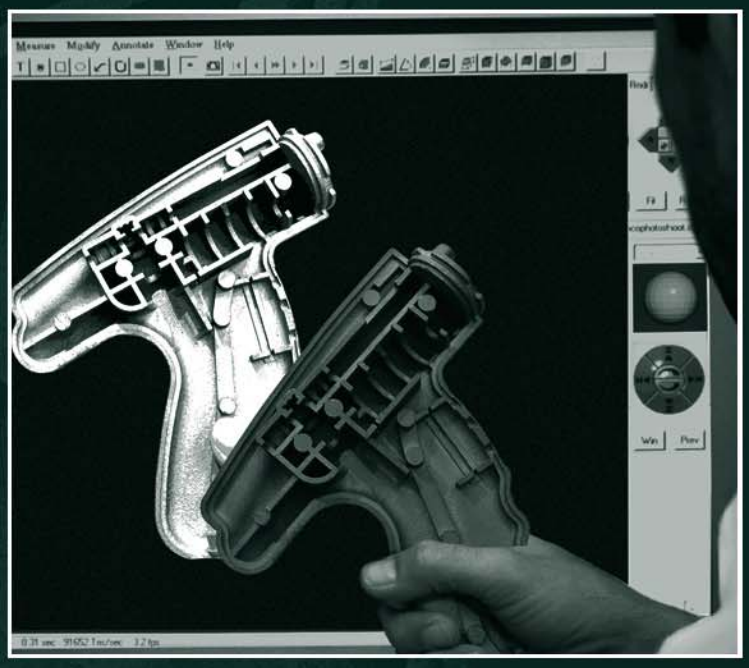
EXECUTIVE SUMMARY

Wohlers Report 2003

Rapid Prototyping, Tooling & Manufacturing State of the Industry

Annual Worldwide Progress Report



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Wohlers Report 2003

This eight-page executive summary provides an overview of the information published in *Wohlers Report 2003*, a 270-page, softbound publication. The report addresses many aspects of rapid prototyping, including the industries served, applications, revenues, unit sales, and forecasts. It also provides current information on industry trends and developments in the areas of service providers, advanced approaches to tooling, system manufacturers, and technology advances in the U.S., Europe, Asia, and other parts of the world.

The report covers research and development activities, growth trends in CAD solid modeling, rapid prototyping materials, medical modeling, rapid manufacturing, and reverse engineering. *Wohlers Report 2003* concludes with a discussion of the future of rapid prototyping—where it is headed and what to expect—to assist in strategic and tactical planning. To support the review and analysis, the report includes 27 charts and graphs, 31 tables, 97 photographs and illustrations, and seven appendices.

Introduction

Rapid prototyping (RP) refers to the physical modeling of a design using digitally driven, additive processes. RP systems quickly produce models and prototype parts from 3D computer-aided design (CAD) data, CT and MRI scans, and data from 3D digitizing systems. Using an additive approach, RP systems join liquid, powder, or sheet materials to form physical objects. Layer by layer, RP machines process plastic, paper, ceramic, metal, and composites from thin, horizontal cross sections of a computer model.

