ADDITIVE AND SUBTRACTIVE: THE NEW MATH OF

METALS & MACHINERY MANUFACTURING

RESEARCH PREPARED FOR

The Advanced Manufacturing Jobs and Innovation Accelerator Challenge
Innovations in Advanced Materials and Metals Manufacturing Project
and The Greater Portland Export Initiative

AUTHOR: DR. BETH FITZ GIBBON | MAY 2015

THIS REPORT WAS PREPARED UNDER AN AWARD FROM THE U.S. DEPARTMENT OF COMMERCE
ECONOMIC DEVELOPMENT ADMINISTRATION | GRANT AWARD NUMBER 07 79 06921

#2-09 “Burning the Board”; oil on canvas 9ft x 6ft, © 2014 Donna Steger

“Burning the Board” depicts a method to achieve real-time feedback about product quality that can only be performed manually during hot steel bar production at Cascade Steel Rolling Mills in McMinnville, Oregon.

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METALS AND MACHINERY

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This publication was prepared by the Columbia River Economic Development Council.
The statements, conclusions, and recommendations are those of the author and do not
reflect the views of the Economic Development Administration.

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PREFACE

The Federal government has awarded a grant in support of advanced materials and metals manufacturing to five counties in Northwest Oregon and Southwest Washington: Multnomah, Clackamas, Washington, Clark and Cowlitz.[1] The Greater Portland region is one of only ten U.S. regions to receive this opportunity.

The Jobs & Innovation Accelerator Challenge Grant for Innovations in Advanced Materials and Metals Manufacturing (JIAC IAM^2) is a three-year award (2012-2015) funded by the Small Business Administration, the National Institute of Standards & Technology and the Economic Development Administration of the Department of Commerce, the Employment and Training Administration of the Department of Labor, and the Department of Energy. It focuses on specific industries with the greatest potential for the regional manufacturing ecosystem.

Two aspects of success singled out the Greater Portland region for this distinctive recognition. First, the collaborative approach among multiple organizations across five counties in two states; and second, the region's manufacturing heritage and its export success, as detailed in the Portland Export Initiative (MEI) done in partnership with the Brookings Institution.

The goal of this research is to provide insights and guidance for strengthening the region's economy by directly affecting its manufacturing capabilities and capacity in two distinct ways:

1. Enable small and medium manufacturers to improve and expand through business and technology improvements, market diversification, and exporting, so they become more productive, hire more employees, and make greater direct financial contributions through wages and taxes.

2. Provide insights that help regional economic development agencies retain existing companies, attract new businesses, and support high-potential companies.

This report is Part IV of a four-part research portfolio addressing advanced manufacturing in major regional industries. Other reports include: (part one) Advanced Manufacturing & Advanced Materials, (part two) Computers & Electronics, and (part three) Aerospace & Defense.

Thirty companies have been selected to receive direct technical assistance. None will receive financial payments; all will receive substantial support in terms of advanced manufacturing process improvements, advanced materials implementation knowledge, workforce training for incumbent and new employees, market research, and export assistance.

While prepared for the Columbia River Economic Development Council by the Oregon Microenterprise Network, this research has been developed in collaboration with many regional entities including: Business Oregon, Oregon Manufacturing Extension Partnership, Impact Washington, Pacific Northwest Defense Coalition, SW Washington Workforce Development Council, and Worksystems, Inc.

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1 Note: This research includes industry and employment statistics that vary depending on sources; data reflects the seven-county Portland Metropolitan Statistical Area (MSA), even though only five of the seven counties were included in the award. However, the variances are not significant enough to affect the overall meaning of the information provided about the grant region.

EXECUTIVE SUMMARY

While similar in format, this research takes a different approach from the other three reports in this portfolio (Advanced Manufacturing & Advanced Materials, Computers & Electronics, and Aerospace & Defense). They are all meant to provide an insider view and to present opportunities for addressing supply chain and economic development opportunities. This report is focused less on particular methods and markets and more on overall changes to industrial manufacturing that will have direct effects on the supply chain, and on small and medium companies in particular. A look at the regional GIS map for metals and machinery manufacturing on page 35, depicting more than 600 companies, illustrates how important this industry is to the regional economy.

Manufacturing has gone through major disruptive changes, from Henry Ford's assembly line to "lean" processes, new materials such as carbon fiber, and lightweight metals, such as graphene. Today it is going through a resurgence of interest as a potential economic savior for the remainder of the 21st century. Economists, scholars, and industrial experts are debating the realities of a "manufacturing renaissance." For leaders of manufacturing enterprises, there is no debate about the need to adapt to changing technologies, globalizing markets and workforce challenges.

