Executive summary of the Wohlers Report 2016

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EXECUTIVE SUMMARY

Wohlers Report 2016
Introduction

This executive summary compiles and condenses information published in Wohlers Report 2016, a 335-page study. The publication provides a global review and update of the technologies and applications of additive manufacturing (AM) and 3D printing—terms used interchangeably throughout the report. This is the 21st consecutive year of the report’s publication.

Wohlers Report 2016 was written for product development and manufacturing professionals and organizations worldwide. Among the groups that have found it useful in the past are original equipment manufacturers, suppliers, service providers, researchers, educators, analysts, and investors.

The ISO/ASTM 52900 standard defines additive manufacturing as the process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive and formative manufacturing methodologies. AM is used to build physical models, prototypes, patterns, tooling components, and production parts in plastic, metal, ceramic, glass, and composite materials. AM encompasses seven distinctly different processes. Parts can be created in a layer-by-layer fashion by extruding, jetting, photo-curing, laminating, or fusing materials.

A key part of Wohlers Report 2016 is its comprehensive coverage of the AM industry’s growth. It includes revenues and machine unit sales, complete with more than 100 tables and charts that illustrate relevant trends, history, and industrial segments. The foundation of this reporting is more than 20 years of data from system manufacturers, service providers, and industry insiders, collected through surveys, interviews, and other means. No other published analysis of the AM industry has two decades of hard data as its basis for computing growth, analyzing trends, and forecasting the future.

Wohlers Report 2016 provides detailed descriptions of the many processes and material families available today. It also covers AM’s history, wide mix of applications, and industries adopting the technology. The report provides a synopsis of each of the manufacturers of industrial AM systems, along with important developments from the past 12–18 months. The report also covers the desktop 3D printer segment, companies that are producing materials for 3D printing, and manufacturers with new and emerging technologies.

The 2016 report provides current information on developments and trends in the production of parts for final products. The study provides updates on recent developments in countries and geographic regions, and documents government-sponsored research and development, collaborations and consortia, and the activities of 107 academic and 12 research institutes around the world. The report includes extensive appendices and links to a large, exclusive collection of supplemental online information.

The report concludes with a discussion of the expanding AM ecosystem, which includes the companies, technologies, markets, and business models that make up the emerging supply chain. It provides insights into the future to assist in strategic planning and investing. It also forecasts future opportunities and growth.
AM surpasses $5.1 billion

In 2015, the AM industry, consisting of all AM products and services worldwide, grew 25.9% (CAGR) to $5.165 billion. This compares to 35.2% growth in 2014, when the industry reached $4.103 billion. The CAGR for the past three years (2013–2015) is 31.5%. The CAGR over the past 27 years is an impressive 26.2%.

This $5.165 billion estimate of worldwide revenues includes both industrial systems and desktop 3D printers (those that sell for less than $5,000). This estimate does not include research and development initiatives at original equipment manufacturers (OEMs) and their suppliers. (They are among the principal customers of AM products and services.) Also, it does not include revenues from AM parts manufactured by OEMs.

Sales of AM systems for metal parts—a market segment that Wohlers Associates has been tracking for 15 years—are increasing. An estimated 808 metal AM machines were sold in 2015, growth of 46.9% over 2014 when 550 metal AM machines were sold.

In 2015, growth in unit sales of desktop 3D printers continued at a strong rate, increasing by 69.7% to an estimated 278,385 machines. Growth in 2014 was 88.0%, with unit sales of 163,999 machines. Average unit sales growth over the past four years (2012–2015) was 87.3%.

The following chart shows the $768.5 million AM materials market segmented by material type. As you can see, photopolymers is the largest segment, due in part to its historical and current use for prototyping and related applications. Laser-sintered polymers and filaments—both thermoplastics—are second and third in size. Metal AM has been available for roughly half of the industry’s 28-year history, yet it already represents 11.5% of the total and is growing fast. The “Other” segment includes materials for binder jetting, Solidscape machines, and sheet lamination.
Increasing number of system manufacturers

In 2015, 62 manufacturers from around the world produced and sold industrial-grade additive manufacturing systems (those that sell for $5,000 or more). This compares to 31 in 2011. As of March 2016, 28 companies in Europe, 10 in China, nine in the U.S., seven in Japan, four in South Korea, and one in Israel (Stratasys and Solidscape are counted as one company) were manufacturing and selling industrial AM systems. Most of the metal powder bed fusion systems are manufactured outside the U.S. Eight manufacturers of these systems are in Europe and six are in Asia. Wohlers Report 2016 includes updated profiles of all these companies, and includes a useful chart that defines the AM processes and materials used by each.

