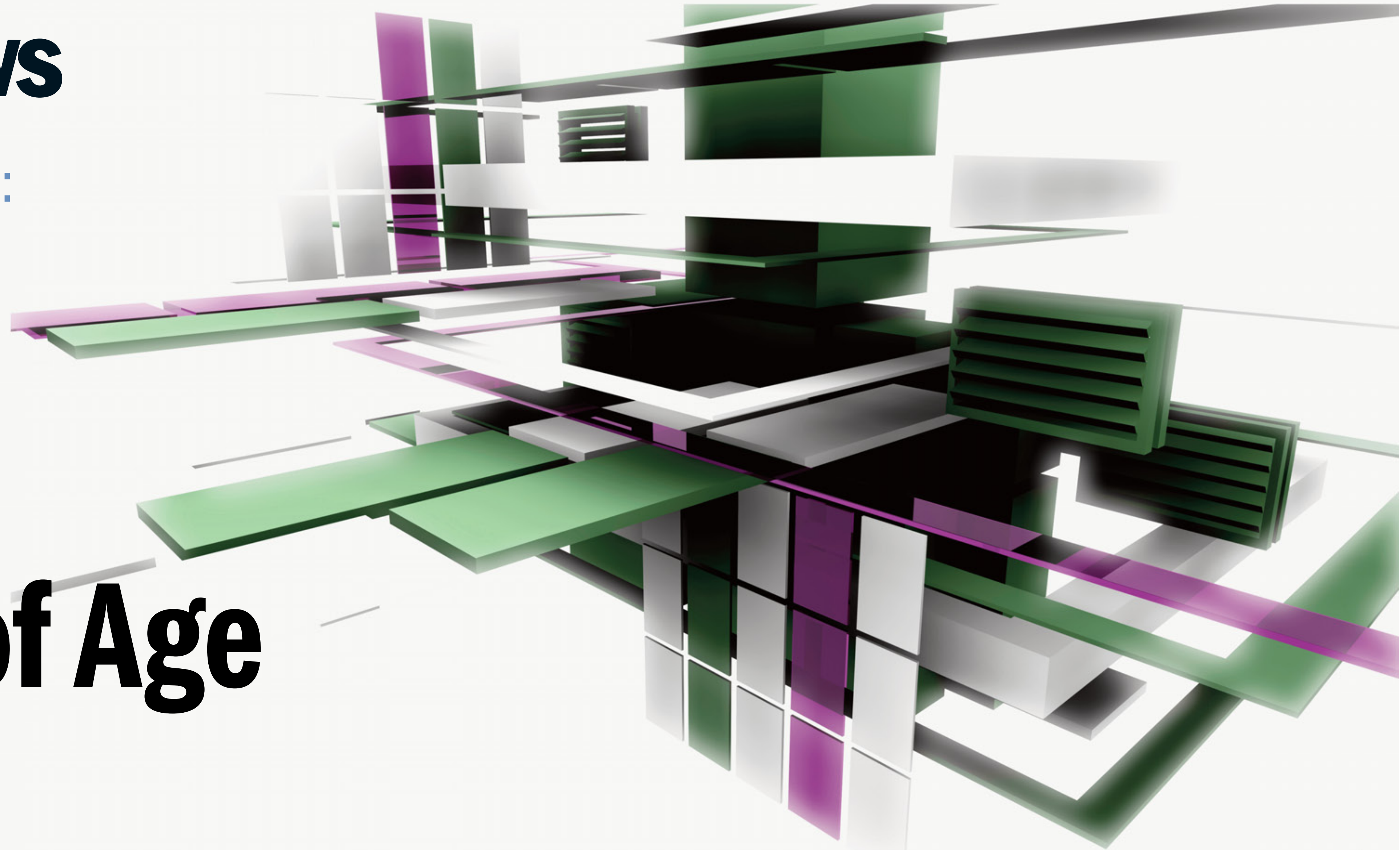
DesignNews

Technology Roundup:

3D Printing Comes of Age



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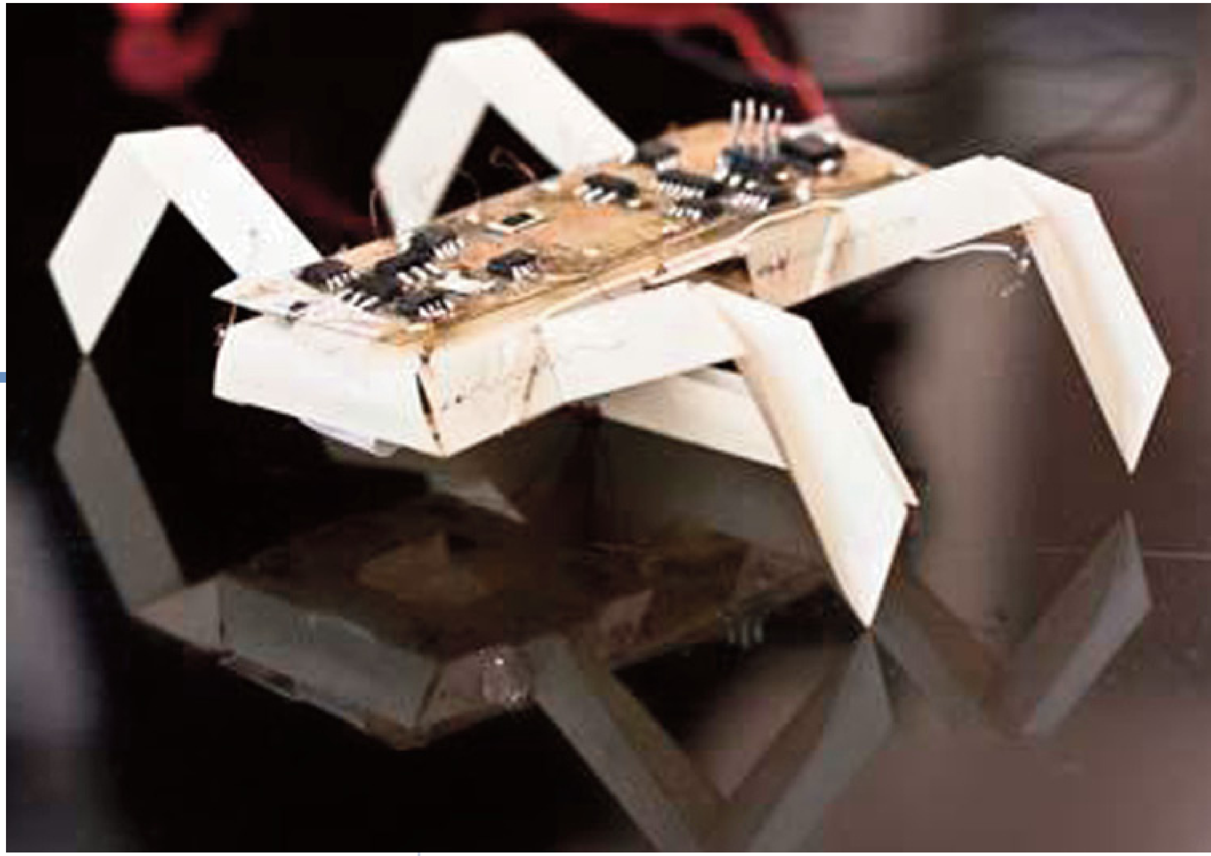
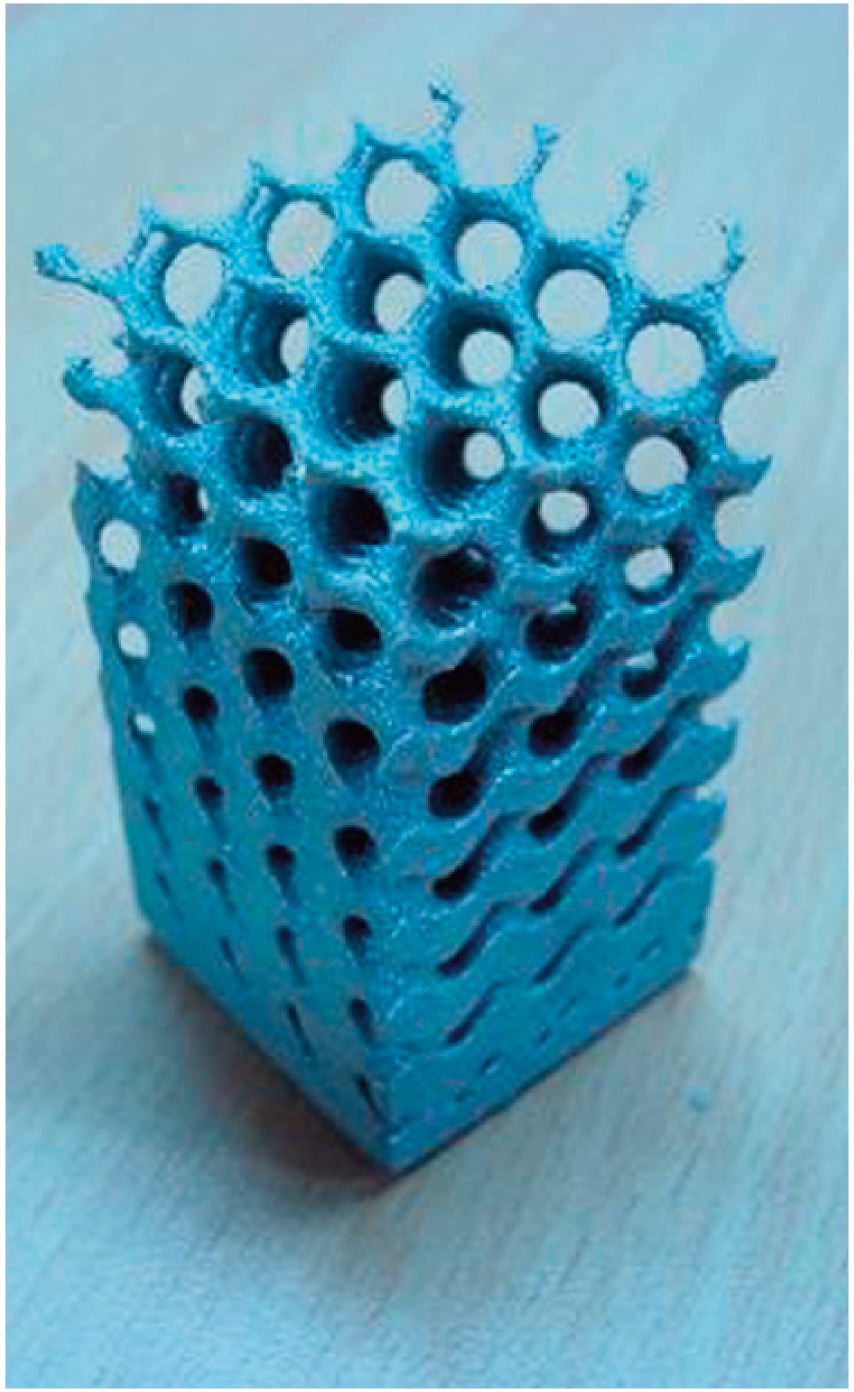