One of the most significant concerns is not if, but how soon, additive manufacturing, known as 3-D printing, will revolutionize the way things are made. The technology has been around for 30 years, but is now advancing rapidly. What was once a novel way to produce prototypes is now a method for printing batteries, transistors, LEDs, complex components and even large objects.

While the materials science is still in progress, 3-D printers can already handle plastics, titanium, and even human cartilage. They can make larger parts with greater precision at higher speeds and lower cost. Additive manufacturing is fast becoming a viable alternative to traditional manufacturing, providing greater flexibility and reduced development time. It also eliminates tooling costs and waste inherent in standard "subtractive" manufacturing methods.

What will all those changes mean for small and medium businesses, for the workforce, and for the Portland regional economy?

Findings of this research indicate that while 3-D technology and new metals and materials developments will have a significant effect on precision and productivity, they will not replace every aspect of production or cause traditional manufacturing to collapse. New manufacturing will, however, change business models, force consolidation or elimination of some companies, and most likely bring about regionalization or even localization of production.[2]

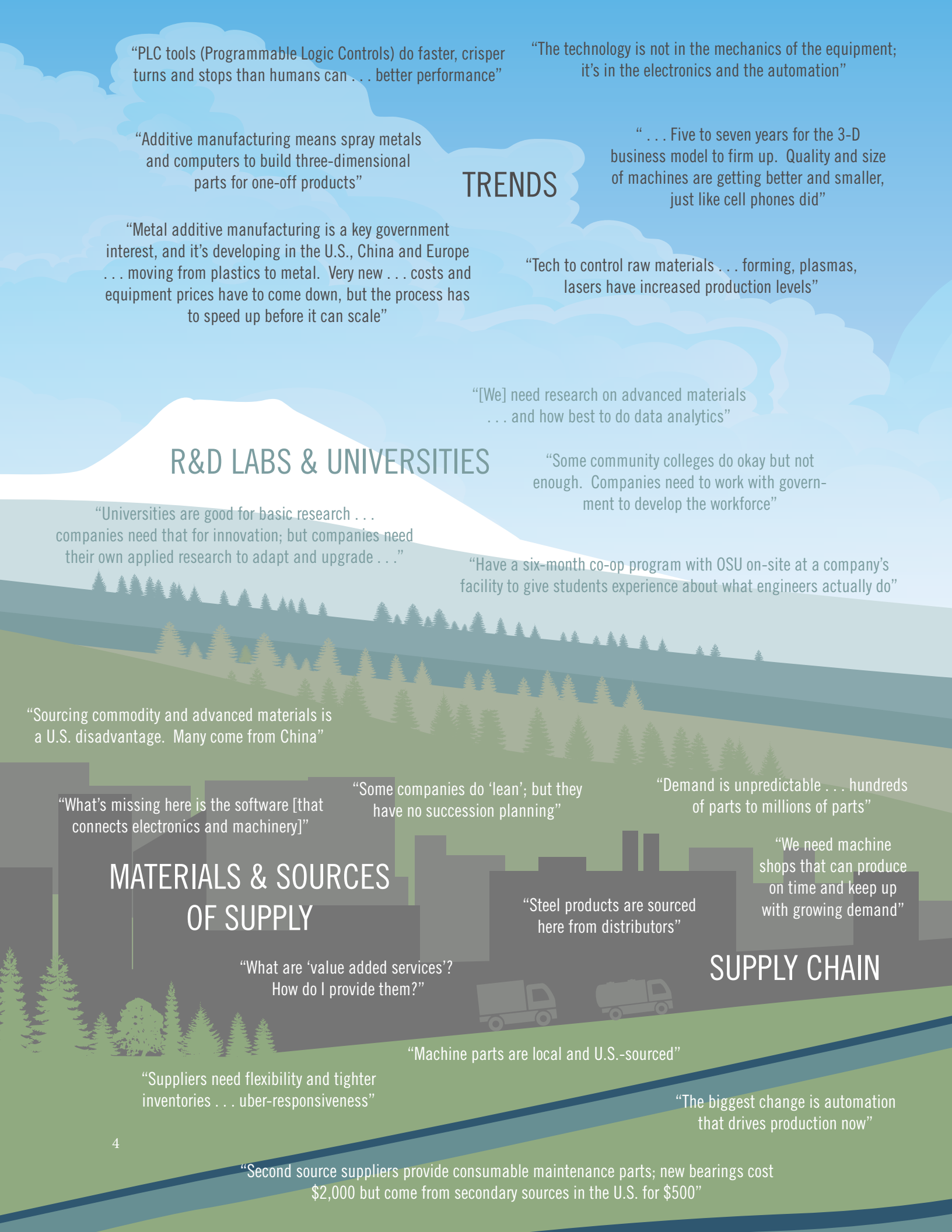
The Greater Portland region has considerable infrastructure and resources for local, national and international trade in machinery manufacturing. From Precision Castparts Corp., Daimler, and Gunderson to small machine shops, trucks, rail cars, ships, bridges, industrial aerospace and big equipment are all made here. Those goods are also in great demand in developed nations upgrading infrastructure, as well as in developing economies building new infrastructure. Small freight or "less than a truckload" (LTL), shipping for fresh food deliveries, locally and regionally, is also expected to grow, requiring more light trucks.