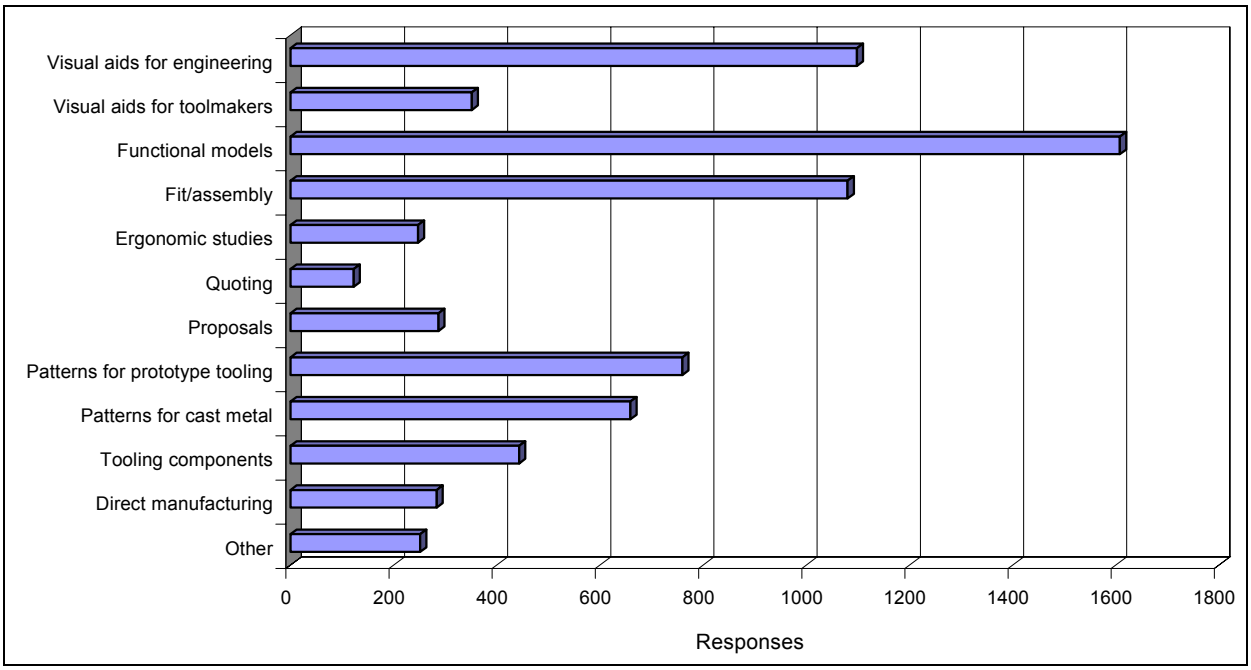
Design and manufacturing organizations use RP to produce models, parts, and patterns for products in the consumer, industrial, medical, and military markets, to name just a few. Copy machines, computers, mobile phones, automobile instrument panels, airplane subassemblies, power tools, and medical diagnostic equipment are just the beginning of a long list of products that have benefited from RP.

Methods, processes, and systems for *rapid tooling (RT)* are also developing. While early efforts were focused on faster delivery of tooling, new developments are underway that improve the performance of short-run and production tooling. Many of these new concepts involve one of the additive RP processes to achieve results that are unthinkable in machined tooling.

RP has a profound impact on the way companies produce models, prototype parts, and tooling. Companies are now extending the application of the technology to the production of finished goods. Some believe this practice, termed *rapid manufacturing (RM)*, will rapidly grow and ultimately overshadow the rapid prototyping and rapid tooling markets.

How RP models are being used

The following graph shows how companies are using RP models. The length of each bar reflects the relative number of responses received from those surveyed. As indicated in this graph, applications are as diverse as the industries that use RP. What is not shown is that a single RP model is often used for two or more applications.