3D Composites Can Make Parts Cheaper

Ann R. Thryft, Senior Technical Editor, Materials & Assembly

Engineers at the University of Exeter have devised a new method for making aircraft and automotive components for short money using additive manufacturing techniques (a frequent topic on our site) and aluminum powders.

Three-dimensional aluminum metal matrix composite components are made by mixing a combination of relatively inexpensive powders to cause a reaction and rapid solidification. This productes particles as small as 50nm to 100nm that are distributed uniformly throughout the composite and strengthen it. A reactive reinforcing material, such as iron oxide, also contributes to the compos-



A metal part made with a complex internal structure demonstrates the University of Exeter's selective laser melting 3D production technology.

Source: University of Exeter

ite's strength.

Liang Hao, a lecturer at the University of Exeter's College of Engineering, Mathematics, and Physical Sciences, and Sasan Dadbakhsh, a doctoral candidate there, developed the technique in the university's Centre for Additive Layer Manufacturing. They say the material and the manufacturing method can produce lightweight parts such as pistons, drive shafts, suspension components, and brake discs for cars and airplanes.

The process can also produce parts with more complex geometries that can reduce structural weight. Such parts can be difficult or expensive to manufacture with traditional methods such as casting and mechanical alloying, rather than the laser sintering method made possible by mixing metal powders.

The researchers have dubbed the new additive manufacturing method selective laser melting. They say the laser technique for melting the powder mix is cheaper and more sustainable than other methods that form composites by blending fine powders directly. Making parts with laser-sintered powders can help save materials, energy, and cost when producing products in small volumes, including single copies, the researchers say.

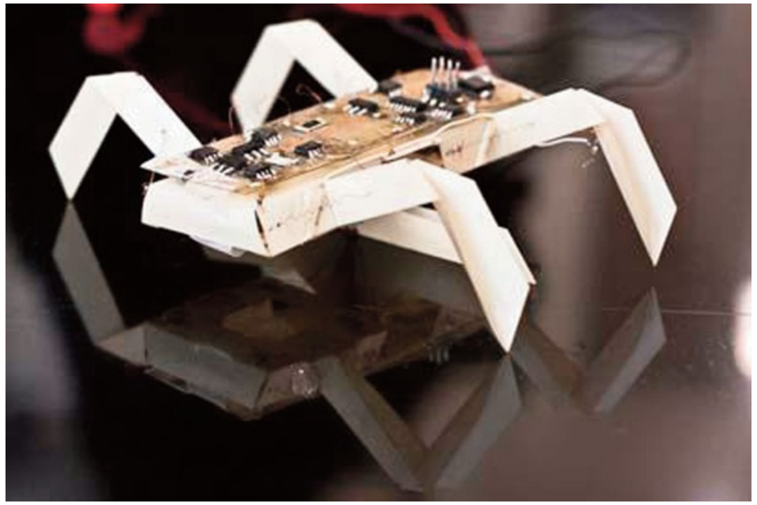
The team has published its findings in the Journal of Alloys and Compounds. An arti-

3D Printable Robots Get NSF Research Funding

Ann R. Thryft, Senior Technical Editor, Materials & Assembly

A research program that aims to let consumers produce their own customized robots with 3D printers and paper hopes to create a platform that allows people to identify household problems that can be solved by a robot, select a blueprint from a library of designs at a local printing store, customize a robotic device that can solve the problem, and then produce a fully assembled, fully programmed robot within 24 hours.