Energy trends such as hydraulic fracturing or "fracking" will increase demand for metals and machinery, from state of the art foundries to mechatronic robots and complex precision-made tubular parts. They will also provide opportunities for new suppliers not currently available in the Pacific Northwest, such as polishing and painting or coating providers. A state-of-the-art advanced materials foundry would be another valuable asset. New foundries have induction furnaces capable of melting multiple-metal alloys that are lighter weight, but have high corrosion and tarnish resistance. They are used in semiconductors, aerospace, military hardware, satellite communications and drug delivery systems. High-tech foundries don't just supply industrial manufacturers; they also provide services and products needed by architects, designers and artists in the creative economy.

Serious questions affecting the future of the regional manufacturing ecosystem need to be addressed. High-speed multi-spindle equipment and 3-D printers are expensive capital investments that may be out of reach for small and medium companies. Helping them remain competitive will take concerted effort on the part of the region and the states. Technology changes will also necessitate investments in workforce education and training, from metallurgy to mechatronics.

The rate and complexity of changes in the metals and machinery industry and competitive efforts in other U.S. regions necessitate regional coordination of business and political leadership, economic development, investment, and education to address science, technology, production, and workforce needs. Efforts such as the JIAC IAM[2] grant and the Oregon Metals Initiative, Inc. (OMI) are imperative for stepping up to that challenge.

2 Harvard Business Review, Will 3-D Printing Cause Traditional Manufacturing to Collapse? Bernstein and Farrington. January 14, 2014


"PLC tools (Programmable Logic Controls) do faster, crisper turns and stops than humans can . . . better performance"
"The technology is not in the mechanics of the equipment; it's in the electronics and the automation"
"Additive manufacturing means spray metals and computers to build three-dimensional parts for one-off products"
TRENDS
" . . . Five to seven years for the 3-D business model to firm up. Quality and size of machines are getting better and smaller, just like cell phones did"
"Metal additive manufacturing is a key government interest, and it's developing in the U.S., China and Europe . . . moving from plastics to metal. Very new . . . costs and equipment prices have to come down, but the process has to speed up before it can scale"
"Tech to control raw materials . . . forming, plasmas, lasers have increased production levels"
"[We] need research on advanced materials . . . and how best to do data analytics"
R&D LABS & UNIVERSITIES
"Some community colleges do okay but not enough. Companies need to work with government to develop the workforce"
"Universities are good for basic research . . . companies need that for innovation; but companies need their own applied research to adapt and upgrade . . ."
"Have a six-month co-op program with OSU on-site at a company's facility to give students experience about what engineers actually do"
"Sourcing commodity and advanced materials is a U.S. disadvantage. Many come from China"
"What's missing here is the software [that connects electronics and machinery]"
"Some companies do 'lean'; but they have no succession planning"
"Demand is unpredictable . . . hundreds of parts to millions of parts"
"We need machine shops that can produce on time and keep up with growing demand"
MATERIALS & SOURCES OF SUPPLY
"Steel products are sourced here from distributors"
SUPPLY CHAIN
"What are 'value added services'? How do I provide them?"
"Machine parts are local and U.S.-sourced"
"Suppliers need flexibility and tighter inventories . . . uber-responsiveness"
"The biggest change is automation that drives production now"
"Second source suppliers provide consumable maintenance parts; new bearings cost $2,000 but come from secondary sources in the U.S. for $500"

REGIONAL INFRASTRUCTURE, INVESTMENT & ADVOCACY

"We need more light rail. It takes one and a half hours to get to [our company] from Vancouver. Worker commute is an issue"

"Do I invest in machines without a customer or wait to get a customer and then try to buy the machine? Banker says wait. Customer says we can't wait"

"College-only track is a mistake . . . critical resource is an individual who can operate, be safe and have high awareness"

"We need well-trained machinists, CNC operators, laser operators"

"It's hard to have a budget to train employees. Advertise that there's help from economic development [agencies]"

"Fewer high school and college grads want manufacturing jobs. They think it's still old-school"

WORKFORCE

". . . CAD-CAM software designers, modelers and programmers"

"3-D doesn't make people obsolete; it makes them change"

". . . fabricators, more technically rounded people"