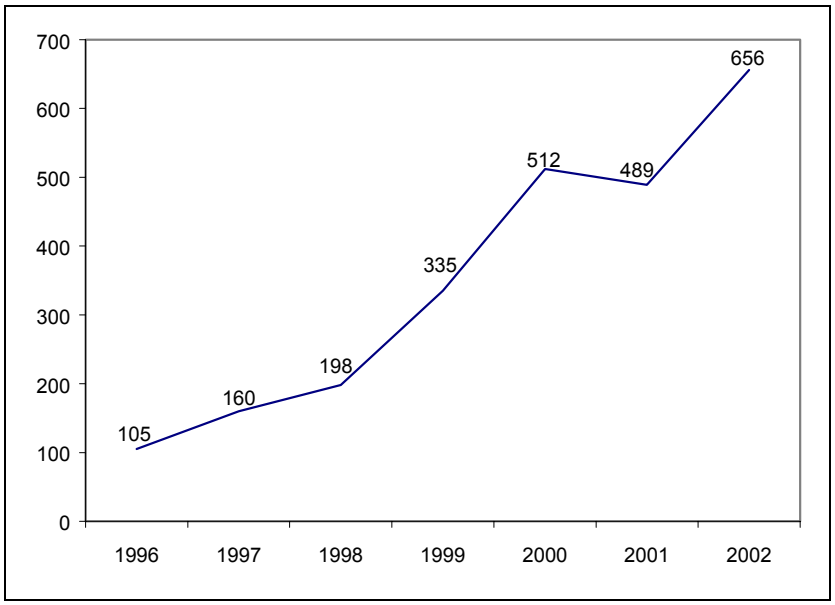
Source: Wohlers Report 2003

Industry growth

Years of growth and decline in rapid prototyping have become the norm. With companies constantly entering and leaving this industry, it is no wonder so many are unclear about the technology's future. Yet, RP continues to grab the interest and imagination of many around the world. Once considered to be just a tool for prototyping, RP has expanded into an impressive range of industries and applications. In the future, the expansion will include organizations, industries, and applications that use RP in ways that today are hard to fathom.

The average annual growth of RP over its entire history has been exciting. The last two years, however, have been a disappointment, as illustrated by the charts, graphs, and tables in the 270-page report. Machine manufacturers and service providers continue to face a host of challenges that just will not go away. Revenues in nearly all areas of the industry were down, with the service sector being hit the hardest. On a positive note, machine unit sales were up, with 3D printer sales faring especially well. The number of prototype parts built last year also increased. However, 2002 was a struggle for most companies in this business.

As the industry develops and matures, there will be a dramatic increase in the application of the technology for early concept models and finished manufactured parts. As shown in the following graph (showing annual unit sales), the rise of 3D printers, most commonly used for concept modeling, has begun.

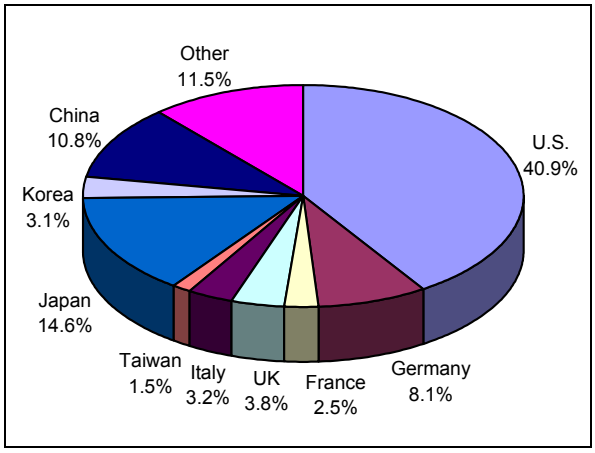


Source: Wohlers Report 2003

For RP to better penetrate new markets, a number of changes must occur. Machines must become less expensive to buy and easier to use and maintain. To entice more users to adopt RP, system prices and the overall cost of ownership must drop further. Materials must improve. New machines and applications must develop that support the production of finished manufactured parts, versus models and prototypes. And finally, the economy must improve and conflicts around the world must be resolved so that capital spending returns to the levels of the past.

Installations by country

Countries around the world continue to adopt RP technology. The following chart shows the systems sold and installed by country in 2002. China edged ahead of Germany for the first time in the history of rapid prototyping. The share held by the U.S. is expected to decline in the years to come as China and other countries embrace the technology.

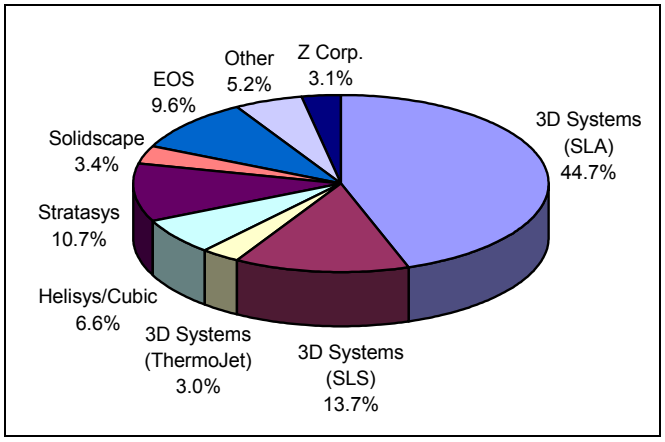


Source: Wohlers Report 2003

Machines at service organizations

Service providers, also referred to as service bureaus, offer prototypes to design and manufacturing organizations as an outsourced service. These companies also offer design, CAD, data translation, tooling, urethane casting, reverse engineering, and other engineering and manufacturing services.