With funding from the National Science Foundation (NSF) to the tune of a $10 million grant, a team of experts from several leading robotics labs will participate in the five-year project, called "An Expedition in Computing for Compiling Printable Programmable Machines." The project is part of



An insect-like robot designed and 3D printed with common materials such as paper could be used for exploring areas inaccessible to, or too dangerous for, humans.

Source: Jason Dorfman, CSAIL/MIT

the NSF's "Expeditions in Computing" program, and will be led by MIT professor Daniela Rus, a principal investigator at MIT's Computer Science and Artificial Intelligence Lab (CSAIL). CSAIL is the same lab that came up with the 3D navigating robot.

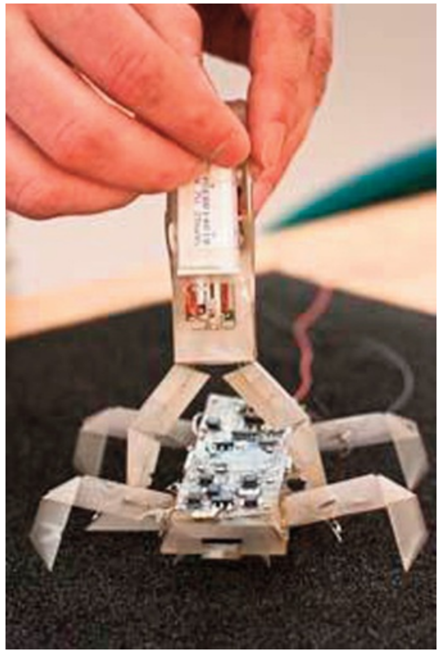
So far, the researchers have prototyped two machines that could be designed, printed, and programmed with a 3D printer. These are an insect-like robot that could explore contaminated or inaccessible areas, and a gripping device for people with limited mobility. All of these efforts are designed to help speed and simplify the labor of developers in industry and university researchers working on new design platforms. The project targets faster and cheaper design and manufacturing by developing a desktop technology that lets the average person design, customize, and print a specialized robot in a few hours.

Professor Vijay Kumar, who is leading the team from the University of Pennsylvania, is also the head of the General Robotics, Automation, Sensing, and Perception (GRASP) Laboratory there, which is responsible for the tiny flying, swarming robots we reported on recently. His team in the NSF project will include Andre DeHon, Sanjeev Khanna, and Insup Lee.

Now, the programming, design, and production of a functional robot takes several years, is extremely expensive, and involves multiple disciplines, such as hardware and software design, advanced programming technique, and machine learning and vision. The research team's goal in the new project is to automate the process of producing functional 3D objects. Interestingly, the other major goal is to let ordinary people design and build fully functioning robots from everyday materi-

A robotic gripper 3D printed with easily accessible materials could be used by people with limited mobility.

Source: Jason Dorfman, CSAIL/MIT



als like sheets of paper, not an entirely new idea in 3D printing.

"Our vision is to develop an end-to-end process; specifically, a compiler for building physical machines that starts with a high level of specification of function, and delivers a programmable machine for that function using simple printing processes," said Rus in a press release. "We believe that [this research] has the potential to transform manufacturing and to democratize access to robots."

Researchers' topics of interest are focused on a number of areas, including developing an application programming interface (API) for function specification and design, writing algorithms to control assembly and operation of a device, creating an easy-to-use programming language environment, and designing new, programmable materials for automatically fabricating robots.

In addition to Rus, other members of the CSAIL team include Martin Demaine, Wojciech Matusik, Martin Rinard, and Sangbae Kim of MIT's department of mechanical engineering. The NSF project team also includes Harvard University's associate professor Rob Wood. ■

Medical Apps Prescribed a Healthy Dose of 3D Printing

By Beth Stackpole,
Contributing Editor, Design Hardware & Software

There's been a lot of recent advances in 3D printing, but the technology has long enjoyed a niche in medical and dental applications.

For years, dental labs have leveraged CAD and 3D printing technologies to improve the quality and precision of dental parts such as crowns, bridges, and a range of orthodontic appliances. New materials like Objet's biocompatible transparent offering and 3D Systems' Accura e-Stone are opening up new possibilities and bringing down costs. On the heels of this success, medical providers are following suit, diving into the exploration of 3D print technologies for producing everything from custom prosthetics to hearing aids.

