling out its method for printing entire rooms or cabins from recycled plastic – they call their project [KamerMaker](#). The details are on their website – for a quick demo take a look at the video above.

The most ambitious home-printing project has been announced in 2013 by European Space Agency (ESA) – it is investigating constructing a manned base on the Moon using 3-D printing technology. ESA has partnered with the firm Foster + Partners (architects of a famous and controversial ‘Gherkin’ building in London). Their building material is regolith, or Moon dirt, and if this can be pulled off, humans will not have to haul houses to the moon at a huge expense. While experimenting with building a lunar station, scientists discovered that volcanic rocks from the Apennine mountains in Italy are 99.8% identical to regolith.



Figure 15 – The 1-ton (2,200 lb) test print of a wall from simulated lunar dirt.

Colonizing the Moon would allow mining of valuable minerals and setting up production lines in a vacuum, using unlimited solar energy in the absence of clouds. Lunar construction would have to protect inhabitants from solar radiation and micrometeorites. It also should withstand extreme temperature fluctuations between lunar days and nights.

The military

Not all applications of AM are warm and cuddly. The military is an active investor in AM technologies and an avid user of its products. The armed drones which patrol the skies above the areas where the infantry cannot go already use some 3D printed parts; such parts also go into jet fighters.

The Department of the Army has an ongoing project for testing 3-D printed UAVs (unmanned aerial vehicles or drones). As always, the young are in the forefront. At a company called Mitre, two summer interns built a UAV with a wingspan of 6.5 feet entirely out of 3-D printed parts. In Army tests their UAV achieved a cruising speed of 45 mph. When its nose was damaged in an early test, the interns simply printed a new one.

BBC reports that the US Army's Space and Missile Defense Command (SMDC) in Alabama is working with 3D printers that can produce spare parts for spacecraft. Their key reason is to produce cheaper spare parts for the sensitive instruments it develops. "Instead of needing a massive manufacturing logistics chain, a device that generates replacement parts is now small and light enough to be easily carried in a backpack or on a truck," said D. Shannon Berry, an operations research analyst at Army's Future Warfare office.



Figure 16 – Point and shoot.

Several parts for this gun were made using a 3D printer.

Now an American gunsmith has become the first person to construct and shoot 200 rounds from a [gun](#) partly made out of plastic 3D-printed parts. The barrel and the chamber are still made from traditional parts, but it is only a matter of time before one can 3D print a complete gun.

In the midst of his 2012 re-election campaign, the President announced the creation of National Additive Manufacturing Innovation Institute (NAMII), a public/private partnership. Tellingly, the agency that the government selected to manage this new institute is NCDMM – National

Center for Defense Manufacturing and Machining. Additive Manufacturing received the imprimatur of our military-industrial complex – the new field is really coming of age!

Education

Future belongs to the young. A reader of this e-book wrote to me “I am an old horse but I am encouraging my grandchildren and others to learn about this fascinating subject.” Not every reader who writes to me calls himself an old horse, but all indicate that they are encouraging the young to become involved in this field. The field of AM is so young and fluid that a newcomer has a great chance of rising to a position of importance. There are no creaky career ladders to climb and no old hierarchies to work your way around – just put your hands on a keyboard, design and print.

Savvy companies are starting to support AM education. The \$100,000 prize to the winner of Seattle’s ‘milk carton derby,’ described in a previous chapter, came from a private company. In November 2012, Autodesk (ADSK), a leading company in 3D modeling, made a \$21.7 million gift to Penn State University, to provide access to animation and modeling software.

An example of a simple AM business

There is a type of New York City locksmith I detest and despise. They stick their business cards into every door and gate in the city, advertising ‘lockout services.’ In the city of millions of people, many of them single, it is inevitable that many accidentally lock themselves out and need help to get back in. The locksmiths dealing with desperate people charge extortionate rates for the simplest jobs, as they cruise the city streets like jackals.

A few years ago an acquaintance of mine tried to start a business: you could store a copy of your keys with his little company and if you got yourself locked out, those keys would be delivered to you by a messenger for a small fee and a tip. His business never took off because most people would not trust their keys to a stranger.

Say hello to 3D printing.

Imagine a company: “Keys Safe.” You walk into a shop and they scan your keys for a nominal fee. No questions asked and you can pay cash if you like. You receive a file which you save in your phone, computer, online storage – anywhere you like, encrypted or not.

If you ever lock yourself out, depending on where you live, you may walk into a 3D print shop and print the keys from your phone. Alternatively, you can email your keys to a shop and wait for a messenger to bring them to some nearby cafe. You can pay cash and nobody will know the address for those keys. You can have both security and privacy.

Let this quick sketch serve as a simple example of how AM can improve our daily lives. I’ll be waiting for the day when the business cards of mercenary locksmiths disappear from my front door.

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A meeting with a founding father

While running a [Traders’ Camp](#) in May 2012 in Macao, I met Zach Smith, a co-founder of [MakerBot](#), an AM company that produces an inexpensive personal 3D printer. Zach took a ferry to Macao from Shenzhen, China, where he now lives, far from his native Iowa. This very bright and unconventional young man joined our small group of financial traders for a conversation over lunch that went on for three hours. Zach brought along two 3D-printed objects – a bottle opener and a figurine from a scan of a woman he knew. For the rest of that lunch we kept opening our beer bottles with Zach’s printed opener.



Figure 17 – A figurine from a scan, plus a bottle opener, by Zach (Hoeken) Smith
Printed on a Makerbot 3D printer.

Zach believes that eventually every home will have a 3D printer and people will be able to download almost any product they need and print it at home. Zach wants to build a huge free online database of products that people can download, use, tweak, improve, and re-upload if they like. He speaks of the great human desire to play, be creative, share, and be recognized. That's why the website he created, with a clever name www.thingiverse.com does not charge its users. Nor is his site limited to MakerBot designs – anyone can post. This is diametrically opposite to the approach of 3D Systems whose consumer website called Cubify.com, charges for downloading designs.

Zach talked freely about emerging 3D technologies. There is a system in the works for shining tightly controlled laser beams into a jar of liquid plastic, turning it solid exactly where one wants to produce parts. It'll provide a higher degree of control at a lower cost than MakerBot's and other companies' current method of injecting melted plastic. Zach's openness to new ideas,

readiness to change gears, and a refusal to defend the status quo made his approach to business very appealing.

Turning to financial aspects, MakerBot has received millions of dollars of ‘angel financing.’ I’d be very surprised if this company doesn’t go public in the years ahead – unless it gets bought out by a bigger firm.

PS: in the months since the first edition of this book came out, Zach has teamed up with Brian Guptill, an engineering executive who introduced us to each other, to work on a new 3D printer. At the time of this writing in April 2013 this is still a work in progress, but you can take a first look at it [here](#).

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3D printers for your home

Revolutions are started by the young. The two Steves – Wozniak and Jobs – got involved with computers in their teens and launched Apple Computer in their early twenties. Reading a recent [article](#) in *Business Week* about a group of 14-year olds in Silicon Valley who keep messing with 3D printers in a family garage had the ring of a new era to it. Some kids of this generation will grow into tycoons of the new technology, but even older investors can appreciate the revolution, enjoy its fruits, and make money on its stocks.



Video 09 - [A pre-teen 3D app developer](#) 03:49 (MakerBot TV)

A 12-year old 3D designer receives a Disruptive Innovation Award.

Large industrial 3D printers may cost up to a million dollars or more and use metal, ceramic and glass in addition to plastic. The new home-use 3D machines that squirt melted plastic from their moving nozzles can be had for under \$2,000. AM is just starting to move downstream, from corporate to private users.

RepRap

The granddaddy of this infant field is [RepRap](#), designed by and for serious hobbyists. It claims to be a self-replicating machine, but that's a bit of a stretch – don't expect a spanking-new printer to emerge from its Out slot. It simply has the ability to print about one half of its plastic parts, and then you buy the rest and assemble a new printer.

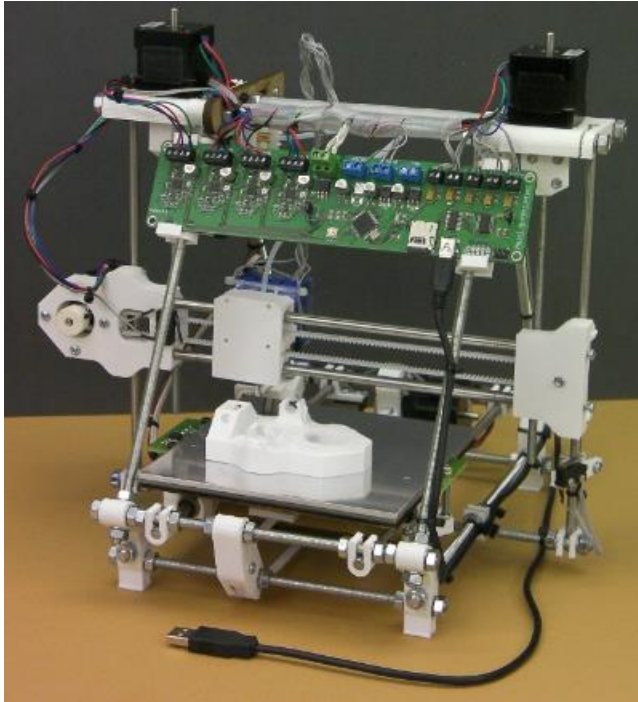


Figure 18 - Huxley, a basic 3D printer from RepRapPro in the UK

Roll up your sleeves – some assembly required.

The RepRapPro Huxley 3D printer is a Replicating Rapid-prototyping machine, or RepRapPro for short. It is an open-source derivative of the equally open-source RepRap Project which was started at Bath University, UK, in 2004. The machine uses a process known as Fused Filament Fabrication, with which it builds three-dimensional objects in a range of plastics.

Users can create almost any shape which can be modeled on a computer, including some which could not be produced by traditional manufacturing techniques. Many examples of objects printed on Huxley and similar machines by various individuals can be found on thingiverse.com.

Build volume: 140x140x110mm, accuracy: 0.1mm. You can see RepRapPro Huxley in action on the eMAKER YouTube channel [here](#).