Through the end of 2002, 3D Systems dominated the installed base of RP machines at these companies, as indicated in the following chart. 3D's share grew from 57.3% in 2001 to 61.4% in 2002. 3D Systems' technologies include stereolithography (44.7%), laser sintering (13.7%), and Multi-Jet Modeling (3%). Stratasys is the number two supplier of RP machines to service providers with 10.7%. EOS is third with 9.6%.



Source: Wohlers Report 2003

Rapid manufacturing

Rapid manufacturing is a vision of the future for many and a reality for a few, but for both, it lacks a clear definition. Beyond the concept of producing products quickly, there is little agreement on its definition. For some, it can mean making end-use parts quickly—by any manufacturing method. For others, it requires the use of an additive freeform fabrication process somewhere along the production chain. Align Technology's InvisAlign manufacturing process is an example of this second definition. The company uses stereolithography to make patterns for thermoforming clear plastic aligners for straightening teeth. Although this is an important application for stereolithography and an often-cited example of RM, it does not conform to the stricter definition of rapid manufacturing.

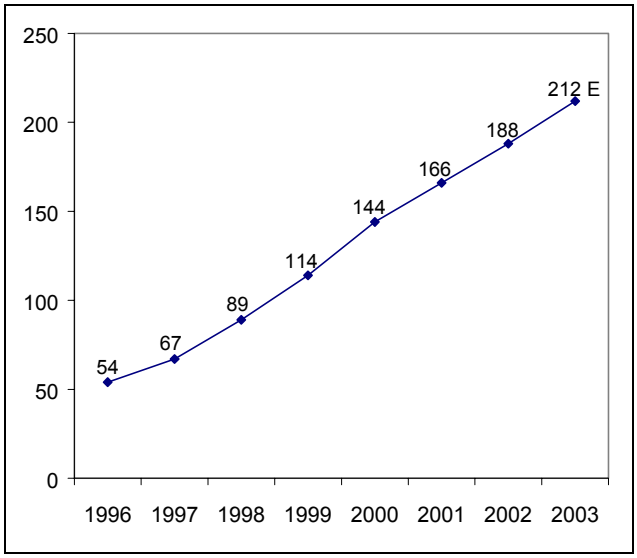
The definition of RM used in *Wohlers Report 2003* is clear and precise. Rapid manufacturing is the direct production of finished goods from a rapid prototyping (RP) device. The technique uses additive processes to deliver finished goods directly from digital data, which eliminates all tooling. As RM technology further develops, the layer-based approach of RP may be combined with subtractive (machining) operations or replaced by additive processes that use a multi-axis approach instead of a layered process. However, the definition of RM will continue to be the direct production of finished goods through additive processes that eliminate tooling.

Currently, there are no rapid manufacturing systems. However, RP systems are being used successfully in RM applications for the production of end-use parts. In this role, the RP devices become general-purpose systems that

are not designed for manufacturing applications. Therefore, there are problems with these systems that must be addressed for RM to succeed and flourish. These include surface finish, repeatability, and material properties, among others. The industry is currently in a transitional phase where RP systems, in spite of their limitations, produce low volume and customized parts. Rapid manufacturing systems, with the desired speed, cost, and quality, do not exist at present. They will in the future.

Research and development

A staggering number of research and development projects are underway at universities, institutes, government laboratories, and corporations around the world. These efforts are evidenced by the increasing number of patents issued, as shown in the following graph, and threefold growth in patent applications from 2001 to 2002. (The figure for 2003 is an estimate.) Much of the funding is coming from government programs. Meanwhile, an increasing number of companies from Europe, Asia, and other parts of the world are entering the industry.