There's even research at play to push 3D printing technology into novel areas. For example, researchers are exploring ways to use 3D printers to create human organs and tissues and serve as home dispensers for outputting drug prescriptions.

A New Mindset in Product Design

3D printing can help bring better products to market faster

By Stratasys Inc.

What is 3D printing?

The terms "3D printing" and "additive manufacturing" refer to processes that automatically build objects layer by layer from computer data. The technology is already well-used in many sectors including transportation, health care, military and education. Uses include building concept models, functional prototypes, factory tooling (such as molds and robot-arm ends), and even finished goods (such as aircraft internal components). The aerospace and medical industries in particular have developed advanced applications for 3D printing. 3D printing is sometimes referred to as "rapid prototyping," but this term does not encompass all current uses for the technology. Materials used in 3D printing include resins, plastics and, in some cases, metal.

The earliest method, stereolithography, has been around since the late 1980s, but adoption was limited because of the toxic chemi-

cals it required and the fragility of its models. Other technologies have evolved since then, including Fused Deposition Modeling (FDM®). FDM, introduced in the early 1990s, lays down super-thin layers of production-grade thermoplastic, yielding comparatively durable models.

Since 3D printing's inception, system reliability and model quality have increased, resulting in diverse applications. At the same time, prices have gone down to the point where some systems are affordable even for small businesses. In a 2011 report, Wohlers Associates predicted that worldwide annual sales of additive manufacturing systems will reach 15,000 units by 2015 — more than double the 2010 rate. Lower-priced professional systems will drive most of this growth.[1]

3D-printed models are shown with soluble support material (brown) intact, and after removal.

In FDM TechnologyTM, printer software on the user's Windows network or workstation accepts computer-aided design (CAD) data in .stl format. The software works like a paper printer's driver, sending data to the 3D printer as a job and telling the print head where to lay down material.

Filaments of plastic modeling material and soluble support material are heated to a semi-liquid state, forced through an extrusion tip and precisely deposited in extremely fine layers. (FDM layer thickness ranges from 0.005 inch [.127 mm] to 0.013 inch [.330 mm], depending on the system.) The print head moves in X-Y coordinates, and the modeling base moves down the Z axis as the model and its support material are built from the bottom up.

The soluble support material (brown in the example photo on this page) holds up overhanging portions while the model is being built, and allows for complex models — even nested structures and multipart assemblies with moving parts — to be 3D printed. When the print job is complete, the support material washes away and the model is ready to be used or, if desired, finished with paint or another process.

Some 3D printers are small enough and clean enough to function as office equipment inside a department or even an individual cubicle. By comparison, large rapid prototyping systems often must be centrally located and run by a dedicated staff of experts. The very cheapest class of 3D printers comprises home-use devices now on the market for hobbyists. While fascinating for enthusiasts, these machines differ from small professional systems in that the resulting models often have poor resolution, are dimensionally inaccurate and unstable, and lack durability.

Trends toward affordability and ease of use are bringing professional 3D printing technology in-house for many designers and engineers. The growing expectation that a CAD drawing can become a real three-dimensional object in a matter of hours is altering how companies see the design process. It can be faster, more effective, and less costly.

Using 3D printing to accelerate design

The longer a product stays in the design cycle, the longer it takes to get to market, meaning less potential profit for the company. Time-to-market considerations were identified as the most critical daily issue facing respondents of a 2008 Product Design & Development readership poll. This group also said prototyping itself presented a time-to-market obstacle in 17 percent of product launches.[2]

With increasing pressure to get products to market quickly, companies are compelled to make quick yet accurate decisions during the conceptual stage of design. These decisions can affect the majority of total cost factors by establishing material selection, manufacturing techniques and design longevity. 3D printing can optimize design processes for greatest potential profit by speeding iterations through product testing.

Time saved prototyping with in-house 3D printing vs. other methods

Industry	Old Method	Time savings
Industrial design	Clay models	96%
Education	Outsourced machining	87%
Aerospace	2D laser cutting	75%
Automotive	Aluminum tooling	67%
Aerospace	Injection molding and CNC tooling	43%

Each example is based on a real customer experience.[4]

For example, Graco Inc. makes paint spraying and texturing equipment for professional use. Its engineers used a 3D printer to experiment with various paint gun and nozzle combinations to create the perfect spray pattern and volume. The resulting new spray-texture gun was based on functional prototypes 3D printed in ABS plastic. Graco estimates that 3D printing helped reduce development time by as much as 75 percent.