"We need engineering and people who can input data"

". . . need assemblers. That's not button pushing. It's putting things together. They have to be able to read blue prints"

". . . mechanical engineers, process engineers"

"Some (suppliers) have no product exploration"

"Currency exchange impacts our global competitiveness . . . it's a cost burden"

EXPORTS

"There's more international government interaction and support for companies; they're more strategic in their support of industries"

"Leading technology separates the U.S. from other manufacturing countries"

"We ship to 200 countries worldwide . . . our parts are proprietary"

"Oregon is the number one producer of grass seed plus food . . . concrete . . . other niche markets. The feds or the state need to help medium-sized businesses export"

". . . public service commercials for wine, cheese, milk. We need one for manufacturing"

INTRODUCTION

The Second Industrial Revolution[3] and the Invention of the Printing Press for Things – Additive Manufacturing

Metal casting has contributed to the development of civilization since 3200 B.C. when a copper frog, the oldest known casting in existence, was cast in Mesopotamia.[4] Iron was discovered in 2000 B.C. and the first Chinese cast iron production was between 800 and 700 B.C. Iron sand molding, still used today, was introduced in 645 B.C., also by the Chinese, who were using cast iron plowshares in 233 B.C. By 500 A.D., cast crucible steel was being produced in India. Interestingly, it became a lost process, but was reinvented in England in 1750, launching the Industrial Revolution.

The world's first cast iron bridge arched over the River Severn in Shropshire, England, in 1781. Created by new technology in response to the need for infrastructure to support transportation among growing regional industries, the achievement was the result of new uses of materials (smelting iron with coke to produce more cheaply), engineering design, and advanced manufacturing processes.[5]

During the late 20th century, new materials such as compacted graphite iron and cast metal matrix composites, and new processes such as plasma ladle refining (melting and refining in one vessel) and electromagnetic edge containment were developed. They reduced cost and energy expenditures in steel production.

Metals and machinery manufacturing (M&M) provides products for aerospace, construction, automotive, defense, industrial, agriculture, energy equipment, medical devices and semiconductor industries.

Additive Manufacturing, also known as 3-D printing, is the next stage. Along with the steam engine and the Internet, it is among the most disruptive innovations since the iron bridge. It is predicted to revolutionize how things are made and who makes them.[6]

The big discussion now among engineers and materials scientists is, "*How commercially viable is additive manufacturing (3-D) for large-scale production?*" The big question among manufacturers is, "*What will 3-D printing do to my business?*" Those queries are particularly relevant to manufacturers in the Greater Portland region, as metals and machinery are a significant part of the supply chain and a major contributor to the economy.

This research looks at the current state of M&M in the Portland region, and hopes to spur discussions about the future of regional manufacturing. In addition to consideration of new methods and materials, it addresses potential new markets, such as oil and gas pipelines and equipment, which offer opportunities for regional suppliers to expand into areas such as the U.S. Midwest.

3 The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies. Erik Brynjolfsson, Andrew McAfee. W.W. Norton & Co. New York. 2014

4 Metal-technologies.com.history

5 BBC.co.uk. July 2006

6 3-D Printing Takes Shape, McKinsey Quarterly. January 2014

MANUFACTURING BUSINESS TRENDS

Circular Production

"Lean" and "quality management" are no longer trends, but well established business processes. What is changing now is the linear one-way industrial production model – the "take, make, and dispose approach to manufacturing."[7]

Linear Production Model

Figure 1

In its place is a circular model. For instance, Renault, the French carmaker, remanufactures automobile engines, transmissions, injection pumps and other components for resale. Remanufacturing uses 80% less energy, 90% less water and generates 70% less oil and detergent waste than new production and delivers higher operating margins. Components are redesigned to enable easy disassembly and re-use. Renault has also formed a joint venture with a steel recycler and waste management company to bring end-of-use expertise into its product design. This helps the company save more money through tighter control of raw materials and vehicle life cycles—which are now called "use cycles." Renault also leases batteries for electric cars. Disposing becomes restoring and customers become users.

Ricoh office copiers and printers are made this way in Europe to use less material, labor, energy, and capital, without reducing quality. Remanufacturing, refurbishing, upgrading, and reusing leaves less to be recycled, reduces the need for new materials, saves materials, and reduces shipping costs.

Michelin leases automobile tires and has 290,000 vehicles under contract in 20 European countries. Tire upgrades and maintenance lower truck fleet costs and provide optimal performance, as Michelin collects worn out tires and retreads them for resale. Retreads are estimated to require half the raw materials and provide 90% of original performance. In the process, Michelin also collects valuable usage and wear data to improve their products.

Monetizing Data

Automated data collection during real-time processing lets manufacturers turn data into useful information for decision making.