Source: Castle Island Company

The trend for the last few years has been toward improving existing RP methods, or exploring significant variations of them, rather than establishing entirely new technologies. This trend continued in 2002. An additional trend of combining aspects of two or more existing technologies is also becoming apparent. These R&D efforts are addressing the limitations of the technology in areas such as materials, accuracy, and speed.

Methods of rapid tooling were once thought to be a key to RP's potential, but many of these have yet to meet expectations. In many cases, the applications and goals—not the technology—have been the limiting factors. With a change in direction, some companies are pursuing interesting developments and applications in rapid manufacturing, and they are on the verge of something very big.

The future

The rapid prototyping industry is on the cusp of monumental change. Advances in technology, materials, and operations will combine with new applications and processes to transform the RP industry. As these developments unfold, there will also be widespread change in design and manufacturing.

The industry is poised for change, but it will take time for the transformation to develop fully. In the short-term (one to three years), the industry will experience small, incremental changes. This will be followed by the mid-term, a transitional phase that will occur in four to six years. With the developments of the mid-term, the industry will be positioned for the sweeping changes of the long-term phase, which will occur seven to 10 years from now.

Change is inevitable, but few things change overnight. With the insight into the future offered in this forecast, companies in the RP industry will have sufficient time to plan and build for the new reality.

A revolution is quietly building. Over the next few decades, it will have taken hold and changed the way design and manufacturing are done. The revolution will sweep across industries as diverse as biomedicine and aerospace, where each will have their own specialized technologies. The new age is coming, and perhaps historians will document it as the digital industrial age.

Acknowledgments

The author thanks Accelerated Technologies for its kind support and sponsorship of this publication. Accelerated Technologies is a leading rapid prototyping service provider that helps companies bring better products to market faster. You can reach the company at 512-990-7199 in Austin, Texas, or 859-692-2600 in Erlanger, Kentucky. The company's website is www.acceleratedtechnologies.com.

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About the author

Industry consultant, author, and speaker Terry Wohlers is president of Wohlers Associates, Inc., an independent consulting firm he founded 17 years ago. For the majority of this time, he has served as a voice in the rapid prototyping and manufacturing industry. He has been quoted in the *Los Angeles Times*, *LA Daily News*, *The Economist*, *FORTUNE* magazine, and countless domestic and foreign magazines, journals, and newspapers. In October 2001, Terry served as analyst in a fast-paced television show on ABC, and has been interviewed twice on German radio. In 1994, Terry presented the critical importance of rapid prototyping technology to the Under Secretary for Technology at the U.S. Department of Commerce.

Terry has authored more than 275 books, articles, reports, and technical papers on engineering and manufacturing automation. He has presented to thousands of engineers and managers and has been a keynote speaker at major industry events around the world. In the recent past, he has given featured presentations in China, Germany, Japan, Puerto Rico, South Africa, UK, and USA. His appetite for adventure has driven him to climb the Great Wall of China, hike the rain forests of New Zealand, dive among sharks in Belize, bathe in the Dead Sea, and encounter lions and rhinos in Africa.

In 1992, Terry led a group of 14 individuals from industry and academia to form the first association dedicated to rapid prototyping. In 1993, the association joined the Society of Manufacturing Engineers (SME) to become the Rapid Prototyping Association (RPA) of SME. In 1998, Terry co-founded the Global Alliance of Rapid Prototyping Associations (GARPA) involving 15 member nations around the world. Today, GARPA serves as a catalyst for the exchange of information on rapid prototyping and tooling across international borders.

How to order the report

In the U.S., *Wohlers Report 2003* is available for $395, which includes Priority Mail shipping. For orders outside the U.S., the price is $425, which includes Global Priority Mail shipping in most countries.

To order one or more copies, please provide a Visa, MasterCard, or American Express number and expiration date by fax, phone, or e-mail. Contact information is provided below.

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Additional information, including an order form, is available at wohlersassociates.com. The website provides access to more than 200 related websites, 190 pages of content, and 120 articles, technical papers, reports, and other documents on rapid prototyping, tooling, and manufacturing, 3D printing, CAD/CAM, and reverse engineering. All 120 documents are available to read on-line free of charge.

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