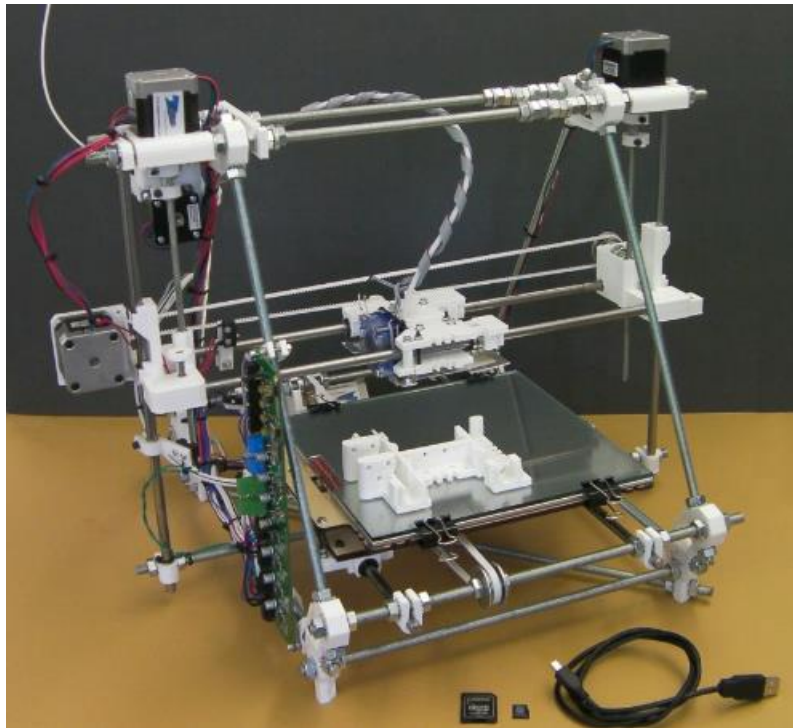


Figure 19 - Mendel, a color-capable 3D printer from RepRapPro in the UK

At the time of this writing RepRapPro Mendel is configured to work with only one type of plastic at a time, but it is designed to work with three deposition heads, allowing you to have three colors or to build single objects with multiple materials. The company promises to ship a multi-material/color version soon, offering existing customers a discount on the upgrade. You can see the RepRapPro Mendel in action on Vimeo [here](#).

MakerBot

Another player in the consumer AM field is a New York-based company called [MakerBot Industries](#); it sells a personal 3D printer called the Replicator, with single or dual extrusion. By choosing the dual extrusion you can make multicolored objects. You can print in either ABS (what Lego® is made of) or PLA (a bio-material made from corn). Build envelope: 225 x145 x150 millimeters or 8.9 x 5.7 x 5.9 inches. Layer thickness .2 or .3mm. Compatibility: Linux, Windows, and OSX, print from SD card or over USB. Input file types: STL and gcode. As the 2nd edition of this e-book was being prepared, the company opened a retail store in New York City.

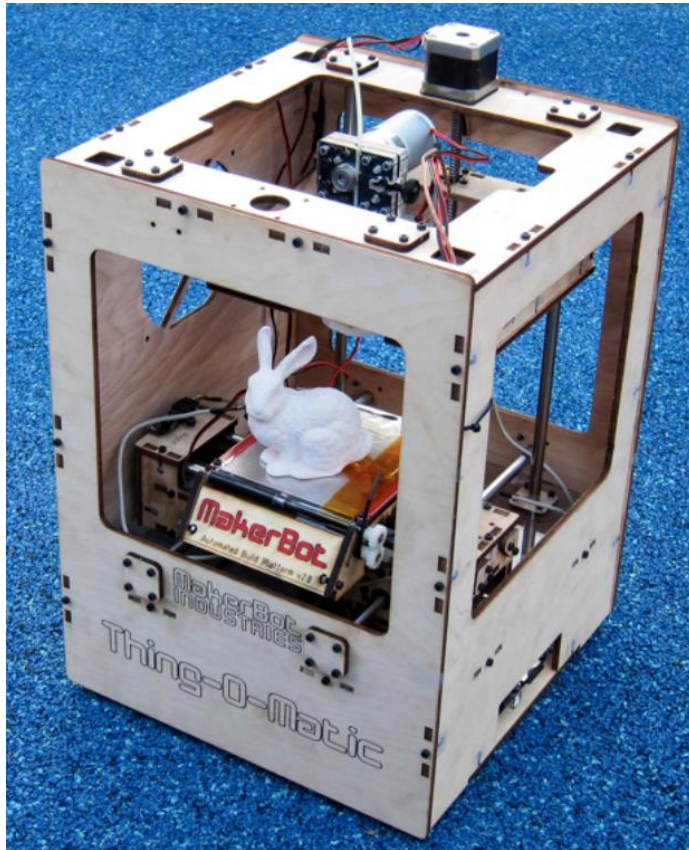


Figure 20 – Replicator, a 3D printer from MakerBot Industries in the US
Modern innards in a retro-chic housing.

One of the big attractions of MakerBot is its affiliated website Thingiverse, where users upload their 3D designs, suitable for any printer, not only MakerBot. You can download and print them; you can also tweak them and upload your own designs.

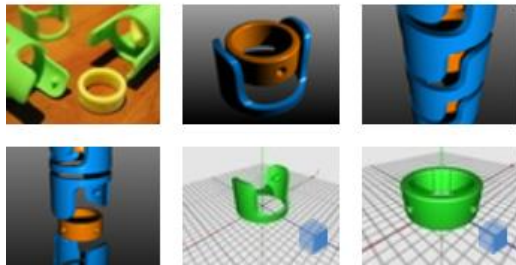


Figure 21 – Modular hollow universal joint for cable management. Thingiverse #25872

This structure can move in two directions at once. It is among tens of thousands of objects you can download from Thingiverse for free.

MakerBot's users keep uploading their designs. They are very generous about sharing their knowledge with new users. Thingiverse is a huge asset, especially for new users.

Cube

[Cube](#) is a consumer platform of 3D Systems – one of the major players in the 3D industry (stock symbol DDD). You can buy a basic version for under \$1,299, and it'll print pretty much anything you design as long as its size is within 5.5*5.5*5.5 inches (14 centimeters cubed). You can see an example in this [video](#). Cube received the 2012 Breakthrough Award from *Popular Mechanics* magazine.

Some experts predict that the 'inflection point' – price level at which new technology breaks into

the mass market – is at \$1,000 for 3-D printers. They say that once prices drop below a grand a piece everyone will run out and buy a 3-D printer. That's what happened with ink-jet printers, catapulting their maker Hewlett-Packard (HPQ) into the stratosphere a decade ago. The problem with that idea is that while everyone knew what to do with an ink-jet printer, most people do not feel any particular need for 3D printers. Developers will need to design a bevy of enticing products for the ordinary folks to become interested in owning this technology.



Figure 22 – Cube, a 3D printer from 3D Systems.

It connects to your computer using wi-fi instead of a cable.

This machine locks users into proprietary materials cartridges. Its website, Cubify, allows you to sell your designs, as it charges customers for downloads. If the object you wish to print is too big for the Cube, you can design it and then upload it to the Cubify website, which will print it and ship it to you.



Figure 23 – a drape dress

This is an example of a cloud printed piece that one can order from Cubify

Shapeways

Speaking of printing online, the company called [Shapeways](http://Shapeways.com) does not sell printers but invites you to email your 3D files to them for printing. They also offer a facility for selling your creations online.

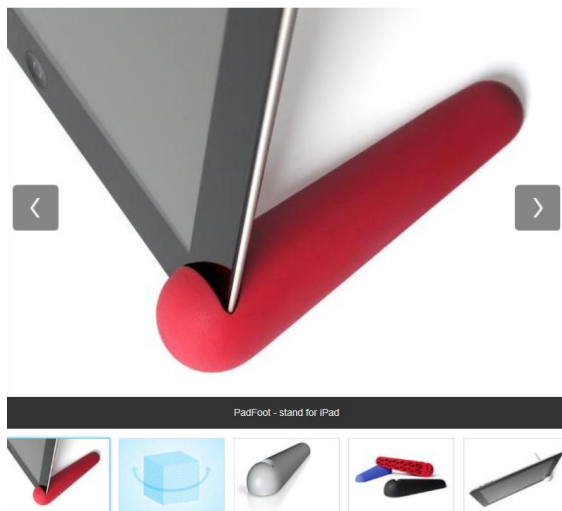


Figure 24 – a PadFoot, a stand for an iPad.

This is an example of a printed object one can order from Shapeways. It costs only \$19.50, although products can be much more elaborate and expensive.

Writing in *Science News*, Rachel Ehrenberg makes a good point: "...envisioning what exactly 3-D printers will deliver is difficult. In some respects it is like trying to imagine back in the 1960s the role computers will play in people's lives today." This is why Shapeways and thingiverse have much clutter, but amidst it there are many useful items.

Staples Easy 3D

Staples (ticker SPLS), a major office supply chain, will begin offering 3D printing services in 2013. Customers will be able to upload STL, OBJ, or VRML files to the Staples website for 3D printing, then either pick up their finished projects at their store or have them shipped.

"Customized parts, prototypes, art objects, architectural models, medical models and 3D maps are items customers need today," said Wouter Van Dijk, president of the Staples' European Printing Systems Division.



Video 10 – [an IRIS printer at work](#)

Staples will utilize IRIS 3D printers from Mcor Technologies. IRIS is a full-color 3D printer that uses regular letter-sized sheets of paper, binding them together with a water-based adhesive.

Because it uses paper and ink, it can print in a huge mix of colors, far ahead of 3D printers that use plastic. If you live in the Netherlands and Belgium you're in luck because that's where Staples will roll out its easy 3D in Q1-2013. Afterwards it plans to expand to other countries.

Mojo

If your taste in driving runs towards Jaguars and Porches, a company called Stratasys (ticker symbol SSYS) has a printer for you. It is the first professional machine to be sold for slightly under \$10,000.



Figure 25 – Mojo printer from Stratasys.

Nothing is home-made here; the look and feel say 'professional.'

The maximum size of a printed object is 5 x 5 x 5 inches. Mojo uses ABS plastic which cost \$5 per cubic inch (sold in 80 cubic inch packs for \$399). To see a video of this printer at work, click [here](#).

