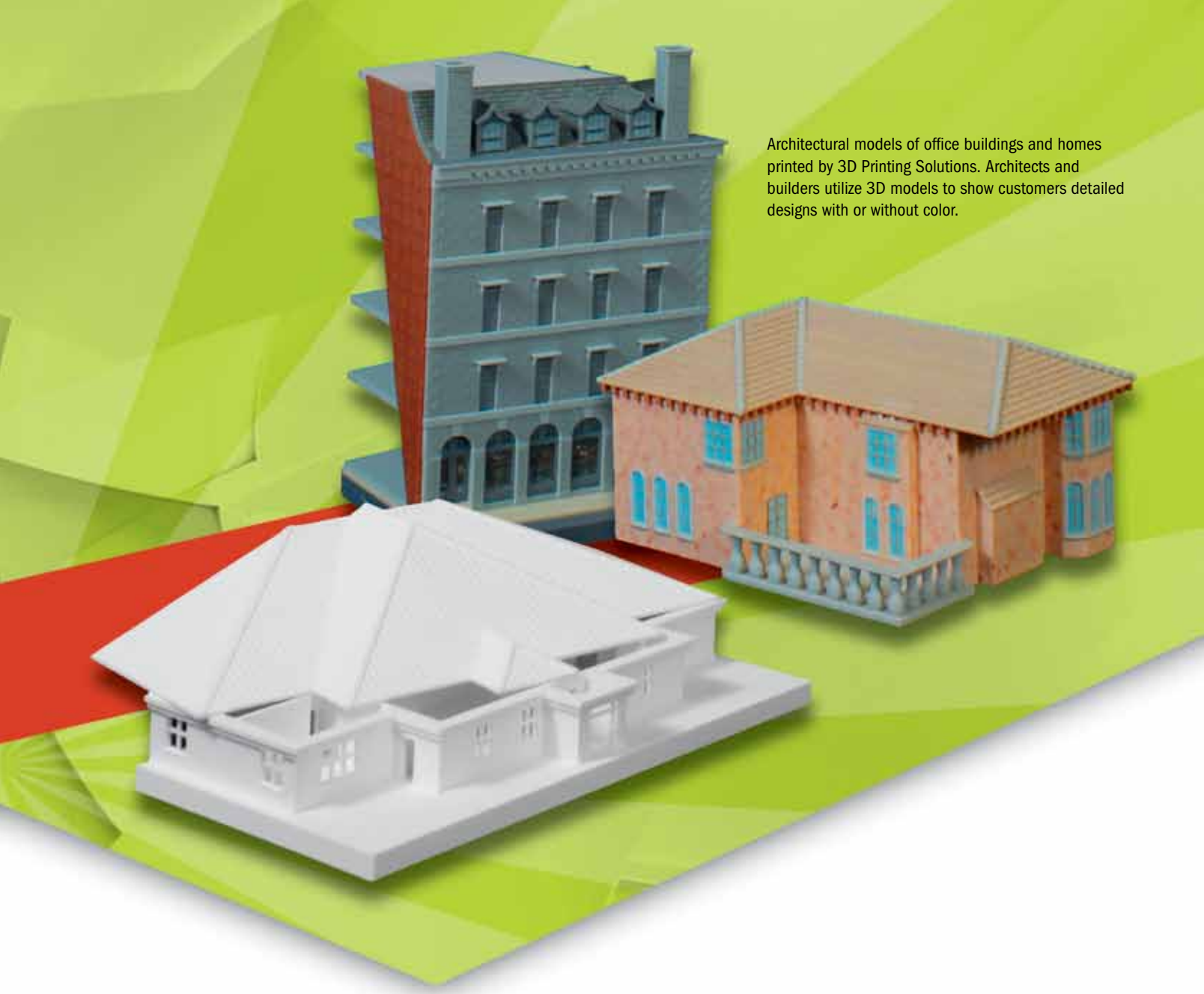
3D IS MORE THAN TV

Prototyping for the 21st CENTURY

By Greg Varhaug



Architectural models of office buildings and homes printed by 3D Printing Solutions. Architects and builders utilize 3D models to show customers detailed designs with or without color.

