DIMENSION WHITE PAPER

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dimension
3D Printers

Enhancing the Design Process with 3D Printing

The Gartner Inc. research firm estimates there will be 300,000 3D printers on the market by 2011, according to Business Week.[1]

3D Printing Comes of Age.

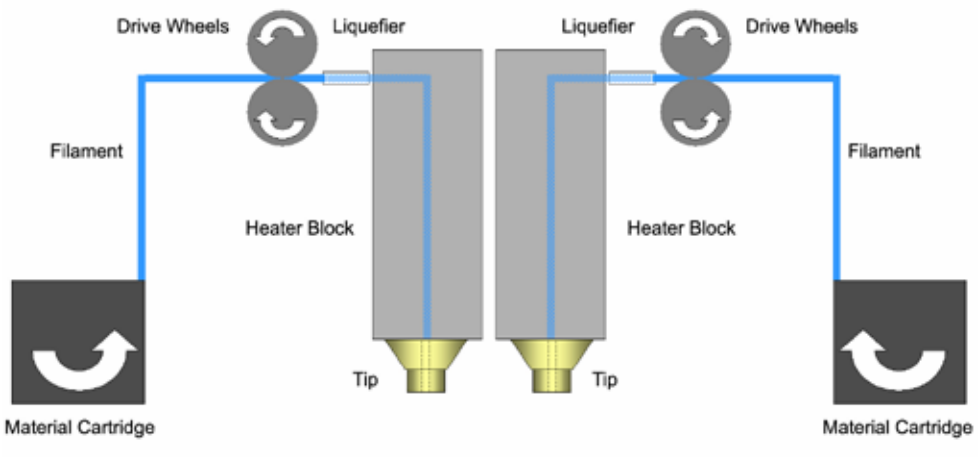
Affordable, quick and easy-to-use 3D printers are changing the face of product design and development, bringing this additive fabrication technology in-house for many designers and manufacturers. Thanks to simple software and advanced technology, it is now just a matter of hours for a computer-aided design (CAD) drawing to become a three-dimensional model.

The term 3D printer generally refers to a class of rapid prototyping systems that are smaller, easier to use and less expensive than average machines. The term 3D printing is often used as a synonym for rapid prototyping, and research data often combine the two. Although rapid prototyping has been around since the late 1980s, 3D printing was introduced in the early 1990s. Since then, quality has increased and prices have gone down, making this technology affordable for even small companies. The Gartner Inc. research firm estimates there will be 300,000 3D printers on the market by 2011, according to Business Week.[1] NextGen Research, in a study published in April, 2009, predicts 3D printing systems, services and materials will grow at a rate of nearly five percent to reach $782.6 million by 2013.[2]

How Does 3D Printing Differ from Rapid Prototyping?

Rapid prototyping refers to a broad category of processes used to build models layer by layer from computer-generated STL data. Two common forms of rapid prototyping are stereolithography (SLA) and selective laser sintering (SLS). By contrast, Dimension 3D printers are based on Stratasys' patented Fused Deposition Modeling (FDM™) technology.

In the FDM process, filaments of plastic modeling material and soluble support material are fed from auto-loading carriers in the material bay up to the extrusion head. There, the materials are heated to a semi-liquid state, forced through dual extrusion tips and precisely deposited onto the modeling base in extremely fine layers. The print head moves in X-Y coordinates, and the modeling base moves down the Z-axis as the model and its support



The FDM process with dual-tip technology.

material are built from the bottom up, layer by layer. After the build is complete, the support material is removed, and the model is ready to use or finish, if needed.

3D Printing technology is often faster and less expensive than other rapid prototyping methods and is especially valuable when creating concept and working models early in a design process. Sending a design to an outside service bureau can cost hundreds of dollars or more, while a 3D printer using FDM technology can produce the same part in hours for a few dollars.