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Who'll benefit from AM

Technological progress blossoms in societies that respect individual rights and private property. Poor people living under oppressive regimes struggle for their daily bread. When a person has enough food and feels safe, his mind naturally turns to creativity and inventiveness. We all benefit from having creative individuals among us.

Discovering how to measure longitude (essential for sea travel), inventing the radio, developing penicillin – those great inventions changed the way we live. Human lives around the globe before and after the radio, or before and after penicillin were dramatically different.

Progress is driven not only by inventors but also by brilliant organizers. Henry Ford did not invent the automobile but he figured out how to mass-produce and mass-market cars, forever changing our society. You probably do not know the name of the man who invented the internet, although he is alive and well today – the revolution in our lives has been driven by the internet's brilliant implementers. Steve Jobs did not invent the computer, the portable music player, or the smartphone – but he implemented them in a way that changed how we live and work.

In the next section of this e-book you'll read a guest chapter by an investor and author Colin Nicholson who writes: "... first mover advantage tends to be a myth. It is the fast moving followers that implement the technologies more efficiently and with higher margins that emerge as winners..."

Many of America's great corporations already have AM departments. The next, hugely explosive stage will begin when this technology is adopted by the masses. Today, almost every home in the developed world has a computer, a printer, and fast internet. We will add 3D printers to this list in the years ahead.

We need to overcome many obstacles. At a recent meeting of traders in my home, an investor named Tom Ku showed two 3D-printed objects he had bought on-line from www.shapeways.com. One was made of metal, the other of plastic. As our group admired and

fingered them, he spoke about the obstacles to implementing 3D into mass use. He pointed out that while most people had digital cameras, very few knew how to use Photoshop or other software to manipulate images. The barrier to mass acceptance will be steeper with AM technologies: after all, photos need to be edited in two dimensions, while AM will require a 3D design.

Jeff Parker, a member of the same traders' group wrote: "I disagree with Tom. Most people will be content to buy existing designs and print them. Also, there will be specialized software to modify and create AM products in particular product lines. This lack of ability will not hamper adaptation. Most computer users have no idea how they work but can still use them."

What first seems like an obstacle is likely to add to the coming AM boom. The challenge outlined by Tom Ku will only drive creative people to invent – and sell – new solutions. The 3D boom is unstoppable.

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Creative destruction

Every revolution has its winners and losers. After every business revolution, some folks who used to have very little end up owning private jets, while others, who used to be comfortable, end up living in fleabag hotels and collecting handouts.

The term 'creative destruction' was coined by an Austrian-American economist [Joseph Schumpeter](#). He showed how the emergence of new technology destroys livelihoods of those who cling to the old ways. Cars destroyed the horse and buggy industry. Computers destroyed the typewriter industry. Digital photography destroyed Kodak.

Some mortal remains of dead industries are still among us. There are artisans in the Amish country of Pennsylvania and around some racetracks who still make and sell horse carts. There are writers in garrets who still use typewriters. But think of hundreds of thousands of Kodak

employees who bought homes and planned their futures around the company which failed to innovate. The quick are gone and the slow will remain depressed and bitter for the rest of their lives.

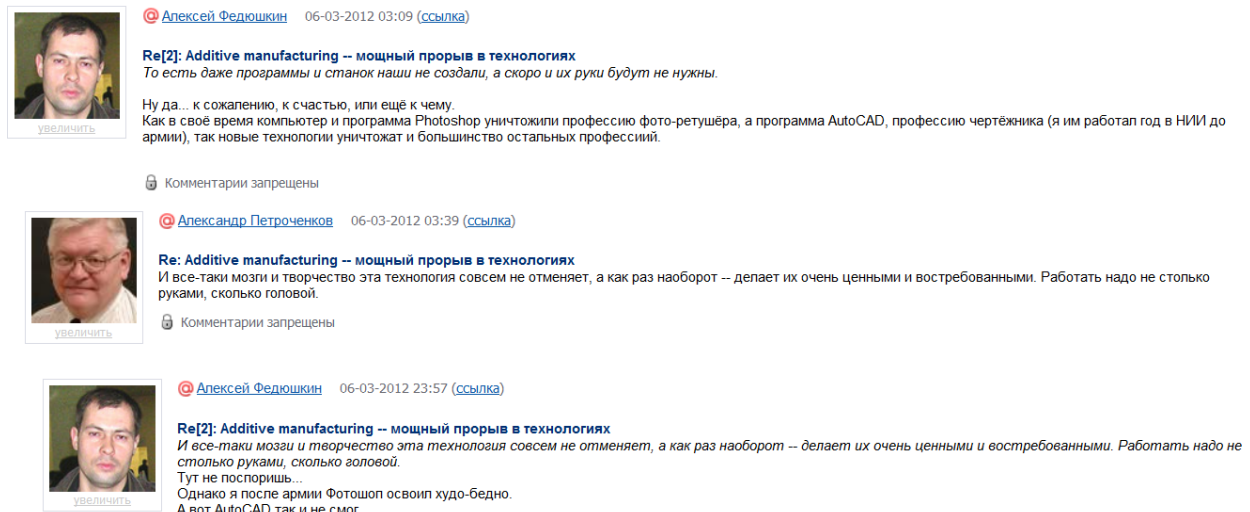


Figure 26 – from Alexander Petrochenkov’s blog

An exchange of messages on the destruction of professions.

I snapped this image from a [blog of a Moscow friend](#) (in white shirt, wearing glasses). After he quoted me on additive manufacturing, one of his fans replied “A while back computers and Photoshop destroyed the profession of retouching; autoCAD destroyed the drafting profession, and these new technologies will destroy many professions.”

That exchange reminded me of how being a draftsman used to be a sought-after trade; I used to see rooms full of draftsmen in architects’ offices. They have been done in by CAD – computer-aided design. I also remember how every newspaper that had photographers also employed a ‘retoucher’ or two – people who fixed problem photos, using a sharp blade and a pen. Where are they today? They have either learned new technologies or sank to being night watchmen and dishwashers (no disrespect towards these professions, simply pointing to large differences in income and perhaps the quality of life).

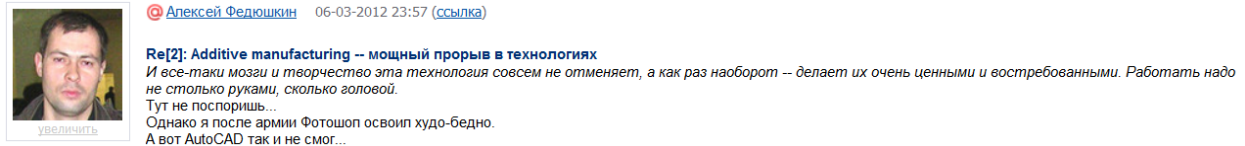


Figure 27 – from Alexander Petrochenkov’s blog

A reader is trying to survive after CAD/CAM makes his profession redundant.

My blogger friend’s correspondent added: “I managed to learn a bit of Photoshop, but could not handle AutoCAD. I am trying to make a little money with Photoshop...”

Progress is good for society as a whole, but it leaves its claw marks on many individuals as well as entire industries. If you agree that we are at an early stage of AM revolution, there are some questions you must ask yourself. Look at yourself, at your skills, at your business and ask – “How will I be affected by the AM revolution? Will I end up among its winners or losers?”

I recently gave a talk about AM at a conference, and afterwards spoke with a friend who came to hear me. His family owns a small but profitable business, creating metal product prototypes. They have been drilling, cutting, and bending for two generations, but now he was afraid: “If you’re right, we may be out of business soon.” “Why don’t you look into buying a machine and getting into AM?” – I asked. “You probably want to get into it before your competitors. Your company’s life is on the line.”

You also want to keep AM in mind when talking to your children or students. You owe it to them to point out the coming technological revolution, so that they can make appropriate education and career choices.

For those of us who plan to invest in AM stocks, there are other questions to ask. What industries and companies are likely to benefit and which will suffer from the AM revolution? What stocks should we be looking to buy and which to sell and sell short once the AM boom gets going? The following section is the first approach to this challenge. Without a doubt, I’ll have to update it in the editions that’ll follow.

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PART 3: RIDING THE NEW BULL MARKET

Innovative investors are paying attention to AM stocks. Two AM companies had been listed for years, two more went public in 2012, one so far in 2013, and many more are waiting in the wings, planning their initial public offerings (IPOs). Going public allows insiders to get rich, while their firms raise capital and gain credibility which improves their access to capital markets.

What is it that makes me so interested in AM stocks?

I've always had a feel for 'the next big thing.' I was one of the first people to buy a personal computer. I was early on the internet (early enough to obtain a short address of elder.com). In 1998 I published a book *Rubles to Dollars*, calling for a boom in the Russian stock market and recommending ADRs of Russian stocks. The Russian index ended up rallying from the level of 38 to over 2,400 within ten years. This is just a partial list, but my point is this – I tend to recognize big social trends in their early stages. I have no special pride about this ability – it's not something I cultivated, it's a given, like eye color. AM is not my first find, but it's the latest and one of the most exciting ever.

What is the basic principle of my campaign for investing in AM stocks? I'll never forget the words of Lou Taylor, my late great friend to whom *Trading for a Living* is dedicated, "a man who knows his principles and lives by them is strong. A man without principles goes chasing random opportunities and always loses in the end." My principle of buying into AM is this:

"Buy early, add on pullbacks, and hold for years."

This is why, as we turn to specific stocks, I remind you that these are not short-term trading ideas. This is a very long-term approach. Think of buying AAPL at \$20 a share and holding it for many years – that's what we want to do in AM. I claim no special ability for picking Apple-like winners among AM stocks, which is why I plan to diversify my investments.

Let me add an important caveat: I'm not offering you advice on what stocks to buy. I'm only sharing my thoughts and views. You must make your investing decisions within the context of your financial situation, obligations, plans, and risk tolerance. All of my books tell you that successful trading is based on three Ms – Mind, Method, and Money (psychology, tactics, and risk management). You're welcome to use my ideas, but please keep in mind that ideas alone are not enough – in order to manage risk you need to select a position size that doesn't make you anxious.