Market opportunity and forecast

The global economy is said to be about $80 trillion, and manufacturing accounts for about 16%, which is $12.8 trillion. At about $5.2 billion in 2015, AM represents about 0.04% of all manufacturing—which is less than half of one percent. If AM grows to capture just 5% of this global market, it would become a $640 billion industry. Wohlers Associates believes that it could someday exceed 5% of the total.

By 2017, Wohlers Associates forecasts the sale of AM products and services to reach nearly $8.8 billion worldwide. This forecast assumes the manufacturing economy will not be affected by larger influences, such as a global economic recession or catastrophic natural disasters.

Never before have we had access to such powerful tools—and so many of them—for design, product development, and manufacturing. This has resulted in a wave of exciting creativity, and an expression of new product ideas at an all-time high. The breadth of new products, services, startup businesses, and entrepreneurship, with funding to support them, is incredibly exciting. And, we have only seen the “tip of the iceberg,” so stayed tuned.
Acknowledgments

Wohlers Associates appreciates the many individuals and organizations that contributed to this report. A sincere thank you goes to the 51 system manufacturers, 15 third-party material producers, and 98 service providers that generously provided input. Wohlers Associates genuinely thanks the following 80 authors and contributors for their hard work and support.

Mukesh Agarwala 3D Product Development India
Nuno Alves Polytechnic Institute of Leiria Portugal
Nic Balc Technical University of Cluj–Napoca Romania
Joseph Beaman, Jr. University of Texas at Austin U.S.
Tyler Benster Azave U.S.
Alain Bernard Ecole Centrale de Nantes France
Klas Boivie SINTEF Norway
Gerrie Booyens Central University of Technology South Africa
Paul Bouwcare EWI U.S.
Bob Bradley RJ Bradley Consulting UK
Milan Brandt RMIT University Australia
Graham Bredemeyer Collider, Inc. U.S.
David Bourrell University of Texas at Austin U.S.
William Cass Cantor Colburn U.S.
Grigory Chuyko Voronezhlesmash Russia
Mel Cossette Edmoms Community College U.S.
Deon de Beer North-West University South Africa
Ryan Dehoff Oak Ridge National Laboratory U.S.
Carl Dekker Met-L-Flo U.S.
Olaf Diegel Lund University and Wohlers Associates Sweden
Brian Drab William Blair & Company U.S.
Igor Drstvenšek University of Maribor Slovenia
Sara Ebright Direct Dimensions U.S.
Khalid Abdel Ghany Central Metallurgical Research and Develop. Institute Egypt
Ismail Fidan Tennessee Tech University U.S.
Jennifer Fielding Air Force Research Laboratory U.S.
Tim Gornet University of Louisville U.S.
Joan Guasch Ascamm Spain
Seiji Hayano Aspect Japan
Robert Honiball CustomMed Namibia
Brecht Van Hooreweder KU Leuven Belgium
Neil Hopkinson Xaar UK
John Hornick Finnegan, Henderson, Farabow, Garrett & Dunner U.S.
Oliver Jay Danish Technological Institute Denmark
Jeng Ywan Jeng National Taiwan University of Science and Tech. Taiwan
Chua Chee Kai Nanyang Technological University Singapore
Ingomar Kelbassa Siemens AG Germany
Shawn Kelly EWI U.S.
Andrzej Kęsy University of Technology and Humanities, Radom Poland
Babak Kianian Blekinge School of Engineering Sweden
Alex Kingsbury CSIRO Australia
Eric Klemp Voestalpine Germany
Joseph Kowen Oryx Business Development Israel
Jean-Pierre Kruth KU Leuven Belgium
Martin Lavoie Canada Makes Canada
Nak-Kyu Lee Korea Institute of Industrial Technology Korea
Jörg Lenz EOS Germany
Feng Lin Tsinghua University China
About the principal authors

Tim Caffrey is a senior consultant at Wohlers Associates and a principal author of the Wohlers Report. His responsibilities include the execution of many consulting projects worldwide, as well as speaking and representing the company at national and international events. He has worked in association with Wohlers Associates since 2000.