If you've never seen 3D printing before, prepare to be amazed! You can now buy a machine the size of an office copier that will "print" a three-dimensional object—not an image on paper, but an object created out of plastic or metal that you can hold in your hand. In fact, a wide range of materials have been adapted for use with this cutting-edge fabrication technology.

It's not a new idea. Your ink-jet printer creates an image by placing a single layer of ink on top of a piece of paper. What if you could use print heads to apply materials other than ink? And what if a print head could keep stacking successive layers of material until they were, say, an inch tall? Stacking solid material in successive layers is the basic idea behind 3D printing.

A Bit of History

For more than two decades, the 3D printing concept has been used to mass-produce computer chips. Chip making also employs other processes like photo-lithography and etching. But chips are built from the bottom up, using print-head technology to precisely distribute the base materials in extremely thin layers.

The latest group of high-end, commercial 3D printers is office-friendly: clean, quiet, and easy to use. And now prices have dropped to the point that they're within reach of small engineering groups and individual designers.

You can buy a very simple, entry-level 3D printer, like MakerBot's The Thing-o-matic, for as little as $1,100 unassembled. (You may have to wait, however, as they're often sold out.) Thing-o-matic can only produce small objects, about 5x5 inches. It can print in metals, so it's become a hit with jewelry makers, who use it to print rings and charms with moving parts.

HP entered the 3D printer market in 2010. Their 3D printers are not to be confused with other, older HP printers that simulate 3D on paper. And don't confuse "3D printing" with "3D plotting," which refers to something else entirely. You can expect other companies to enter the 3D printer market in the next few years, especially if sales of machines like the Thing-o-matic continue at their current rate.

ZCorp (now 3D Printing Systems) is the leading manufacturer of 3D printers for professional applications. They introduced their first line of 3D printers in 1996. ZCorp offers a line

TOP: A 3D printing machine prints solid physical models at 3D Printing Solutions. 3D models are created for classroom training of workers for the oil industry.

BOTTOM: Jeff Purvis and Homer Stewart with Subsea Solutions work with the 3D models in class-room training as well as on the oil rig.

UPPER RIGHT: Barry Calnan with 3D Printing Solutions shows a cross-sectional sample of a Ram BOP Lock, a model used in training among many other components displayed in the background.

of machines that print in full color, with up to a 1,200-cubic-inch print volume, which allows the creation of objects up to 15 inches tall.

For its 150-650 line, ZCorp uses a powder that combines with a binder to produce a hard, plaster-like substance. A vacuum line loads powder into the machine from an air-tight container. The binding agent and colored toners are each packaged in separate cartridges that plug directly into the machine.

The Printing Process

The print process starts off with a clean surface. Print heads apply a single, precisely controlled layer of powder over the entire print surface. Some of this layer is loose powder not used to form the actual object. The loose powder is recovered later and can be reused. The rest of the layer contains powder combined with the binder to create the bottom layer of the object being printed.

After the first layer is applied, the platform holding the printing surface is lowered (relative to the print heads) by an infinitesimal distance, just enough so the machine is ready to apply the next layer of material. The object being printed is built up this way, in successive vertical layers.

The powder that doesn't mix with the binder is necessary because it acts as a temporary spacer. The loose powder acts to secure the object and hold it in place while it's being printed.

This is what makes it possible to print objects with moving parts, like a functioning crescent wrench, or two rings separated by ball bearings. The loose powder keeps the bearings in place while the object is being printed. When the loose powder is removed, the bearings and the inner ring are free to move.

Other machines can print in metals. Different machines use different methods. The Thing-o-matic uses a precision, servo-extrusion mechanism to produce an object from metal powder. Thing-o-matic produces no excess powder and uses a special means to secure the object to the print tray while it's being printed.

Object has a 3D printing system called Connex that produces "digital materials." They define "digital materials" as "composite materials with pre-determined mechanical properties." Object's Connex system "can create as many as 51 different Digital Materials™ based on various combinations of Object's existing material families." Finished pieces "can be printed with up to 14 materials in one build process."

Applications

At present, the main applications for 3D printing involve rapid prototyping. Digital milling and cutting machines, like those from Roland Corp, have been the traditional mainstays for rapid prototyping based on subtractive—that is, cutting—processes. But 3D printing is an additive process and can create things that no subtractive process can.