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Fundamental thoughts on investing in additive manufacturing

A guest chapter by Colin Nicholson



Figure 28 - Colin Nicholson with Dr. Alexander Elder and Zach Smith of MakerBot.

Macao, May 2012. Photo Patricia Liu

This is a guest chapter by [Colin Nicholson](#), an Australian investor who was a Guest Instructor in our 2012 Pacific Traders' Camp in Macao. He wrote these comments after participating in a three-hour working lunch with Zach Smith, a co-founder of MakerBot.

First, some general ideas:

1. Additive manufacturing is a new technology, but based on expired or aging patents. This suggests that the money may not lie with the patent owners, or at least not for long. A good example is the pharmaceutical industry. It seems to make a lot of money (high margin) while the patent is current, but longer term, the money may be with the efficient high-volume generic makers.
2. There are bound to be many starters. Early adopters tend to be pioneers with arrows in their backs; first mover advantage tends to be a myth. It is the fast moving followers that implement the technologies more efficiently and with higher margins that emerge as winners. They do not have to carry the costs of now obsolete plants from earlier attempts to be the first to market, perhaps without proper research.
3. The US seems to have some initial advantages in this field, but China, Korea and possibly Japan may not be far behind. Nor is Europe asleep – watch for the Netherlands, the UK and Germany in particular. The eventual winners may not be listed in the US, but be available for investment in other jurisdictions with varying levels of information and sovereign/legal risk involved.
4. It is tempting to see the bright technology geeks as the ones to back. However, past experience in countless industries suggests that the eventual winners are businesses driven by great managers, who make things happen effectively. In particular, I think we should be watching for the emergence of those entrepreneurs who quickly buy up new technologies and efficiently consolidate the industry. In other words, we need to look for great managers rather than great technology. That can be bought at a price.

Now, some thoughts on how to invest in this technology:

1. One approach that has been used in the past is to make small bets on every listed company concerned with the technology. Most will fail, but a very small number may make spectacular gains. This is a buy-and-hold approach and it requires patience and a long time horizon. Ask: over what period do I want results and if it is less than a decade or maybe two, this might not be the best way to go.
2. Some spectacular gains might also be made by investing in small start-ups before they are taken

public. This is a high-risk proposition which also requires a rare gift of being an expert in the field with great foresight. It is also a zero-liquidity route in that the money may be locked in for many years and even if you see a business failing early on it may not be possible to sell out.

3. It is quite possible that what is needed is in fact what we already do as investors. To use a horse race analogy, investing in stocks is like betting on a horse race that allows us to put bets on and take them off during the race. So, the strategy is simple: we place a bet on a selection of horses in the race that we think look best on past performance. Then as the race goes on, we take bets off any that fall back and make/increase bets on horses that are moving up towards the front, even if we did not back them in the first place. This is not a perfect analogy because the race that is the stock market is a never-ending one.

My suggested approach is simply to apply that analogy to the additive manufacturing sector. Find existing companies in the sector:

1. That show strongly growing earnings with a strong return on equity.
2. Are not wildly over-valued. I would use a PE ratio, but any method that measures intrinsic value will probably work well enough. Forget dividends because most will not pay dividends for years.
3. I would be looking for those stocks with a growth model chart and begin buying on whichever method is found to be most comfortable: breakouts or dips with bullish divergences.
4. I would also be looking for those stocks with a value model chart. In these cases I would be more selective and buy during an accumulation pattern on a bullish divergence, or on a breakout. The positions could then be built over time as an uptrend unfolds in the same way that is suggested for growth model stocks.
5. I would be looking also for charismatic entrepreneurs who are also great managers. These may be the leaders who consolidate the industry. They will be the most difficult to spot in advance and they will probably come into view initially as strongly performing growth or value model stocks.

Colin Nicholson, May 2012

For an explanation of Colin's value and growth models, see his book [*Building Wealth in the Stock Market*](#).

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The AM stocks to watch

At this point I have five stocks on my main AM list. We will review the following:

- DDD and SSYS are the granddaddies of this young industry.
- PRLB is a 3D prototyping company whose shares were listed in 2012.
- ONVO is a bright new star – a recently listed bio-printer company.
- XONE (ExOne) is the latest IPO in this industry.

I also have two stocks on my auxiliary list: ADSK and DASTY, and we'll take a quick look at them. I'm sure that both lists will grow in the months and years ahead, and I will update them in future editions of this e-book.

Revolutions move very fast. Suddenly, life accelerates to a terrific speed, and what used to take years happens in weeks. The young do well in revolutions. They leave behind the comfortable, the slow, the creatures of habit. I don't care what the age is on your driver's license, as long as it's over 18. I want you to think young – go with the flow. This may be hard to do after a certain age in sports or sex, but it's very doable in the financial markets.

Let's review each stock on the AM list as follows: first, a quick look at the fundamentals, then the current technical situation, followed by a plan. Please keep in mind that our chart reviews will only touch on key points. I keep updating them in the Members' section of a website which I co-manage, called SpikeTrade.com

Fundamentals reflect the numbers released by companies and analysts' research into their business (Patricia Liu, MBA, CFA helped prepare this chapter). Charts reflect behavior of masses of market participants. Teaching either of these crafts is outside the scope of this book; those interested in technical analysis may look up my other works, starting with a basic e-book *To Trade or Not to Trade*.

3D Systems Corp – ticker DDD

One of the oldest listed AM companies is 3D Systems Corp., with a clever ticker **DDD**. Its website is www.ddd.com. According to Yahoo Finance, the company is located in Rock Hill, SC and has over 1,000 full-time employees, a nearly 50% increase in the past year. It engages in the design, development, manufacture, marketing, and servicing of 3D printers and related products. Its print engines comprise stereolithography, selective laser sintering, and multi-jet modeling.

DDD maintains multiple websites, describing its various products: www.printin3D.com, www.production3dprinters.com, www.3Dproparts.com, www.toptobottomdental.com, www.quickparts.com, www.alibre.com, www.sycode.com, www.myrobotnation.com, www.freshfiber.com, www.The3dStudio.com, www.freedomofcreation.com, www.paramountind.com.

DDD is an active acquirer of smaller AM companies, having purchased more than 20 of them since 2009, according to Patrick Seitz of *Investors' Business Daily*. It bought Z Corp. and Vidar Systems for \$135.5 million cash in 2012. Most of DDD purchases use company shares as currency. The higher they rise, the more it can buy. So far in 2013 DDD is in the process of buying Geomagic, a leading provider of software for creating 3D objects.

In February 2013 DDD had a three for two stock split.

Fundamentals: Adjusting for its 3 for 2 stock split, DDD reported 2012 fully diluted earnings of 83 cents per share on a non-GAAP basis. Its 2012 net profit was \$67.9 million on revenue of \$353.6 million. The net profit margin was 19.2%. If measured on GAAP basis, 2012 net profit was \$39.9 million, with EPS of only 47 cents and net profit margin would be only 11.3%. Companies like DDD, SSYS, and PRLB like to report earnings based on both GAAP and non-GAAP basis. When analysts forecast earnings, they tend to do it on a non-GAAP basis.

The major difference between the non-GAAP and GAAP accounting is the treatment of amortization of intangible items. This is why the reported earnings based on non-GAAP are always higher. Wall Street analysts forecast non-GAAP projected EPS of \$1.06 and revenue of \$440 million for 2013. These numbers are in line with the company management's earnings guidelines.



Figure 29 – DDD Monthly, to March 27, 2013. Click [here](#) to see a large chart online.

This monthly chart of DDD shows that for nearly two decades following its listing in 1992 the stock found insurmountable resistance at the \$12 level. It broke out above it in 2010 (green arrow), pulled back briefly in 2011 (blue vertical arrow), and then began its current bull market. It had a wild run in 2012, but if we consider the area between two moving averages (12 and 24 months) its “value zone,” then DDD is now approaching that zone which is currently between \$23 and \$29 (marked by a green rectangle near the right edge of the chart).

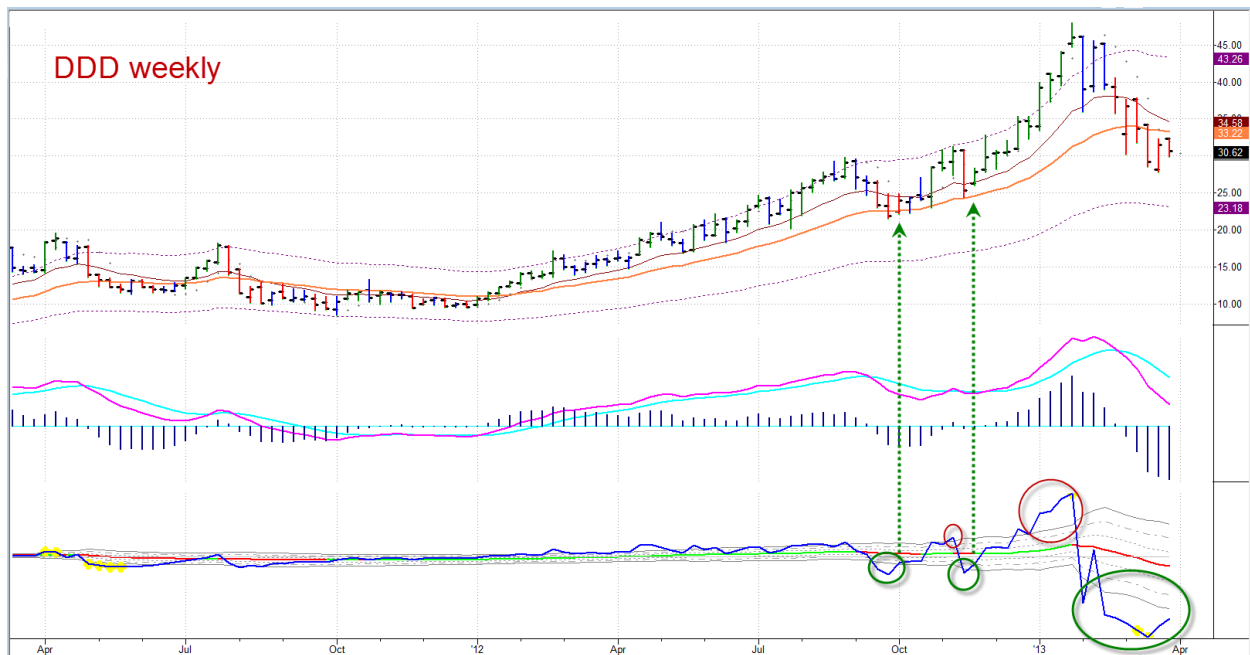


Figure 30 – DDD Weekly, to March 27, 2013. Click [here](#) to see a large chart online.