Caffrey holds a bachelor's degree in mechanical engineering from the University of New Mexico. His career in additive manufacturing began in 1992 at Boeing's Propulsion Laboratory. He directed the company's first in-house AM facility, which grew from one system for wind tunnel models into a large operation that supported the entire corporation. Starting in 1996, Caffrey managed the AM operation at Plynetics Express, which had, at the time, the largest installed base of AM systems in the world.

His experience includes 24 years of professional writing and editing, which includes this annual publication, reports and roadmaps for consulting projects, and eight annual revisions of the textbook Applying AutoCAD. It
also includes maintenance procedures for Boeing aircraft, operational tests for Boeing flight test engineering, engine case repair procedures at Pratt & Whitney, advertising and marketing at Walmart’s corporate headquarters, and personal creative writing projects.

Caffrey’s not-so-traditional career also includes stints as a cabinetmaker, handyman, stagehand, audio technician, basketball coach, and actor. He once won a national championship in ultimate frisbee, and has also coached high school ultimate. He and his wife live in Fayetteville, Arkansas. They have three adult children.

Industry consultant and analyst Terry Wohlers is president of Wohlers Associates, Inc., an independent consulting firm he founded more than 29 years ago. Through this company, Wohlers and his team has provided consulting assistance to more than 240 organizations in 24 countries. He has also provided insight to 150+ additional clients from the investment community.


In 2007, more than 1,000 industry professionals from around the world selected Wohlers as the #1 most influential person in rapid product development and additive manufacturing (AM) by the UK’s TCT magazine as part of its Top 25 Influential People survey.

Wohlers has authored more than 400 books, articles, and technical papers on rapid product development and manufacturing. He has given 125 keynote presentations on five continents in cities ranging from New York and Cape Town to Melbourne and São Paulo.

His appetite for adventure has motivated him to climb the Great Wall of China, hike the rain forests of New Zealand, dive among sharks in Belize, and bathe in the Dead Sea. He has ridden elephants in Thailand, encountered lions in Africa, explored the ancient pyramids of Egypt, and traveled the crocodile-infested rivers of Malaysian Borneo.

Wohlers received an Honorary Doctoral Degree of Mechanical Engineering from Central University of Technology in Bloemfontein, South Africa in 2004. In 2005, he became a Fellow of the Society of Manufacturing Engineers, a distinction granted to less than 1% of the membership.
Associate consultant Ian Campbell is a reader (associate professor) in computer-aided product design at Loughborough University in the UK. He has led the Design Practice Research Group, served as director of the Research School of Design, and led the Digital Technologies Research Theme. Prior to 2000, Campbell was a lecturer at the University of Nottingham, working in the groundbreaking Rapid Prototyping Research Group led by Phil Dickens. Campbell began his career as an engineering designer at Ford Motor Company and the Rover Group.

Campbell has been working in the field of additive manufacturing since 1993. He has established international partnerships with colleagues in South Africa, Portugal, Slovenia, Egypt, and Romania. He is particularly interested in new design opportunities afforded by additive manufacturing and has advised industrial partners on how to best exploit them. He is an international honorary member of the Rapid Product Development Association of South Africa (RAPDASA) and has been editor of the Rapid Prototyping Journal since 1995.

How to order the report

Go to wohlersassociates.com to order the report online. The report, available as a color PDF, is US$495 worldwide. The printed and bound version is $595 worldwide. Credit card payment is preferred.
# Acknowledgments

## About the Principal Authors

## Part 1: Introduction

### Focus of This Report

- **Introduction to additive manufacturing and 3D printing**
- **History of additive manufacturing**
  - 1960s to the modern era
  - April 2015 through March 2016

## Industries, Applications, and Regions

- **Industries**
- **Applications**
- **Installations by country**

## Growth of CAD solid modeling

## Part 2: Processes and Materials

### Processes

- Material extrusion
  - Material jetting
  - Binder jetting
  - Sheet lamination
- Vat photopolymerization
- Powder bed fusion
- Directed energy deposition

### Post-processing

- General post-processing
- Post-processing of metal AM parts

### Materials

- Polymers
- Material pricing
- Metals
- Metal powders for AM
- Composites and hybrid materials
- Materials for metal-casting processes
- Ceramics and other materials
- New materials
- Materials testing and international standards