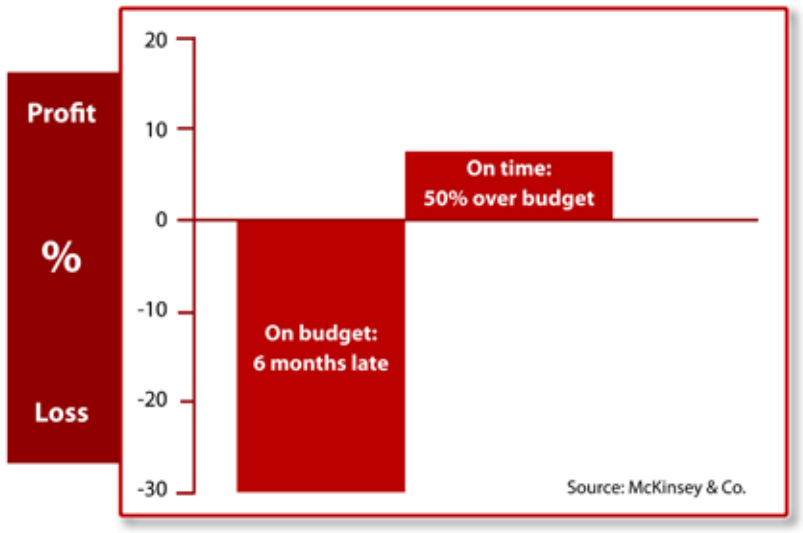
The small size of 3D printers enables them to function as office equipment that stays within a department. By comparison, large rapid prototyping systems often need to be centrally located and run by a dedicated staff of experts.

More and more companies are realizing the benefits of 3D printing. Terry Wohlers, president of Wohlers Associates, an additive manufacturing consulting firm, calls 3D printers the 'crown jewel' of the rapid prototyping industry."[3]

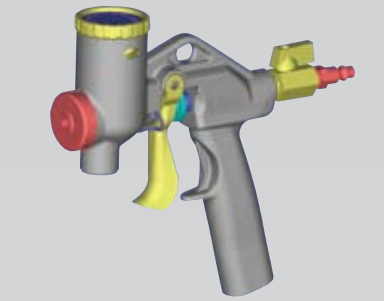
3D Printing Offers Many Competitive Advantages.

Quicker Time to Market. The longer a product stays in the design cycle, the longer its time to market, meaning less profit for the company. Time-to-market considerations were identified as the most critical daily issue facing respondents of a 2008 Product Design and Development readership poll.[4] In addition, this group said prototyping itself presented a time-to-market obstacle nearly 17 percent of the time.

With increasing pressure to get products into the marketplace quickly, companies are compelled to make quick and accurate decisions during the conceptual stage of design. These decisions can affect almost 80 percent of the product's total cost by establishing material selection, manufacturing techniques and longevity of the design. 3D printing



Entering a market 6 months late could cost a product up to 33% of its gross profit potential.



At Graco, engineers used a Dimension 3D printer to experiment with various paint gun and nozzle combinations to create the perfect spray pattern and volume.

EOIR Technology created a camera and mount for gun sights on Bradley fighting vehicles for the Mississippi National Guard with its Dimension 3D Printer.

optimizes profits by shortening design processes. With 3D printing, companies can now build parts within hours, not days or weeks.

At Graco, Inc. engineers used a Dimension 3D printer to experiment with various paint gun and nozzle combinations to create the perfect spray pattern and volume. Graco makes paint spraying and texturing equipment for professional use.

It designed a spray texture gun based on functional models built with ABS plastic parts from a 3D printer. **Graco estimates this helped reduce development time by as much as 75 percent.**

In addition, in-house 3D printing eliminates shipping delays and reduces administrative slowdowns that sometimes occur with sourcing prototypes from external services. Manufacturers thus have greater flexibility to manage their own production.

Cost Savings. The acquisition cost of a 3D printer can be as little as $15,000 (USD) versus as much as $500,000 for a rapid prototype machine, making them a good option for companies of all sizes. Annual operating costs are generally lower, too.

EOIR Technology created a camera and mount for gun sights on Bradley fighting vehicles for the Mississippi National Guard with its Dimension 3D Printer. It found that the functional models built with ABS plastic were so tough that it manufactured 40 camera mounts using the 3D printer to be used as final production parts. This saved time and reduced the cost of parts. Manufacturing costs for these components would have exceeded $100,000. For less than $40,000, EOIR acquired a CAD software package, a 3D printer and ABS modeling materials.