Prototyping versus final products – The finished products that emerge from 3D printers are often used for models, prototypes, and positives for creating molds and dyes (including risers). These are things that represent other things, or things that are used to create other things. But 3D printers are also used to create usable, even functional, finished objects. There are, after all, a wide variety of materials in use, although each machine is limited to using only the materials it's designed for. Terry Wohlers, of Wohlers Associates, recently estimated that 20 percent of the output of 3D printers is finished product, as opposed to models and prototypes. He expects that percentage to increase in the coming years.

The plaster substance from the ZCorp machines can be used for limited runs of low-pressure injection molding, using plastics with low melting temperatures. The molds wear out quickly, but the cost to print each copy of a mold (from a digital file) is low. ZCorp now offers a machine that competes with the Thing-o-matic in an attempt to make 3D printing technology more widely available to schools and hobbyists.

How do you tell the printer what to print? If you're copying an object that already exists, the printer works from a digital scan of the object. If you want to print a new object, something that doesn't yet exist, you can create the plans for your object using standard CAD software or Google Sketchup, which is free online.

ZCorp also makes a hand-held scanner designed to work with their line of 3D printers. You essentially wave the scanner in front of the object you're scanning. Compared to other scanners, calibrating units and setting apertures is easy.

Impacts on the Oil & Gas Industry

Beyond prototyping – Subsea Solutions is a Houston well-control equipment-survey company that uses 3D printers to create visual aids for use in its certification classes. They train the people who inspect blowout preventers on offshore rigs, as well as other equipment.

Stan Bugara is the president of Subsea Solutions. 3d-Printing Solutions is a subsidiary of Subsea Solutions and a reseller for ZCorp 3D printers. Why did a well-control company branch out into selling 3D printers? Years ago, Bugara was approached by an oil company about creating a training program for its employees. Bugara started with animated PowerPoint presentations that demonstrated the assembly of large oil-well components. His animations depicted these components in exposed cross-sections.

Then he learned that it was possible to 3D print scaled-down versions of the pieces he had drawn. Bugara remembers, "As soon as I saw the potential, a light bulb went off. I can

MIT's Fab Labs:

Creating a New World of Smart Materials

3D printing technology was developed and licensed by a professor from MIT, Dr. Charles Hull. MIT's Center for Bits and Atoms (CBA) is the site of some of the world's most advanced fabrication-technologies research. The technologies under development there span the range from nano-scale to building-scale.

Sherry Lassiter is CBA's program manager. She describes CBA as "the marriage of computer science and physical science, where bits meet atoms." Her description of what they do starts off simply enough: "Looking for better and more efficient computer models."

But some of CBA's other projects give a sense of just how different the world of tomorrow will look. One of their more futuristic projects is creating "smart materials." CBA is discovering "how to make things with logic embedded in the materials."

Lassiter explains, "We are used to the idea of smart devices. Now we are looking at the prospect of 'smart materials,' which are essentially programmable, and borrow ideas from the mechanics behind DNA." Protein is an example of a material that is itself the code for making more of the same material. CBA researchers are borrowing from the mechanics of DNA to create materials capable of self-organizing.

MIT professor Neil Gershenfeld describes extremely small, Lego-like pieces that fit together in a precise way, so that they automatically self-correct for errors in construction. These pieces are wrapped in conductive materials and include small electronic components. These pieces can then organize themselves into larger structures. Some will assemble themselves into resistors, others into capacitors; others will become processors. These aren't just theories. CBA has developed materials that can be programmed to construct themselves, then later deconstruct themselves and reconstruct themselves into something else.

Gershenfeld talks about "building buildings not by having blueprints but by having the parts code for the structure of the building."

But CBA is generating the most attention for its innovative Fab Labs, a group of 50 workshops worldwide that combine some of the most advanced fabrication tools available. The Fab Lab idea grew out of a course offered at MIT called "How to Make Almost Anything."