7 Re-Making the Industrial Economy. McKinsey Quarterly, January 2014

Automation

For consumer products: A rolling six-foot belt in a French fries processing plant throws freshly cut potatoes, three inches deep, into the air. Cameras inspect the fries to collect quality data; but they also direct knives, moving faster than the human eye can see, to cut away blemishes for a higher-qualityproduct.[8]

For metal manufacturing: Anodizing aluminum requires a carefully formulated chemical bath, at just the right temperature, for the perfect amount of time. The chemicals are costly. Small batches and broad output tolerances require third-party lab testing that can take up to three days; however, a larger business with its own lab can cut testing time to 24 hours. "*Real time chemical analysis streams data to automatically adjust time, temperature and chemical composition of anodizing baths*."[9]

Integrating data into operations enables companies to gauge and adjust capacity, anticipate supply and inventory needs, quantify the value of production changes, and compare actual performance to business plans.

Hardware Incubators

HAXLR8R in Shenzhen, China, Lemnos Labs in San Francisco, California, and Bolt in Boston, Massachusetts, are business accelerators for entrepreneurial engineers developing electronics and for makers of physical things. They provide space and technical support to help build stable, scalable businesses that are profitable and sustainable. Similar to TechStars and Y Combinator, they provide mentoring, shop space, access to suppliers, industrial equipment for prototyping, and access to startup funding and venture capital in return for equity. Other hardware incubators include:

- PCH International, San Francisco, California
- AlphaLab Gear, Pittsburgh, Pennsylvania
- Nike+ Accelerator, Portland, Oregon
- Highway1, San Francisco, California
- Zahn Center, New York, New York
- IoT Works, Needham, Massachusetts
- Dragon Innovation, Cambridge, Massachusetts

Siemens Venture Capital, the corporate financing arm of Europe's largest engineering company, is launching a $100 million fund to back early-stage startups working on industrial automation and other digital technologies that can transform manufacturing. It will provide capital to companies with innovative technologies that have the potential to change the manufacturing landscape and industrial automation.[10]

Industrial Internet

The integration of machinery with software and networked sensors is a reality for IBM, AT&T, and GE. The term refers to machine connectivity and intelligent platforms that enable devices, objects and systems to communicate and interact. It allows companies to analyze industrial data and engage and collaborate in cloud communities to solve common business problems. It increases the speed and accuracy of knowledge, and captures and transfers knowledge among people, systems, and sites.[11]

8 Infinity Zen Guide to Manufacturing Intelligence. InfinityQS International Inc. www.infinityqs.com
9 Ibid
10 Siegfried Russwurm, CEO of the Siemens Industry Sector, cited on www.techcrunch.com
11 GE Intelligent Platforms www.ge-ip.com/industrial.internet

MANUFACTURING TECHNOLOGY TRENDS

Mechatronics

The need for precision has driven manufacturing beyond human capability. Machining was manual and an operator decided where and how much to remove. Fine quality today is produced with the aid of mechatronics, the marriage of electronics, computer science and mechanical engineering. A high tolerance is 1/4,000^{ths} of an inch, finer than a human hair, which is 1/1,000^{ths} of an inch. Tolerances can go to 1/10,000^{ths} of an inch in machining; and you have to be able to produce to those tolerances consistently, with quality, and on time.

Repeatable, accurate, precision manufacturing from solid pieces of metal, such as brass, copper, and steel, as well as graphite, plastics, and carbon fiber composites, is required for the ultra-high precision needed in medical and aerospace applications. Human joints are all machined; a patient can be scanned and their bone structure replicated exactly through 3-D printing.

Machine Intelligence

Machines and robots are not good at idea creation—the basic inputs for innovation. They give answers, but cannot tell you the questions you should be asking. Although they cannot replace people for complex problem solving or creating new industries, they can make and replicate parts quickly and accurately. As they become more self-contained and easier to use, they will replace even some highly skilled workers.

Metallurgy

The science of metals studies physical and chemical properties and the behavior of metallic elements and their mixtures. Use of powdered metals, liquid metals, shape metal alloys, and light metals, combined with waste minimization and recycling, computer modeling and process simulation for metal processing (casting, forging, welding, heat treating) will increase efficiency and reduce defects.

- Near-net-shape (NNS) processing uses direct deposition of particles or drops and sintering or freezing to build up layers as directed by computerized design drawings
- Welders use friction stir welding (FSW) and TIG (gas tungsten arc) welding for better control and more refined results to improve output

Other techniques and materials include:

- Direct strip casting
- Spray metals
- Powdered metals
- Lasers for etching and cutting to replace CNC machining
- Physical vapor deposition (PVD) to adhere metal to metal

Lightweight metals, such as high strength steel and aluminum alloys, have reduced the weight of parts—with no increased cost.[12] While the demand for metals has declined due to the recent economic climate, technology bringing increased safety and strength with reduced weight is now creating demand in industries such as energy, transportation, agriculture, and petrochemicals.