In addition to the obvious cost savings, giving a toolmaker a prototype along with a CAD drawing can result in a more accurate part as well as a more accurate price quote, sometimes saving companies up to 8 percent of tooling costs, according to industry experts. Other costs to consider are printer maintenance, which can run between $3,000 and $9,000 per year, and material costs that vary depending on use.

In-House Convenience. 3D printing technology can create multiple, ready-to-use models right from a desktop, making it especially convenient for companies needing a high number of models. The printers are versatile, yet easy to use and require no special training. Users just load the printer software onto a Windows network and start printing. Most software accepts major 3D file formats, including .stl, .wrl, .ply and .sfx files. Some also accept CT and MRI diagnostic data, protein molecule modeling database data and digitized 3D-scan data.

Increased Data Security. Everyone is concerned about security today, and while sending confidential STL files to an outside vendor is generally safe, having a 3D printer in-house removes any worry about risking intellectual property.

More Rigorous Product Testing. 3D printers can produce models with fine feature detailing, yet are strong enough to stand up to rigorous testing. At MSA Auer, the world's leading

manufacturer of high-end safety products and gas measuring systems, models must be durable enough to withstand planned drops onto concrete from a defined height. MSA Auer designers cannot risk a fracture of their safety equipment. They have been pleased with the strength of models produced with 3D printers.

Because leading 3D printers use production-grade thermoplastics, companies can test the form, fit and function for every design iteration. A true industrial thermoplastic, ABS is widely used in thousands of applications. ABS models won't warp, shrink or absorb moisture, and they can be drilled, tapped, sanded and painted.

The ABS material used in Dimension 3D Printers is environmentally stable, so overall shape and part accuracy don't change with ambient conditions over time, unlike resins and powders in other 3D printing technologies. Dimension's ABS has been tested for the following characteristics:

Tensile Strength:	5300 psi (37 MPa)
Tensile Elongation:	3.0%
Flexural Stress:	7600 psi (53 MPa)
IZOD Impact, notched:	2.0 ft-lb/in (106 J/m)
Heat Deflection:	204 F (96 C)

How Does 3D Printing Benefit the Design Process?

Today, 3D printers are used by designers and engineers for concept development and product design. They help users and potential customers see and feel an actual part, rather than rely on their imagination to bring a computer image to life. Models are also used as a visual aid to support tooling development.

Design iterations are created faster. Each year, a considerable number of new product initiatives fail. Analysis of new product development by Greg Stevens and James Burley in their study "3,000 Raw Ideas = 1 Commercial Success"[5] found that in addition to 3,000 raw ideas, a single product success also requires 125 small projects, four major developments and 1.7 product launches.

In a business climate where many companies are asking employees to do more with less, CAD solid modeling and 3D printing capabilities are essential for efficient product design and

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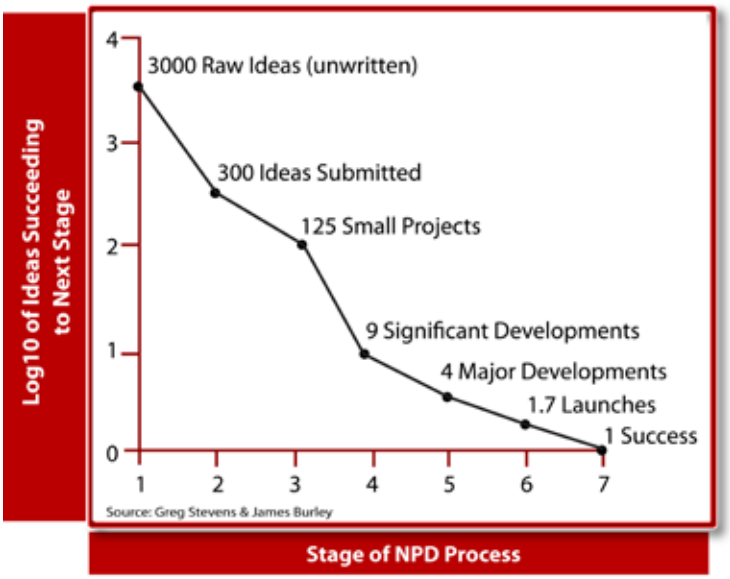


"Universal" Industrial Success Curve for New Products

development. With 3D printing, companies can experiment with new ideas and numerous design iterations, without extensive time or tooling expense, to determine whether product concepts are worthy of additional resources.