As DDD shares rallied from below \$2 in 2009 to \$47 in January 2013, this stock became a darling of the trend-following crowd. Masses of poorly informed investors and lemming-like fund managers piled into its runaway uptrend, afraid to miss “a good thing.” I suspect that few of them escaped when DDD plunged, losing nearly half of its price.

The previous edition of this book stated: “I’ll continue to monitor DDD with an eye towards a long-term buy in the low 30s.” I’m now focused on the indicator called the Force Index. When it surges outside of its channel, it indicates unsustainable levels of volume pouring into a stock.

When Force Index rises above its upper channel, it identifies a bullish extreme – such periods are marked with red circles, providing a warning sign to sell. When Force Index sinks below its lower channel line, it identifies a panicky liquidation – such periods are marked with green circles. DDD is just coming out of one of those periods right now. A buy signal is about to be given when Force Index rises back into its channel. This signal may come soon, and when it does, we’ll identify it in www.SpikeTrade.com – a website where I post my market views.

Stratasys, Inc – ticker SSYS

Another AM company that has been listed since the 1990s is Stratasys, Inc., whose ticker is **SSYS**. Its website is www.stratasys.com. The company engages in the development, manufacture, marketing, and servicing of three-dimensional printers, rapid prototyping systems, and related consumable materials.

Stratasys is located in Eden Prairie, MN. In 2012 it merged with Objet, a leading privately held 3D designer and manufacturer, based in Rehovot, Israel. The combined company retains the Stratasys name and ticker symbol. It has nearly 1,200 employees, with headquarters in both Eden Prairie and Rehovot, Israel's equivalent of Silicon Valley.

Fundamentals: SSYS reported 2012 earnings of \$1.49 per share, on a non-GAAP basis on revenue of \$359.1 million. On GAAP basis, the EPS was a loss of 58 cents. Consensus earnings per share for 2013 are \$1.82 on a non-GAAP basis.

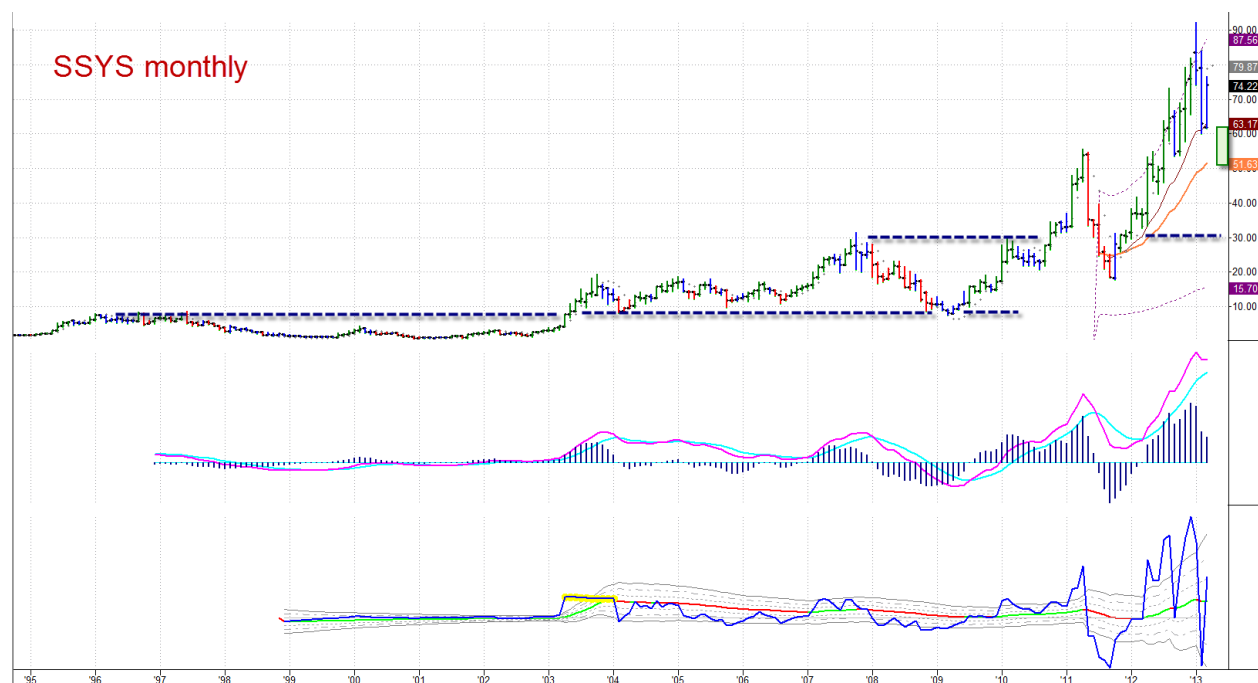


Figure 31 – SSYS monthly, to March 28, 2013. Click [here](#) to see a large chart online.

For nearly a decade following its IPO in 1994 SSYS languished below \$10, then broke out

sharply in 2003. It reached \$30 in 2007, revisited the area below \$10 in 2009, then rallied to its previous top and after a pause of several months broke through it. It then rallied near \$55 but fell below \$20 before launching the latest upleg which took it above \$90. At the time of this writing, SSYS has pulled back near \$53. Its value zone, marked with a green rectangle on this monthly chart, is between \$52 and \$63.



Figure 32 – SSYS Weekly, to March 28, 2013. Click [here](#) to see a large chart online.

This weekly chart of SSYS reflects its clear tendency to trade within a well-established channel. Its rallies gather speed and then run out of steam in areas marked by red Xs above the upper channel line. All such rallies are followed by declines – either into the ‘value zone’ between its moving averages or even below them, sometimes down to the lower channel line.

A paper clip marks the date when the first edition of this e-book was published. A red pen marks the time of the second edition, which said: “The drop of Force index below its lower channel line reflects panicky liquidation by weak holders, which tends to be an early stage of a bottoming-out process. Prices may fluctuate here and decline a bit lower, but it appears that the bulk of the damage has been done.”

Since then, SSYS had a sharp rally, followed by a steep pullback of nearly 30%, which cleared the air by shaking out weak late-comers. At the right edge of the chart the rally is in full swing, confirmed by rallies in all the key indicators: moving averages, MACD, and Force Index.

Proto Labs Inc - ticker PRLB

Proto Labs, Inc. produces machined and injection molded plastic parts. Its website is www.protomold.com. The company was founded in 1999 and went public in February 2012. It has over 500 employees and is headquartered in Maple Plain, Minnesota. It has locations in the United States, the United Kingdom, Germany, Japan, Italy, France, and Spain. The founder claims an impressive resume which includes founding another company in 1985 that according to him became a major force in laser and ink-jet printing. Proto Labs has totally automated the process of making injection mold tooling, using advanced aluminum alloys. It promises to deliver real injection molded parts as quickly as the next business day, at prices starting at \$1,495.

Fundamentals: PRLB went public on February 24, 2012. It reported 2012 EPS of \$1.07 on a non-GAAP basis, with revenues of \$126 million. The 2013 EPS consensus is \$1.33.

The underwriter priced PRLB shares at \$16, but they traded between \$24 and \$30 on the first day. Since then, it fluctuated in a range between \$29 and \$39, before breaking out decisively in 2013 and rallying above \$50.

Since charts reflect patterns of mass behavior, a very short-term chart provides little information. This stock is so young that there is not enough data to draw a monthly chart. The weekly chart shows a nice technical pattern: after breaking above resistance, PRLB briefly pulled back to it in the area marked by a green arrow. The broken resistance line turned into support, with PRLB rocketing above it.

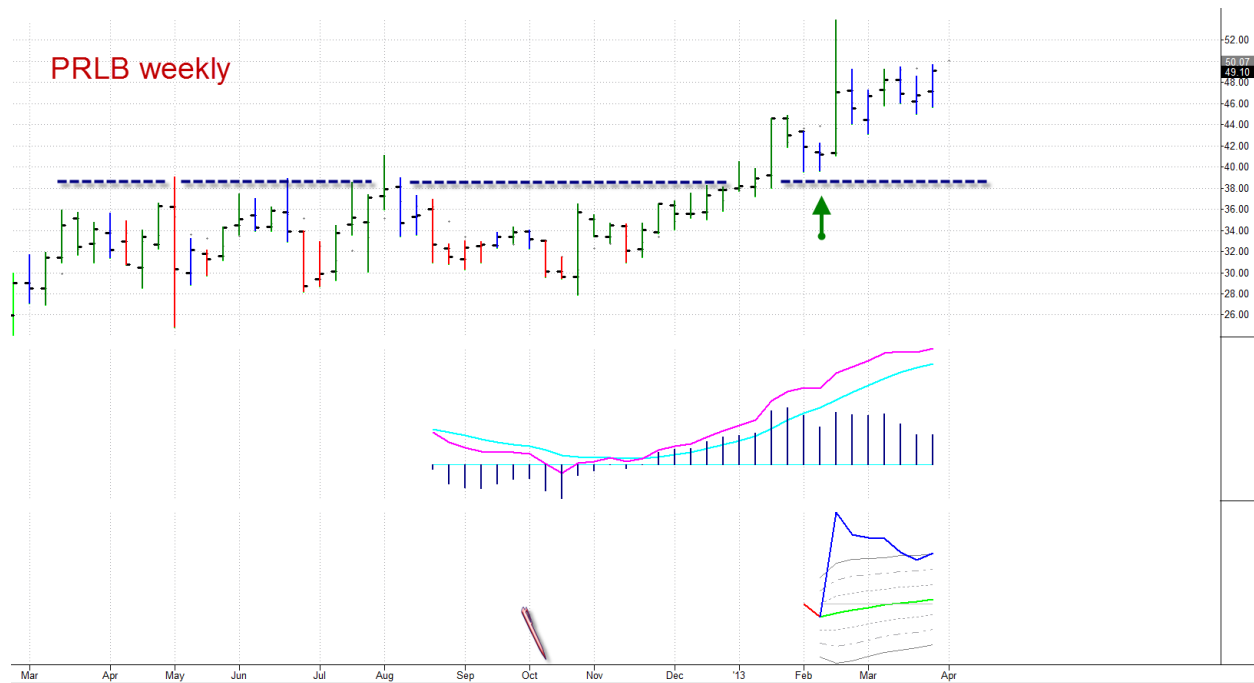


Figure 33 – PRLB weekly, to March 28, 2013. Click [here](#) to see a large chart online.