The journey from brilliant idea to successful product is fraught with hurdles. Analysis of new product development by Greg Stevens and James Burley in their oft-cited study “3,000 Raw Ideas = 1 Commercial Success” found that in addition to 3,000 raw ideas, a single successful innovation also requires 125 small projects, four major developments and 1.7 product launches.[3] 3D printing capabilities can speed the process by which companies determine whether concepts are worthy of development resources.

While outsourcing 3D printing might result in models equal in quality to those 3D printed in-house, the Graco example illustrates the benefits of investing in your own machine. A highly iterative process can only happen in a feasible time frame when engineers can see quick feedback on design changes. In-house 3D printing eliminates shipping delays and reduces administrative slowdowns that can accompany sourcing prototypes from external services. With some systems now available to lease, businesses might find that as few as one in-house model per month justifies the cost of a printer versus money spent outsourcing.

More effective design through 3D printing

3D printing can increase the chances of a successful product launch by enabling more thorough design evaluations and a more iterative process.

At Henk and I, an industrial design firm in Johannesburg, South Africa, designers created and extensively tested a new kind of pool-cleaner motor that works well with low-flow, energy-saving filters. The high-torque design was the result of an iterative refinement process using the office 3D printer. In the functional testing stage, 30 3D-printed prototypes cleaned pools in various regions worldwide. The result was a new pool cleaner model, the MX 8, for the firm's client, Zodiac. According to Henk van der Meijden of Henk and I, the motor innovation would have been impossible without 3D printing.

Successful product design requires review and input from many sources. With in-house 3D printers, design teams can review concepts earlier with others who may provide feedback. Fast collaboration with engineering, marketing and quality assurance can empower designers to make adjustments throughout the design process and follow-up testing.

Faster turnaround is the only way to enable iterative discovery without lengthening the design process. 3D printing users in aerospace, automotive, industrial design and education have reported improvements of 43 to 96 percent in prototyping speed when switching from traditional methods to 3D printing.[4] Traditional prototyping methods include injection molding, CNC machining, metal machining and 2D laser cutting. In some cases, lead time required by a machine shop had been a major factor in slowing prototype creation.

As the trend toward affordable 3D printing continues to result in more decentralized machines, for example in

At Acist Medical Systems, medical-device designers test ideas with 3D-printed prototypes and low quantities of end-use parts.

departments or individual cubicles, opportunities to speed the design cycle are multiplying.

An optimized design process with more prototype iterations can help minimize risk of product failure. Because 3D printers can produce models with fine feature details and the strength to withstand rigorous testing, designers can be more confident in their work. Additionally, data integrity and security is paramount in a competitive environment. While sharing confidential STL files with trusted vendors is generally safe, having a 3D printer in-house removes any worry that might stem from sending intellectual property offsite.

Making needed changes as early as possible saves money and time. 3D-printed models can give designers and engineers a thorough understanding of potential products earlier in the design process than other methods, minimizing the risk that problems will go unnoticed until it's too late.

Acist Medical Systems designs and manufactures contrast-injection devices for cardiologists and radiologists. The company uses 3D printed parts in functional testing, fixtures and end-use parts. In complex assemblies, Acist uses 3D printing to design plastic parts as efficiently as possible around machined parts, circuit boards and integrated circuits. In one display unit, Acist reduced part count from 15 to seven because of 3D printing's ability to help evaluate complex geometries. The company even tests functional 3D-printed units in customer settings, working out design problems and incorporating real customer feedback before committing to large-scale tooling.

Adopting 3D Printing to Reduce Product-Design Costs

The acquisition cost of a professional 3D printing system can be as little as $10,000 (USD), which may surprise engineers and designers who've priced larger 3D production systems. Annual operating costs are generally lower too, partly because 3D printers require no dedicated facility or special expertise to run. Leasing options can mitigate the cost barriers that may have restricted adoption of 3D printing technology in the past. Other costs to consider are printer maintenance and material costs, which vary depending on use. When evaluating 3D printing systems, consider facilities requirements; expertise needed to run the system; accuracy, durability and size of models; available materials; speed; and, of course, cost.

Your desired application will help you determine the best system for you, but keep in mind that many users report discovering diverse uses after acquiring a 3D printing system. For example, a system purchased for functional prototypes might prove useful for building manufacturing tools.

At Leptron, a developer of remotely piloted helicopters for law-enforcement, military and civilian use, engineers used a 3D printer to design, test and build a tiny surveillance drone. The RDASS 4 has eight modular fuselage components that can combine for various uses. Designing the complex drone and testing it to withstand crash landings required an iterative approach involving 200 design changes, including structural reinforcements and aerodynamic improvements. In-house 3D printing cut product-development costs for the RDASS 4 by 60 percent over injection molding. Further, the project may not have been commercially feasible without the 6-month head start that 3D printing offered in getting the drone to market.