Shape memory metals, or "smart" alloys, remember their shapes and can be deformed and then returned to their original shape by applying heat. They have the ability to sense and respond to environmental changes. This creates a lightweight, solid-state alternative to conventional actuators such as hydraulic, pneumatic, and motor-based systems. Shape memory alloys have applications in aerospace, medical devices, and other industries.

Advanced Materials

- Alloys of palladium and silver, copper, gold and platinum
- Titanium alloys
- Aluminum alloys
- Beryllium, lead, chrome, zirconium and nickel alloys
- Silicon carbide
- Carbon fiber
- Powdered metal
- Diamond wire used for cutting steel

"BMW has seen the future, and it's carbon"[13]

Carbon fiber consists of hundreds of thousands of fine white filaments made at the SGL Automotive Carbon Fibers plant in Moses Lake, Washington. The $100 million plant is located there because of proximity to the Columbia River and hydroelectric power that is three cents per kilowatt hour, one-fifth of what the company would have to pay in Germany. The strands are stretched, toasted, and scorched black to create carbon fiber reinforced plastic that is thinner than a human hair, but tougher than steel. Spools of carbon fiber are shipped from Moses Lake to Germany to be woven into fabric and then molded into parts at BMW's Leipzig factory. Already used in Formula 1 racers, BMW's i3 electric car, and jet planes, carbon fiber makes things lighter and more fuel efficient, while maintaining speed. Carbon fiber is half the weight of steel and a third lighter than aluminum, yet it's the strongest material available—and 20 times more costly than steel.

12 Platts McGraw Hill Financial, www.globalmetalsawards.com

13 Seattle Times, Nov. 7, 2013; and Bloomberg Business Week, p. 21, Nov 18-22, 2013

In a Class by Itself: Additive Manufacturing

" . . . combining the digital precision and repeatability of a factory floor with an artisan's design freedoms"[14]

Additive manufacturing, better known as three-dimensional (3-D) printing, is also known as additive fabrication, fused deposition modeling (FDM), selective laser sintering (SLS), and stereolithography (SLA). Used for making prototypes, as well as manufacturing final products, it evolved from the "rapid prototyping" industry, pioneered by Chuck Hull of 3D Systems in the mid-1980s. The 30-year-old technology only recently became more affordable and widespread. Global sales and services related to 3-D printing reached $2.2 billion in 2012, up 28.6% from 2011. The industry is projected to reach $6.5 billion by 2019.[15]

Although various techniques are used, all 3-D printers use methods of "additive fabrication," building parts one layer at a time, with layers ranging from a millimeter to less than 1/1,000th of an inch. It is a computer-driven, additive process that builds plastic and metal parts directly from computer-aided design (CAD) drawings that have been cross-sectioned into thousands of layers.

The building material can be a liquid, powder, or sheet material that is cured by heat, UV light, a chemical reaction, or other method. The process provides a faster and less costly alternative to machining (cutting, turning, grinding, and drilling) solid materials.[16]

The term 3-D printing has evolved to include both rapid prototyping and rapid manufacturing. Initially, 3-D printing referred only to the relatively small, inexpensive, office-based machines that jetted a wax, photopolymer, or binder. Increasingly, the term refers to any machine that uses a method of additive fabrication, either in an office or on a shop floor.

There are numerous 3-D printing methods, including the cutting of paper, plastic, and metal sheets with a laser or knife and fusing or gluing the layers. The more common methods use filaments, liquids, or powders.

14 Fabricated: The New World of 3D Printing by Hod Lipson and Melba Kurman. 2013

15 The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies. Brynjolfsson and McAfee. Norton & Co. 2014

16 PC Magazine Encyclopedia, 3-D Printing

17 Fabricated: The New World of 3D Printing. Lipson and Kurman. 2013

Laser sintering

is a stereolithography process using powder and lasers. Also called "selective laser sintering" (SLS), it is one of several additive fabrication technologies used in rapid prototyping and rapid manufacturing. SLS builds prototypes and finished parts in a machine using powdered thermoplastics and metals that are cured by heat from a laser. From CAD drawings that have been cross-sectioned into thousands of layers, the machine builds up the part by curing one layer at a time and powder is added for succeeding layers. At the end of the job, the excess powder is removed and recycled for the next product. Standard smaller machines have either a 12x12-inch bed or a 15x15-inch bed, which produces two materials at once. To make a larger part, a 2x2-foot machine is used.[17] Basic 3-D printers are compact and inexpensive, with prices starting around $1,000 and going up to $20,000. Professional rapid prototyping machines range in price from $50,000 to $500,000. In addition, the software is often very expensive; programs include 3Dtin, Blender, OpenSCAD, and Tinkercad. Commercial use software includes CAD, AutoCAD and Pro Engineer, Rhino, Maya, and SolidWorks.