Prices for these tools have dropped dramatically in the past few years. These tools include computers with design software, scanning and x-ray equipment, a lathe, a water jet, a vinyl cutter, laser cutters, 3D printers, a five-axis digital milling machine, and a sewing machine. A facility that would have cost over $200,000 only a few years ago costs just $20,000 to $50,000 now. Students at MIT are even designing and building 3D printers and 3D scanners from scratch, using commercially available parts.

3D printing is just one additive fabrication method. Other additive fabrication methods use lasers and electron beams to melt and shape metals, as with laser sintering.

Lassiter believes these innovations will eventually make current manufacturing methods obsolete and create the need to retrain manufacturing workers worldwide. N

take this big piece of equipment from a rig, miniaturize it, and three-quarter it so you can see inside."

He created a line of color-coded models that his trainees could physically hold, take apart, view from any angle, and put back together. The impact this strategy had on the presentation was immediate: the trainees were noticeably more engaged.

Subsea Solutions' approach to training now integrates auditory, visual, and tactile senses. The firm has two on-site 12-person training rooms, one of which contains a 20-foot Cyviz projection screen.

The company started with a standard two-day course, but it has added more specialized courses, including a course in reading schematics. Bugara states, "We've got a whole plethora of courses that we plan on doing."

Subsea Solutions now makes copies of its models so that its clients on the rigs can use them as a reference. "Now when the engineers video-conference each other, they each have a model on their desk," says Bugara.

Subsea Solutions contracted Barry Calnan to help create its first round of 3D models. Calnan, a former Halliburton engineer, was already selling ZCorp 3D printers and was well-versed in 3D printing technology. When Subsea Solutions later purchased its own 3D printer, it brought Calnan on board to run its 3D printing operation.

Calnan explains, "If you are an inventor, it is really difficult to get something of yours created without spending a fortune. A couple of years after leaving Halliburton, I had an idea. I was able to rapid-prototype it and bring it to the lawyers to help them write the patent." The ability to create a model of his invention proved to be invaluable. "If you can hand it to a lawyer (with an engineering background) and explain it to them in a few minutes and they're charging $400 an hour, as an independent, you've just saved yourself a lot of time and money."

Spreading the word – It's hard to believe that when Xerox introduced the first copying machines, there was almost no demand for them. We already had typing pools, mimeographs, and offset printers. Why did we need copying machines? But businesses quickly embraced them and grew to depend on the technology.

Harder to believe, the same thing

Skull model printed by 3D Printing Solutions.

was true for computers, on which we now depend completely. The point is, no one in the business world was waiting for these inventions to come along.

3D printing is different. We've been dreaming about automated replication technologies since *Star Trek*. At MIT, automated replication is being studied in earnest and is no longer just theory.

3D printing is a technology that immediately fires the imagination. Artists and hobbyists are embracing it now that the cost is down, and its cache is high.

Huge Benefits to Healthcare Industry

Potential new markets are everywhere. One is in bio-tech. ZCorp's plaster can be treated with wax to create a substance that feels enough like real bone that surgeons use it to create full-scale models so they can practice their procedures before an actual operation.

Barry Calnan points out that doctors aren't currently free to take advantage of this technology because insurance doesn't usually provide for it. But that is beginning to change. Insurance now covers some modeling. Detailed medical imaging is already common, and scanning is half the work in 3D modeling. Calnan says that hospitals and insurers are beginning to understand the potential cost savings and improved patient outcomes that this technology can provide.

3D modeling also allows surgeons to perform virtual plastic surgery: patients can see what a new nose or chin will look like after surgery, in three dimensions.

And researchers have just developed a new bone-substitute material for making prosthetics and replacement joints. One day soon, they will scan your knee or hip and print your replacement joint the same day. Within 20 years, organ printing may allow for the creation of new kidneys and livers while you wait.

Technology Advances to Crime Scenes

Attorneys are now using 3D-printing technology to create dioramas of crime and accident scenes. Because these dioramas are scale-accurate, they allow you to take photos that demonstrate the exact line of sight at a given location. This simple matter is often key to winning accident cases.

3D-printing technology opens the door to transformative future possibilities. From the art world to the energy industry, from healthcare to law enforcement, the technology is redrawing the parameters of the possible. N

Greg Varhaug has written software instruction manuals and procedural manuals for many Houston companies. He operates HoustonGuitar.com, a commercial music-instruction website.