3D printing provides a highly cost-efficient means of producing numerous design iterations and gaining immediate feedback throughout the critical beginning stages of the development process. The ability to refine form, fit and function quickly can significantly improve production costs and time to market. This can create a distinct competitive advantage for those companies who include 3D printing as an integral part of their design process.

Lower costs will continue to expand the 3D printing market, especially in small to medium-sized businesses and schools. The speed, consistency, accuracy and low cost of these printers will help companies reduce time-to-market and maintain a competitive edge. ■

1. Terry Wohlers, "Wohlers Report 2011: Additive manufacturing and 3D printing state of the industry" (Wohlers Associates, May 2011)
2. David Mantey, "Smaller, Cheaper, Faster" (Product Design & Development, June 2008)
3. James Burley and Greg Stevens, "3,000 Raw Ideas = 1 Commercial Success," (Research Technology Management, May-June 1997, 16-27)
4. Stratasys; "Bringing Imaginative Products to Market" (2011), "Rapid Learners" (2011), "Trial and Air" (2012), "3D Printing Wins Prototyping Time Trial" (2010), "Bird's Eye View" (2011)

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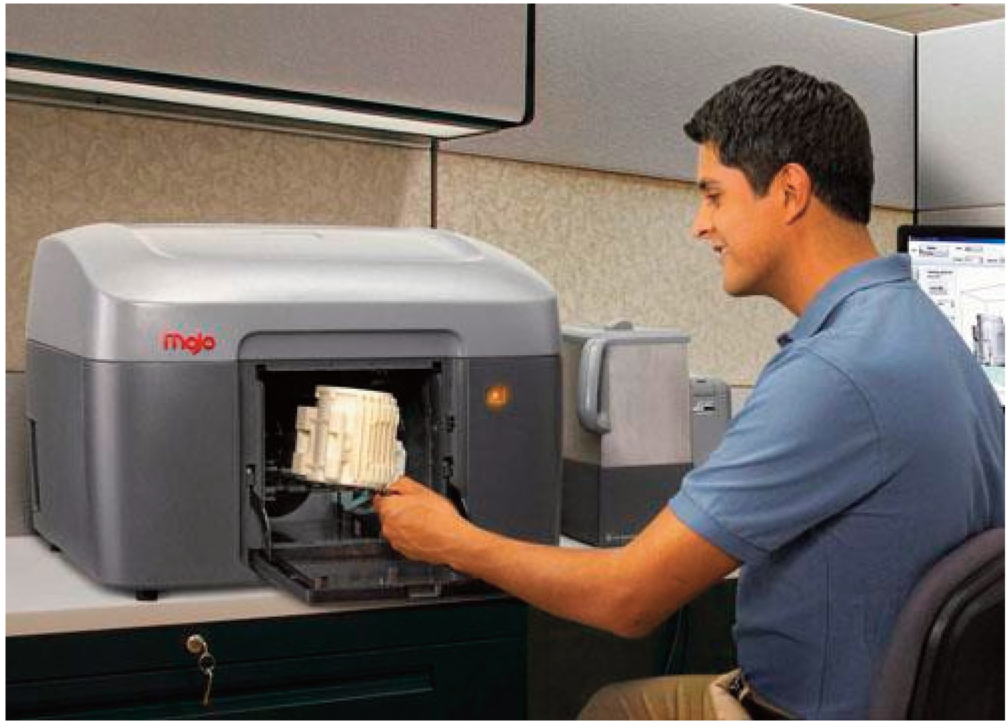
STRATASYS®

Stratasys Gets Mojo With Sub-$10K Printer

Beth Stackpole, Contributing Editor, Design Hardware & Software



The Mojo 3D Print Pack is Stratasys' first sub-$10,000 desktop, professional-grade 3D printer.
Source: Stratasys

Stratasys' Mojo 3D Print Pack, priced at $9,900, is packaged as a system providing everything needed to produce models, from the printer to the material, and a support removal system. The Mojo uses Stratasys' patented Fused Deposition Modeling (FDM) technology, and the firm is offering a leasing option, with payments as low as $185 a month, to get engineering shops on board.

In a video announcing the product (on page 15), Jon Cobb, Stratasys' global marketing vice president, said the "magic" of the Mojo is that, despite the low price point, it delivers genuine FDM technology, enabling teams or individuals to produce durable ABS models in a cube of up to five inches to test for form, fit, and function.

The message here is that the Mojo isn't intended for the consumer and hobbyist market, which has gotten a lot of attention as of late from 3D

printer players. Rather, this printer aims to appeal to the untapped universe of hardcore CAD and engineering users. As such, the printer's fast-build capabilities and its
capacity to print in fine detail with a layer thickness of 0.007 inches (0.178mm) are targeted at professional applications for concept prototyping, design collaboration, and even some rapid production of functional parts.