Concept, Prototype and Final Product

Capable of making a part from scratch in just hours, 3-D printers create models called prototypes to determine if a design meets the customer's concept and functional expectations. It is also used to test parts for their form, fit and function with other parts in an assembly.

Using printing technologies such as laser sintering and electron beam melting, "rapid prototyping" evolved into "rapid manufacturing," in which short runs of actual finished parts are made. The process can create individually customized products such as hearing aids, dental crowns and medical implants. Conventional manufacturing processes can require 15 to 20 steps that can be accomplished in one step with additive manufacturing.

3-D printing is also used to make tooling, such as molds and dies, as well as patterns for castings. Either the actual mold, or the model to make the mold, can be produced more quickly and is less costly than with conventional methods.

There are seven types of 3-D printing machinery:[18]

1. Binder jetting, in which a binder glues materials together
2. Directed energy deposition, in which a laser or electron beam joins materials
3. Material extrusion, in which a polymer is melted and extruded
4. Vat photopolymerization, an older technique such as stereolithography
5. Powder bed fusion, in which an energy beam is used to melt powder in a bed
6. Sheet lamination, which is a cut and stack approach

Materials used in 3-D Printing

Most of the materials used in 3-D printing are polymers and plastics; however, there is great interest in developing new metals and ceramics. New metal alloys are needed with characteristics appropriate for additive manufacturing, but much research is needed and certification is an issue. The military will reject altered metals without a lengthy certification process.

- ABS plastic
- Aluminum fused nylon
- PLA – Polylactic Acid or Polylactide is a bioplastic and thermoplastic polyester derived from corn-starch, tapioca or sugar cane
- Polyamide (nylon)
- Glass filled polyamide
- Stereolithography materials: epoxy resins
- Silver
- Titanium
- Steel
- Wax
- Photopolymers
- Polycarbonate

18 Novel Processes for Advanced Manufacturing, National Research Council, 2013

Current printers are slow and the materials they use are expensive and inconsistent. However, as the technology advances, R&D and product development costs are coming down and product development cycles are speeding up.

There are 35 companies currently engaged in developing additive manufacturing technologies and materials, with U.S. and European enterprises leading the way. Six hundred to 800 patent applications a year are being filed (2012); and the industry is growing at 15% to 20% per year.[19]

In standard injection molding, cost per part declines as production increases. With additive manufacturing, the cost of producing one product is the same as producing 100,000 parts. That makes additive manufacturing attractive for low-volume, high-mix production. Its advantage lies in the ability to produce very complex structures of which standard injection molding is not capable.

Once the price of the printing machinery comes down and productivity increases, the cost of the process will decrease. As machinery and materials patents expire over the next few years, competition will increase and product prices will fall. However, most machines are made in Germany, and buying a custom machine is expensive. More machines need to be made by multiple producers before prices will decline.

Currently, the industries that are predicted to benefit most from additive manufacturing include:

- Prototyping, enabling a faster, more efficient product development process
- Automotive – for support items and custom autos
- Aerospace – numbers of parts for aircraft can be fairly small; for example, only 1,524 Boeing 747s have been ordered
- Tooling for injection molding
- Medical implants and prosthetics – each item is custom fit so items are produced individually
- Art and jewelry – Custom-made pieces and complex geometries
- Architecture – Scale models and custom pieces with high levels of detail

General Electric (GE) is using 3-D printing for rapid prototyping, compressing the design cycle from a few years to a few months for engine parts. GE also uses the process to manufacture high-performance products that were previously difficult to produce, at lower cost. 3-D printing eliminates joints, providing a performance advantage. Additionally, GE is developing processes to print ceramics and is printing sensors on top of existing turbo machinery applications.

Printing-on-demand could reduce assembly lines, shorten supply chains and erase the need for warehouses—in addition to reducing shipping costs and eliminating waste and pollution.

Important applications today are designed for the aerospace and medical industries. Researchers in Europe, China, and the Middle East are using 3-D printing to print living tissue, create replacement jawbones, and regenerate damaged coral reefs.