The previous edition (in the area marked with a red pen) stated: “The fact that for most of its short history PRLB has been holding above its first day’s range is a sign of strength. Most IPOs would have sunk below that range by now – think of Facebook which shed more than half of its value. At the time of this writing I’m about to begin nibbling on PRLB shares.” The stock has nearly doubled since then. I’m not a fan of chasing strength and would rather wait for a pullback. My very long-term view of AM stocks does not call for jumping and running after them.

Organovo Holdings Inc – ticker ONVO

Organovo has developed a printing technology that creates human tissues for research and surgery. Its NovoGen 3D printer works across various tissue and cell types. Organovo serves researchers in the fields of cardiovascular medicine, transplant medicine, and drug testing. The company has 29 employees (up from 16 a year ago) and is based in San Diego, California. Its website is www.organovo.com.

The company was founded in 2007 and its first private placement of shares was in February 2012, at \$1 per share. This is an OTC “pink sheet” stock.

Fundamentals: ONVO reported a net loss of \$1.01 per share in 2012. Its revenue has risen by 20% from the previous year, to \$1.2 million from \$1 million. The company continues to burn through cash. One way to track its prospects would be by watching who they’re hiring. If you see them hiring sales people, that’ll mean they have something to sell.

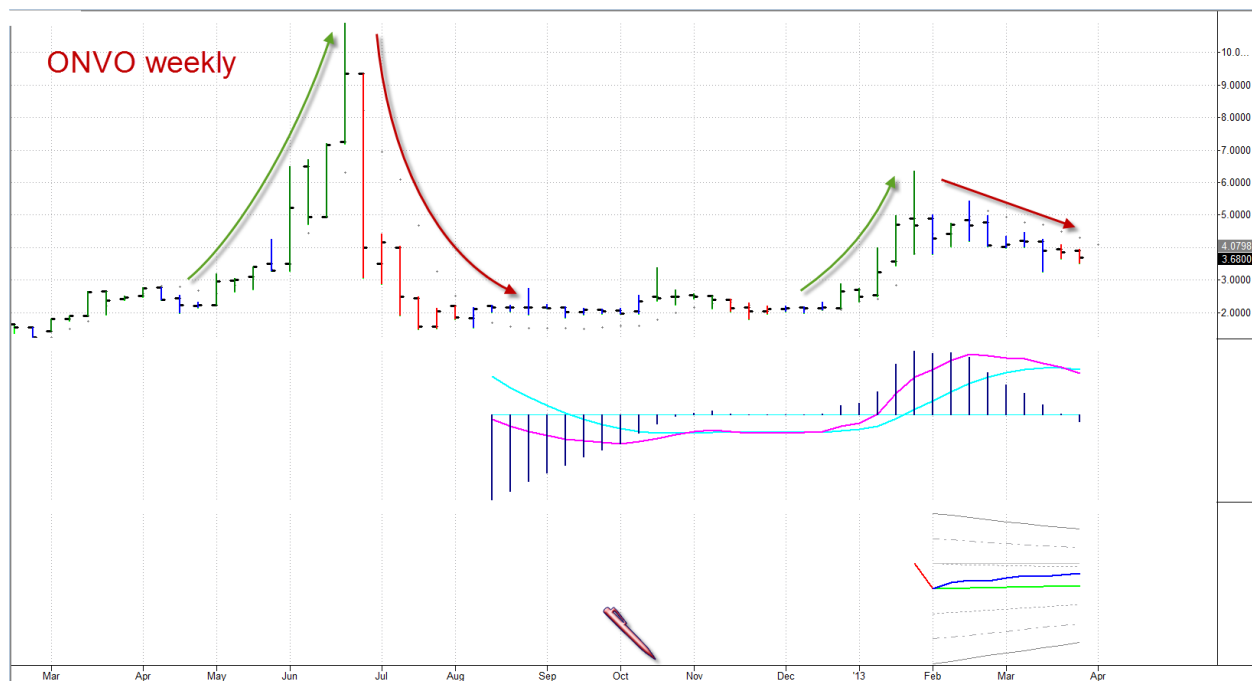


Figure 34 – ONVO weekly, to March 28, 2013. A foretaste of future fireworks! Click [here](#) to see a large chart online.

With health care being responsible for the lion’s share of the US economy, it is no surprise that AM is starting to find applications in this huge field. One of the most exciting new uses of AM is ‘bioprinting’ – printing human tissue and even entire organs. This can be done using the recipient’s own genetic code, sharply reducing any immune response. Such transplant recipients will not need large doses of immune suppressants, which they receive today to prevent transplant rejections.

Sounds like science fiction – only it isn’t. Organovo developed its first commercial bioprinter in

2009. Their machine, called NovoGen, prints skin, blood vessels, and patches of heart muscle. Their products have not gone through the approval process for medical use, but they're in demand from institutions that need tissues for research, including Harvard and Stanford. The company is working to bioprint functioning kidneys and bone cartilage. Outside researchers, not affiliated with the company, predict that a human heart will be printed within a generation. For more details on Organovo you can visit the company's website and also read this [article](#) at T. Rowe Price.

The current customers of Organovo are research centers and pharmaceutical companies that need tissues for testing their drugs. ONVO has collaborative agreements with United Therapeutics and Pfizer. In 2012 it has partnered with Autodesk (ADSK) to create software for bioprinting. Further down the road are clinical trials, leading to an eventual application to the Food and Drug Administration for an approval for therapeutic use. In 2013 Organovo formed a collaboration with Knight Cancer Institute at Oregon Health and Science University, famed for its development of Gleevec treatment. Instead of just selling bioprinters, Organovo included a royalty clause in this collaboration, creating an unlimited upside in case of clinical success – with very little risk.

In July 2012 ONVO announced that it received a UK patent for 'multilayer vascular tubes,' in other words for printing blood vessels – and its stock dropped 40% on that day. Buying ONVO sure gets you a ticket to a wild roller-coaster ride.

The company went public in February 2012 and had a screaming rally from a bit over a dollar to \$10.90 in four months. Explosive? Yes! The shape of trends to come? Quite likely! Following that meteoric rise, the stock hit its head on the ceiling and collapsed back into its base. In 2013 ONVO had a smaller price explosion and is settling down at the time of this writing, with all indicators confirming the downtrend.

This stock has a very exciting fundamental story. Once its price goes flat below its current level, ONVO may well become an attractive buy again. Perhaps it can 3D-print some new skins for the butts it kicked on the way down. Buying this stock requires two qualities: patience to hold it

during long flat periods and fortitude to take profits during its next explosion.

ExOne – ticker XONE

ExOne engages in the manufacture and sale of three-dimensional printing machines as well as in designing and 3-D printing products for its customers. Its website is www.exone.com.

ExOne was founded in 2005 and is based in Irwin, Pennsylvania, with additional locations in the US, Germany, and Japan. It markets its products to aerospace, automotive, heavy equipment, and power fluid handling industries, offering 3-D printing in sand, metal and glass.

ExOne went public in February 2013, a little over a month before this edition of this e-book. Its revenue for 2012 was \$28.7 million, nearly double that of \$15.3 million in 2011. Since charts reflect patterns of mass behavior, a very short-term chart provides little information. This stock is so young that there is not enough data to draw a weekly chart.

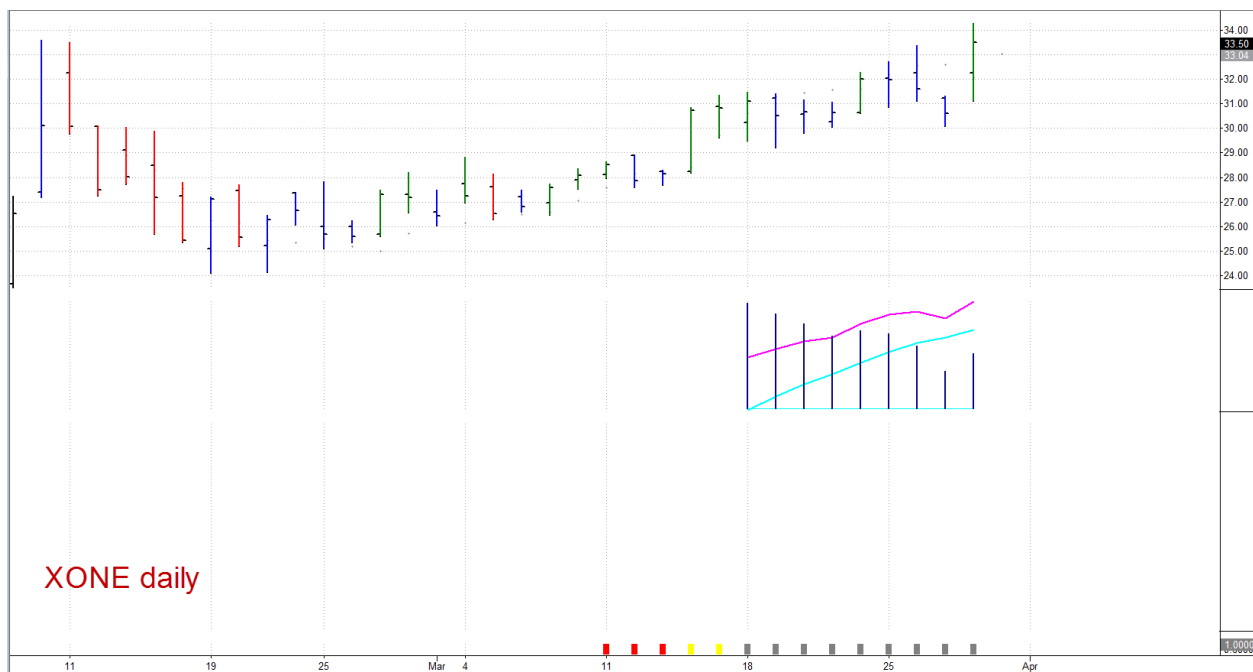


Figure 35 – XONE daily, to March 28, 2013. A jump off the starting blocks. Click [here](#) to see a large chart online.