At 25 inches wide and 21 inches deep, the Mojo is about the size of a standard office multifunction printer. Its design, including easy-to-replace print cartridges, mimics that of a typical office printer in many ways, according to Cobb.

The QuickPack print engine is where the unit differs from Stratasys' other lower-priced offerings. The technology, a variation of traditional FDM material extrusion, integrates both the ABS material spool and the print head into a single package, so a fresh print head is part of each material change. This is meant to reduce potential problems. Other features designed to simplify the experience include the addition of Print Wizard, Mojo's preprocessing software for preparing models and managing workflow, and WaveWash 55, a self-contained, hands-free cleaning system that removes support material and requires no plumbing. ■

Prodrive Shifts 3D Printing Into High Gear

By Beth Stackpole, Contributing Editor, Design Hardware & Software

There's been talk lately about how new, low-cost 3D printers are fueling a consumer-driven wave of do-it-yourself innovation and personal manufacturing.

Yet despite all the focus on the accessibility of low-end 3D printer offerings, there's been some fairly significant advances in higher-end technology that are helping to transform how companies not only prototype products, but also produce commercial parts.

Prodrive, a leading motorsport company and the primary engine behind the design and engineering of the MINI John Cooper

Prodrive uses additive manufacturing to accelerate the development of the MINI John Cooper Works World Rally Car and to reduce production costs.
Source: Stratasys

Works World Rally Car, is one of the companies leveraging 3D printing advances to bring efficiencies to its development processes and optimize its car designs.

Prodrive has been using additive manufacturing or 3D printing technology for years, but primarily in a traditional way. For example, once a part design was frozen, engineers on the Rally car team would employ 3D printers to create a surrogate part to perform installation checks and to make some minor assessments. This was in lieu of the traditional design approach where engineers would take foam and wood and cobble together a prototype to evaluate the part design before moving on to the production stage.

With the MINI John Cooper Works World Rally Car (WRC) project, which was the first car from Prodrive in years to command a fresh-from-the-ground-up design, the team decided to experiment with a number of new design approaches. The first was designing the whole car as a digital model using PTC's Windchill PLM platform and CATIA, a CAD tool from Dassault Systemes.

"This was to be the first car that was designed as a unitary CAD layout and the first car to be designed in a single package," Doe told us. "In the past, people did their piece of the design in different packages and nothing was put together. Thanks to the introduction of better PLM technology, we could create a single virtual car model."

In addition to the single virtual model, the Prodrive team wanted to build a full physical mockup in parallel so it could spend time refining the areas that were most likely to cause problems.

That's where additive manufacturing came in. The team brought in a Stratasys Dimension 1200ES 3D printer, and, in phase one of its implementation, put it through its paces to test surrogate parts.

After a team member accidentally dropped a 3D printed gear box and it "bounced across the workshop" and didn't break, it became pretty clear that additive manufacturing technology could serve a much greater role, according to Doe. Specifically, the team moved into phase two of deployment, using the Dimension 3D printer to create some test parts that were actually fit onto the car to prove out the design prior to investing in expensive tooling.

"This allowed us to take more risk," Doe said. "It allowed us to prove out a concept by running a part for a couple of days and determining whether the performance was good enough to invest in tooling. We were able to go through a lot of iterations quickly and thus go through the development cycle much faster."

Eventually, during the course of the WRC's two-year development cycle, the Prodrive team was able to shift into phase three of its 3D printing deployment. Thanks to decreasing costs of 3D printers and the higher performance of available materials, the WRC team was able to deploy additive manufacturing technologies to create end-use parts for the finished car. Currently, Doe says more than 20 parts on the finished car are 3D-printed, including an ergonomically styled gearshift display and control panel which are mounted on the steering column.

Prodrive engineers employed 3D printing to create large parts of the engine bay, multiple display housings, the gearbox, and even some engine components.

Source: Stratasys

"3D printing has created opportunities to innovate that were previously considered a dead end without a significant investment in tooling, and has freed our team from the constraints that are applied when manufacturing by more traditional production methods," Doe said. "The simplicity of 3D printing combined with the relatively low-cost of materials make it the obvious choice for manufacturing parts." ■

Slideshow: The Fun Side of 3D Printing

By Beth Stackpole,
Contributing Editor, Design Hardware & Software

3D printing has been around for years and has nestled its way into lots of companies' product development processes as a more effective way to produce prototype products, test functional parts, and perhaps even pump out limited-run production parts.

Yet in addition to that so-called serious product development and engineering work, there's a significant number of less serious, but equally important, efforts underway. These are pushing the limits of 3D printing toward more consumer-friendly – even quirky, some might say – applications. We're talking 3D-printed chocolate, 3D-printed fabric and clothes, and even 3D-printed body parts. ■