### Process/Material matrix

## Part 3: System and Material Producers

<table>
<thead>
<tr>
<th>Company</th>
<th>Region</th>
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<tbody>
<tr>
<td>Arcam</td>
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<td>Europe</td>
</tr>
<tr>
<td>CARIMA</td>
<td>USA</td>
</tr>
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<td>Concept Laser</td>
<td>USA, Germany</td>
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<td>DWS</td>
<td>Europe</td>
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<td>SLM Solutions</td>
<td>USA</td>
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## Part 4: Industry Growth

### Revenue from AM worldwide

- Products and services
- Growth percentages

### Industrial system unit sales

- Unit sales growth percentages
- Market shares
- Systems sold by region
- Average selling price
- Metal AM systems
- Unit sales by manufacturer and year

### Desktop 3D printer unit sales

- A different “animal”
- Desktop 3D printer ASP

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### Advantages of AM for production

- Reduction of tooling
- Agile manufacturing operations
- Decentralized manufacturing
- Reduction in inventory and part consolidation

### Challenges

- Cost of machines and materials
- Speed and throughput
- Cost justification
- Quality assurance
- Traditional attitudes

### Design for AM

- Lightweight structures
- Lattice structures
- Improved fluid dynamics

### Education designers

- Design guidelines
- Education curricula and training

## Part 6: Global Reports

### Africa

- South Africa
- Namibia
- Other countries

### Asia

- China
- India
- Japan
- Korea
- Singapore
- Taiwan

### Australasia

- Australia
- New Zealand

### Europe

- Austria
- Belgium
- Denmark
- Finland
- France
- Germany
- Italy
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Russia
- Slovenia
- Spain

### Middle East

- Egypt
- Israel
- Turkey
- Other countries

### Other Regions

- Brazil
- Canada

### U.S. Government-sponsored R&D

- National Science Foundation
- Basic research on AM technology
- Meso, micro, and nanoscale technology
- National Institutes of Health
- Department of Defense

### U.S. National Laboratories

- Oak Ridge National Laboratory
- Lawrence Livermore National Laboratory
- Sandia National Laboratories

### Government-sponsored R&D in Europe

- Academia activities and capabilities
- AM educational activities
- Research innovations
- Academic institutions with AM capabilities
- Research institutes with AM capabilities
- Future trends and contributions

## Part 7: Research and Development

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- New AM machine developments

### Patents

- R&D projects
- Arcam
- Concept Laser
- EOS
- SLM Solutions
- Sigma Labs
- Outlook

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- Commitment by OEMs
- Airbus
- New machines/materials from established corporations
- Key investments

### Market opportunity and forecast

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- 3D printing’s place in history

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- The hype hangover
- After the hype
- A bright future

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### Appendix B: System and material suppliers

### Appendix C: System specifications

### Appendix D: Desktop 3D printers

### Appendix E: Material properties

### Appendix F: Metal AM comparison matrix

### Appendix G: AM software tools

### Appendix H: 3D scanning systems

### Appendix I: 3D scan-processing software

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- United Kingdom

### Middle East

- Egypt
- Israel
- Turkey

### Other regions

- Brazil
- Canada

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- Non cost-effective use case
- Quality-dependent use case

### Metal AM part production

- Quality and performance improvements
- Cost improvements
- Delivery and lead time improvements

### Metal part production cost considerations

- Process monitoring in metal powder bed fusion
- R&D projects
- Arcam
- Concept Laser
- EOS
- SLM Solutions
- Sigma Labs
- Outlook

### Academic Institutions with AM capabilities

- Research institutes with AM capabilities
- Future trends and contributions

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- Academia activities and capabilities
- AM educational activities
- Research innovations
- Academic institutions with AM capabilities
- Research institutes with AM capabilities
- Future trends and contributions

### Technology

- Manufacturing
- Manufacturing
- Manufacturing (GO Additive)

### Manufacturing

- Investment in publicly traded companies
- Online marketplaces
- Supplier competition

### Other regions

- Other regions
- Brazil
- Canada

### Other regions

- Middle East
- Egypt
- Israel
- Turkey
- Other countries

### Other regions

- Other regions
- Brazil
- Canada

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