The daily chart shows that the stock opened below \$24 on its first day of trading, ran up above \$33, and then proceeded to sink back near its opening price. It rallied from that level and reached a new high above \$34. Its short price history cannot provide a basis for thoughtful decision-making. Still, the fact that most of the time XONE has been holding above its first day's range is a sign of strength (making it similar to PRLB's launch pattern).

The auxiliary list

In addition to the list of companies directly involved in AM, I keep a list of other firms that are starting to move into this field. At an early stage of such a move a company may derive only a small percentage of its income from AM, but the fact that it is getting into AM reflects foresight and bodes well for the future. As more and more mainstream companies get into AM, I expect my auxiliary list to grow. As companies get deeper and deeper into AM, I'll move them from this list into the main AM list and buy their shares.

Autodesk Inc. (ADSK) is a key company in CAD/CAM (computer aided design and manufacturing). This company is actively involved in programming for 3D printing. It has developed software that allow novice designers to create and export 3D models. Users can print those models themselves or pay a fee to Autodesk to create a physical model for them. AM seems like a natural fit for them, but it is too early to see any meaningful impact on their earnings.

Dassault Systemes, SA (DASTY) is an ADR for a French company. It is involved in 3D design as well as educational services. The problem for US investors at the time of this writing is that its trading volume is very thin, only about 10,000 shares/day. A thinly traded stock may be easy to buy but you can expect horrendous slippage when you need to sell it.

Cimatron Ltd (CMT) is an Israeli company listed in the US that designs and develops CAD/CAM products. It appears to be moving into design for Additive Manufacturing.

Hewlett-Packard (HPQ) is a dark horse of the 3-D field. As a leading provider of printers and

printing supplies, it would be natural for it to become interested in 3-D. Our sources tell us that a secretive company unit located in Spain is spearheading their development of 3-D technology. Something may well be cooking because in the second half of 2012 a manufacturing and distribution agreement between Hewlett-Packard and Stratasys was terminated,

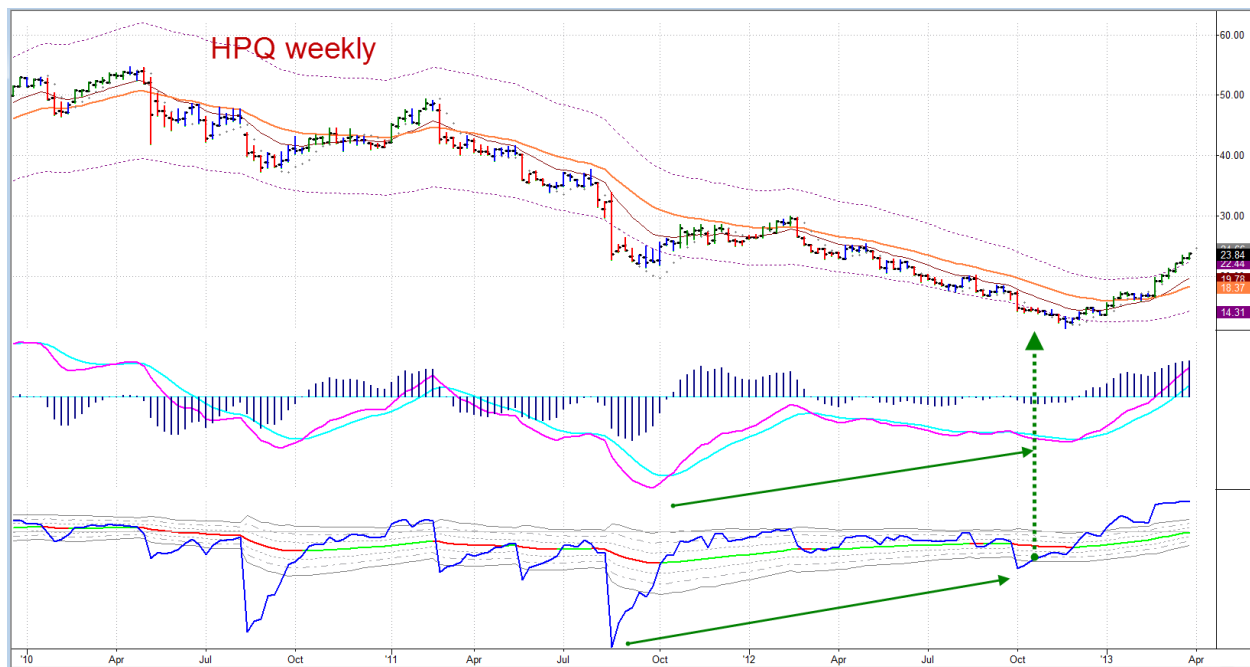


Figure 36 – HPQ weekly, to March 28, 2013. Indicators called MACD and Force Index have traced out “bullish divergences” – they bottomed out at higher levels as the stock declined, giving buy signals. Click [here](#) to see a large chart online.

Hewlett-Packard shares have been under pressure, as mobile internet and social networks reduced printing needs. Could its recent rally have been driven by 3-D prospects? This company know-how and reputation would make it an awesome competitor.

Do you have an AM stock that should be included in this book? If so, please write and we’ll be happy to review it and perhaps include it in the next edition.

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Companies outside the US

The upsurge of AM is happening worldwide. The relative cheapness of new technology and the fact the key patents are expiring is lowering the barriers to entry. AM companies already exist in Australia, Belgium, Germany, Israel, the Netherlands, United Kingdom, and other countries.

Some of these companies have already listed their shares on their local markets, others may list them in the future. It wouldn't be surprising if some of these companies apply for dual listings, the way Dassault Systemes already did – in France as well as in the USA.

The following is a brief list of some of the more visible firms. If you notice that your firm is missing from this list, please send the author a [note](#), and we'll correct our oversight.

- Australia – [Ferra](#) is an aerospace company in Brisbane, rapidly moving into AM.
- Belgium – [Materialise](#). A worldwide company with multiple products and a lot of flair. Click on their website to watch a video of a 3D race car they printed.
- France – [Dassault Systemes SA](#) (reviewed in the previous section)
- Germany – [EOS](#). The company, founded in 1989, is a leader in using AM techniques for manufacturing UAV (drone) parts.
- Germany – [SLM Solutions](#). This company, specializing in selective laser melting (SLM) recently opened an office in Michigan in the US. Its latest achievement is a build chamber with double laser technology, speeding up build times by a factor of 10.
- New Zealand – [Ponoko](#) calls itself a “personal factory.” It works with designers and uses a growing variety of materials for 3D printing.
- Switzerland – [iSquared GmbH](#) is dedicated to providing an inexpensive alternative to the original equipment manufacturers' consumables.
- UK – [Renishaw plc](#) (ticker RSW.L) has nearly 3,000 employees. This company, originally involved in precision metrology, is rapidly moving into the AM sector. An early adopter of selective laser melting (SLM), it is now 3D printing titanium.

Unlisted companies in the US

A stock market listing is one of the key signs of a company's maturity. Even such giants as

Microsoft, Apple and Google started out as small, privately held firms. ‘Angel investors’ who put money into startups tend to say that going public is a very rare outcome for a private firm. Most successful startups are acquired by bigger players – sometimes for tens or even hundreds of millions of dollars. Still, it makes sense for traders to keep an eye on prominent private firms. Some of them will surely go public in an AM-driven stock market boom. ExOne, which was listed here in the previous, 2nd edition of this book already went public.

Here, in addition to several privately held companies mentioned above, are a few of the prominent private firms in the AM field:

[Afinia](#) makes “out of the box-ready” 3D printers. It also makes and sells 3D plastic filament for 3D printers. As demand for 3D printers grows, Afinia’s lower-priced supplies may give the majors a run for their money.

[Geomagic](#) is a global company based in North Carolina. Its software was used to shape the body of a vehicle that beat the world’s 763 mph land speed record.

[GROWit](#) is a privately held company in California. It offers rapid prototyping and small-batch manufacturing services.

[Optomec](#) is a privately held supplier of AM systems, located in New Mexico. It has sales and support offices across the US as well as overseas. Its aerosol jet printer was featured in *The Economist* article *Print Me a Phone*.

[Sciaky Inc](#), a subsidiary of Phillips Service Industries, has many customers in the defense establishment. It recently released a snazzy [video](#) on its large-scale AM capability.

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How to hop off before a bubble bursts

Human history is dotted with mass manias, and the history of financial markets is punctuated by price bubbles, which always end in panics and crashes. Centuries ago, there were the Dutch Tulip Mania and the English South Seas Bubble. The US stock market boom of the 1920s seems remote, but the Crash of 1929 and the Great Depression that followed have been seared into the nation's memory.

Following each crash comes a period of anger and repentance, with folks saying 'never again.' The morning after a wild party, a drunk on his knees barfing into a toilet may promise never to drink again, but do you really believe him?

After a bubble bursts, its losers wash out of the market, but new participants trickle in, and that trickle turns into a flood as a new bubble develops. Each bubble is based on a new concept that sounds eminently reasonable. Tulips were very beautiful and sought after, the South Seas trade very profitable, and the stock market in the early 1920s was definitely undervalued, with the boom driven by the new industries of oil, cars, and radio.

In recent years, the US stock market has had a new bubble approximately once a decade. There was an internet bubble in the 1990s, topping out in March 2000. Another bubble was driven by wireless telecoms, cheap credit and real estate, but that topped out in October 2007. Anyone who thinks that was our last bubble ever has to be very naive.

Bubbles keep emerging in every decade, but they don't repeat. You will not see another internet bubble or a wireless bubble because we already had them; enough people remember getting burned, preventing a new bubble from forming on the same ground. Nor are we likely to see a biotech or a nanotech bubble because those industries, however promising, are no longer new. A bubble has to happen in a new area, allowing participants to chant the mantra of every bubble: "This time is different!"