Mayo Clinic asked for help from Rochester Community and Technical College to print 3D models of the bile duct and liver of two conjoined twins to help evaluate their condition.

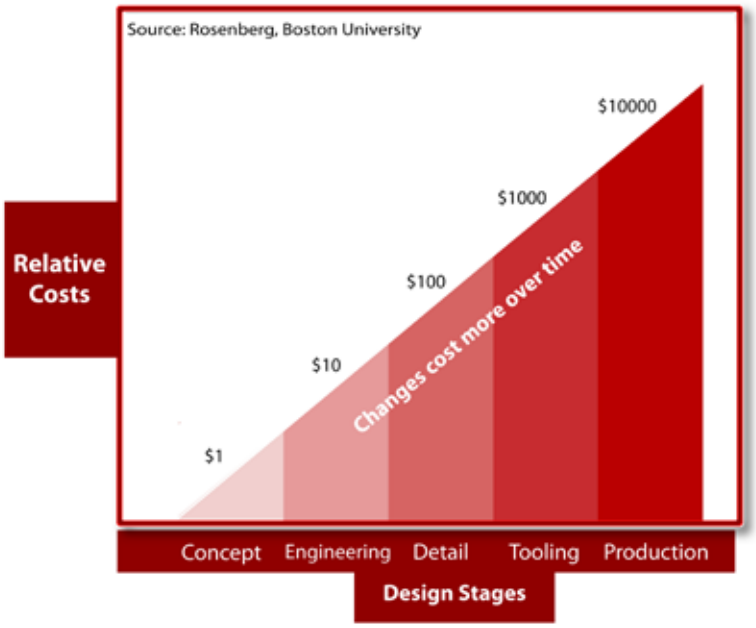
Time was of the essence for Mayo Clinic physicians in Rochester, Minn., who asked the Computer-Aided Drafting Technology instructors at Rochester Community and Technical College to print 3D models of the bile duct and liver of two conjoined twins. Physicians used these models to help them evaluate the twins' medical condition and determine appropriate surgical procedures for separation. After a team of 18 doctors successfully separated the twins in an 11-hour procedure, physicians used the models again to show the media how the procedure was accomplished.

Early feedback identifies design flaws. 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. This real-time collaboration with engineering, marketing and quality assurance can lead to early quality suggestions, enabling designers to make adjustments throughout the design process and follow-up testing.

Early changes save money. Changes cost more the later they occur in the design process. Early and frequent communication and collaboration can reduce these costs. The diagram on the next page illustrates how the cost of changing a product in the concept stage may cost only $1, but as the design progresses, so does the cost of making changes. By the time a product is in production, the change that would have cost $1 in the concept stage now costs $10,000.

The Future is Now

3D printing provides a highly cost-efficient means of producing numerous design iterations and immediate feedback throughout the critical beginning stages of the development



process. The ability to refine form, fit and function quickly can significantly affect 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 schools and small to medium sized businesses. The speed, consistency, accuracy and low cost of these printers will help companies reduce time-to-market and maintain a competitive edge.

About Dimension

Dimension is a brand of 3D printers by Stratasys that offers CAD (computer-aided design) users a low-cost, networked alternative for building functional 3D models from the desktop. The printers build models layer by layer using ABS plastic, one of the most widely used thermoplastics in today's injection-molded products. Dimension 3D printers enable users to evaluate design concepts and test models for functionality, form and fit. Contact Dimension at info@dimensionprinting.com, by phone at 866-721-9244 or online at: www.dimensionprinting.com.

1. King, Rachael. "Printing in 3D Gets Practical." Business Week, 6 October 2008.
2. NextGen Research. "Rapid Prototyping/Additive Fabrication/Solid Imaging via Stereolithography, Fused Deposition Modeling, Selective Laser Sintering and Inkjet Technologies," April 2009.
3. Wohlers, T. "3D Printers Lead Growth of Rapid Prototyping." Plastics Technology, August 2004.
4. Mantey, David. "Smaller, Cheaper, Faster." Product Design and Development, June 2008.
5. Stevens, G; Burley.J. "3,000 Raw Ideas = 1 Commercial Success," Research Technology Management, 40(3), May-June 1997, 16-27.

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