Additive Manufacturing is the best candidate for the next bubble. It is new, revolutionary, and

promises to change the fabric of our lives.

There is a course of action I'd suggest to a savvy investor.

Jump in when the new bull market begins to emerge. Do not allow sanctimonious "it is a bubble" keep you out of one of the best trends of a generation. Yes, a bubble will grow and burst, but don't let your knowledge of its eventual burst keep you out of the game.

Don't miss this ride – just learn when to hop off.

Get in even if you miss getting aboard early. Great bull markets always overshoot reasonable targets, as major trends keep feeding on themselves, just like tornadoes in the Great Plains. That's why all bubbles eventually burst – because they blow up beyond any logical forecast. It pays to be on board for that crazy ride.

You can ride a bull market into a bubble, but don't buy into its craziness. Keep a cool head and remember that "this time" is never different, no matter how great the new technology. Additive manufacturing will transform our lives, but the stock market bubble will eventually burst. There will be no soft landing. Bubbles end in crashes.

For a lesson in how to trade a bubble let's take a look at the iconic Internet bubble of the 1990s.

The first web browser was released in 1993; a dot-com bull market emerged in 1995 and in a few years morphed into a bubble, hitting the top in 2000.

Dot-com companies whose stocks levitated in that bubble either worked or promised to begin working in some area of internet economy. Nobody knew for sure how the internet could be monetized, but as soon as a company added a prefix "e-" to its name, its stock soared. Many e-companies came into being thanks to easy money from venture capitalists in the environment of low interest rates.

While some dot-com entrepreneurs had realistic plans and administrative abilities (for example, Jeff Bezos of Amazon.com and Pierre Omidyar of Ebay.com), many others had neither but were able to sell their ideas to investors enamored of new technology's fantastic potential.

A typical company would raise cash and then burn through it, operating at a loss to gain market share. Nobody really knew how to value these companies, and new firms kept going public at ridiculous price-earnings multiples, making insiders and venture capitalists rich, at least on paper. Even small investors with spare cash garnered fantastic paper profits. My e-book *To Trade or Not to Trade* offers an example:

“A friend of mine immigrated to the US with only the clothes on her back; she spent the next 20 years helping her husband build his dental practice, while keeping an eye on the kids. Finally she had some money and free time. She took \$50,000 from the office and opened a stock brokerage account. Her timing couldn't have been better – it was 1999, the last year of the tech bubble.

“She kept buying stocks she heard about, selling them a few days later, then buying more and selling again. By the end of the year she ran up her account to \$964,000. The next year the bubble popped and she began to lose money. When her account dropped below \$600,000 she closed it and signed up for a technical analysis course. In April she was surprised to learn from her accountant that she owed taxes on her short-term profits from the previous year.”

This true story provides two lessons.

First, do not argue with the trend. When a bull market morphs into a bubble, buckle your seatbelt and hold on for the ride. Expunge the words “it is too high” and “it can't go any higher” from your vocabulary. There is nothing reasonable about a trend that takes a beginner's account from \$50,000 to nearly a million within a few months. ‘Reasonable people’ would have sold long ago. When a bubble gets going, hold on and ride!

Second lesson: you need to be absolutely clear about the signs of a bubble popping. When you

see them, sell everything. Expunge the words “soft landing” and “I’ll sell the next rally” from your vocabulary. If you have any “fundamentally good” stocks, sell them as well – you’ll be able to repurchase them for 20 cents on the dollar after the bubble bursts.

What are the signs of a bubble popping?



Figure 30 – Nasdaq monthly, 1994 – 2001

Take a look at this monthly chart of the NASDAQ, where each bar represents one month’s action. The height of each bar reflects the emotional temperature of the market crowd. The bars are short when the crowd is in a peaceful mood, but become taller as the crowd becomes agitated (this concept is explained in my book *Come into My Trading Room*).

This chart of the Nasdaq shows the three stages of the Internet bull market, where the third stage is a bubble. During the first stage (yellow bar), 1995 through 1998, the index rose in a steady manner. During the second stage (rose bar), 1998 – 1999, the index accelerated. The morphing of a bull market into a bubble is marked by a thick red arrow – it points to a bar which was three times taller than the previous monthly bar.

This triple height showed that the bull market had gone ballistic. It was the time to implement a simple rule for getting out of a long position – put a protective stop below the low of the most recent complete bar. The bubble blew up to a fantastic height, but when it popped, that stop, indicated by a thin red arrow on the right, salvaged the lion's share of profits.



Figure 31 – Infoseek monthly, 1999 – 2002

America's Super Bowl in January 2001 featured 17 dot-com companies; each paid upwards of \$2 million for a 30-second spot. Burning through cash to gain market share was the mode of the day. A year later only three of these companies ran Super Bowl ads; half of the dot-com start-ups became end-ups: they went bust.

This is the chart of one of the survivors – Infoseek, that recently changed its corporate name and

ticker symbol. You can see that this basic rule – placing a stop at the previous month’s low – would have saved the bulk of profits, as the stock collapsed from above \$500 to below \$3 per share (adjusted for a reverse split).

The lessons of these charts will help you ride the coming bull market in additive manufacturing, buckle up for the bubble stage, and get out with the bulk of your profits by trailing a stop below the previous month’s low to sidestep the inevitable crash. Of course we plan to track these stages in SpikeTrade.com.

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For the young

If you have children in school or in college, be sure to alert them to additive manufacturing. If they are passionate about studying something else, that’s great – we should all follow our passions. If, on the other hand, they’re unsure what to do next, you would do them a favor by opening their eyes to a promising new area.

My primary activity is trading the markets. A while back I worked for a year in a local high school as a volunteer, teaching a class ‘Money & Trading.’ I taught the kids my method, opened a \$40,000 account and we traded it as a group. At the end of the school year I donated half the profit to the school and the other half to class members. I kept saying to the kids: “Not all of you can become traders, but you should consider Wall Street as a career path. If you’re passionate about something else – science, art, whatever – by all means, follow your passion. If, like most kids, you do not know what to do, strongly consider going into Wall Street. No matter what you do there, whether as an executive, programmer, or even a secretary, your income will be about double as that of your colleagues in other industries. Go to work where the money is. Today I would add to that advice: get into the hot new area, additive manufacturing.

Talk to your kids about AM, show them some videos. Consider getting them a 3D printer, and play with it yourself. Even if your kids are in grad school, studying a specialty such biology or

law, this may open their eyes to a hot growing field. The people who became successful in computers were those who got into them early, tinkering with clunky early machines. The early bird gets the worm – and a great deal more.

The road ahead

Additive manufacturing will change our lives, and we should get ready for it now, before the revolution gathers full speed. We can begin preparing our businesses for it and draw a list of stocks that may enable us to profit from this revolution.

I definitely plan to keep updating this e-book, as the field of AM expands. I will continue to draw your attention to new investing ideas as new stocks get listed and some older companies become heavily involved in AM. If you bought this e-book from elder.com, we'll be automatically sending you updates at no charge. If you bought it elsewhere, please send us your proof of purchase, and we'll add you to the free update list. Please recommend this e-book to your friends, but take the high road and don't commit piracy – just give your friends a link to where they can buy it and also get on our update list.

Thank you for joining me on this journey. I wish you success and look forward to writing to you again in the months ahead.

Dr. Alexander Elder

New York City

April, 2013

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Sources

Elder, Dr. Alexander. *Come into My Trading Room*. New York, NY: John Wiley & Sons, 2002

Elder, Dr. Alexander. *Rubbles to Dollars*. New York, NY: Prentice Hall, 1998

Elder, Dr. Alexander. *To Trade or Not to Trade: A Beginner's Guide*. elder.com, 2011

Mackay, Charles. *Extraordinary Popular Delusions and the Madness of Crowds*. New York, NY: John Wiley & Sons, 1998

McGregor, Neil. *History of the World in 100 Objects*. (BBC podcasts and a Viking book), 2011

In addition to the regular book sources, I dipped into a multitude of **online resources**. These include but are not limited to the following:

[Angerman Communications Group](#) daily posts – a must for anyone in the AM field

[Rapid Ready Technology](#) posts

[Seeking Alpha](#) posts

[T. Rowe Price](#) series of articles

[Wikipedia](#) various articles

If you feel we've either overlooked or misquoted you, please [contact us](#) for an immediate response.

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Thank you

This is the most pleasant part of writing a book – saying thanks to friends who helped me.

Alexander Petrochenkov was among the first to recognize the value of AM; he became a volunteer research associate, sending me useful links. Brian Guptill gave me the first inside look into AM and invited Zach (Hoeken) Smith of MakerBot to meet me. Colin Nicholson participated in that meeting and sent me a lengthy email on the fundamentals of investing in new technology, which became a chapter in this book. Patricia Liu, CFA reviewed the fundamental information for listed companies in this book.

My friend and partner in SpikeTrade, Kerry Lovvorn, supported AM publications in SpikeTrade.com and offered sensible advice. He helped design the cover of this e-book together with Luke Lewis. As always, Carol Keegan Kayne performed the final edit, making sure this book was up to her sky-high standards.

Thanks to many friends and readers who share my enthusiasm about AM and keep sending useful links. Thank you for buying this book!

Dr. Alexander Elder
New York, April 2013

About the author

Dr. Alexander Elder is a professional trader based in New York City. He is the author of 14 books, including *Trading for a Living* (1993) and *Come into My Trading Room* (Barron's 2002 Book of the Year), considered modern classics among traders.

Dr. Elder was born in Leningrad and grew up in Estonia, where he entered medical school at the age of 16. At 23, while working as a ship's doctor, he jumped a Soviet ship in Africa and received political asylum in the United States. He worked as a psychiatrist in New York City and taught at Columbia University. His experience as a psychiatrist provides him with unique insight into the psychology of trading. Dr. Elder's books, articles, and software reviews have established him as one of today's leading experts on trading.

Dr. Elder is the originator of Traders' Camps—week-long classes for traders. He is the founder of the [Spike group](#) whose members compete for best stock picks of each week. He continues to trade and is a sought-after speaker at conferences in the US and abroad.

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