19 Novel Processes for Advanced Manufacturing. National Research Council, 2013

As engineers learn to blend raw materials in new ways, using nanotechnology and artificial intelligence, they can create objects that interact with their physical surroundings. The 2013 FabTech Expo in Chicago, Illinois, presented new 3-D technologies such as:

- Military armor embedded with sensors that track wear and tear
- A turbine blade that monitors its own temperature
- 3-Doodler (basically a hot glue gun shaped like a pen that extrudes plastic, so you can draw in 3-D within the limits of physics)
- Stem cells cultured and pushed through a 3-D printer, but on a biographic base for growing cells
- BioPen (a scalpel that puts out stem cells, like a 3-D pen, for skin grafts and knee bones: no scar, no tissue rejection)

Experts predict a $5 to $8 billion industry by 2018.[20] The industry is growing incredibly fast; 2012 estimates were less than half that projection.[21]

In the future, consumers will be able to make replacement parts for products they own, invent new products and sell customized items on line . . . potentially creating new industries. As with cell phones, prices are predicted to drop dramatically as the technology develops and demand grows.

The Urbee 2 car weighs 1,200 lbs. and is made of 40 pieces of thermoplastic, which is resilient and aerodynamic. Building it required almost no labor, just a little time to print and assemble the parts. The prototype, produced by KOR Ecologic Inc, was introduced at the November 2013 London, England, 3-D Print Show.

When ready for its first U.S. cross-country trip, it is expected to achieve 290 miles per gallon. It will follow the path of the first cross-country motorcar road trip taken in 1903. That trip took two months and nine days, and required 800 gallons of gas. The Urbee 2's trip is expected to take two days and use ten gallons of gas.[22]

20 www.3ders.org, SmarTech Publishing, July 2, 2013; www.disrupt3d.com, TCT Magazine, February 17, 2014
21 www.prnewswire, July 20, 2012
22 www.korelogic.com and Wired, February 27, 2013

Cautions

Defense Distributed, a non-profit digital publisher and 3-D printing R&D company, published online instructions for a printable gun that fires. A printer reads the file, and then shoots out layer upon layer of specialized plastic or other raw material through a heated nozzle in the specified shape. Once it cures, the gun is ready for use. Over 100,000 people downloaded the plans before the U.S. Department of State took it down as a violation of export control laws. Counterfeited goods can also be made by downloading a digital file.[23]

Challenges

With the right policies, this disruptive new technology may make the world a better place; however, as of yet, there are no ethics for this "brave new world." The following issues will need to be addressed, and possibly regulated, in the near future.

- Certification of machinery, materials and parts for military and aerospace products can take ten to twelve years; it needs to drop to one to two years
- Intellectual property and counterfeiting
- Copyright infringement and appropriation of pop culture artifacts
- Lawsuits and lobbying
- Safety: objects of questionable quality, from strollers to junk food, can be made quickly and easily; who is liable when harm is done?
- Medical regulatory issues: hospitals are using 3-D printers to arrange human cells to create blood vessels and bone tissue. Soon they will be trying to print precise replicas for organ replacements
- 3-D printing has the potential to displace many workers, especially in industries that depend on assembly-line workers

Examples Of 3-D Manufacturing Companies

Regional

RapidMade, Portland, Oregon, is a "custom fab shop" specializing in 3-D printing. RapidMade is the only Portland company with a range of guaranteed fast manufacturing options and six days to two weeks delivery. RapidMade is not a transactional 3-D print service, as are many online offerings. It is a custom engineering manufacturer that designs, engineers and creates prototypes. *www.rapidmade.com*

National

3D Systems, Rock Hill, South Carolina, is a global, integrated solutions 3-D printing company specializing in printers, print materials, professional and consumer custom-parts services and 3-D imaging and customization software. Considered the premium East Coast company, 3D Systems made 23 acquisitions in 2012 and 2013.

23 Why 3-D Printing Can Make the World a Better Place. Bloomberg BusinessWeek, p. 8, May 20, 2013

Revenue for the first nine months of 2013 grew more than 40%. For the second year in a row, the company also made Fortune Magazine's 2013 list of the fastest-growing companies, climbing to number two in tech and number five overall out of 100 global companies listed.[24] *www.3dsystems.com*

Rhinoceros, Seattle, Washington, is an on-line global service owned by McNeel Inc. It offers information, products and services for creating 3-D printing models from jewelry to industrial products. *www.rhino3d.com*

Stratasys, Eden Prairie, Minnesota and Rehovot, Israel, is an industry leader in manufacturing 3-D printing equipment and materials. Their uPrint Personal 3-D Printer is $14,900. Owns MakerBot, Thingiverse, and manufactures SolidScape machines and RedEye On Demand digital products. *www.stratasys.com*

Shapeways.com is an on-line 3-D printing service. Design files can be emailed directly to them and they will send the completed product. *www.shapeways.com*

3-D Supply Chain

3D Systems and Stratasys currently have a near monopoly on materials. They have been acquiring materials suppliers. The raw materials model is the same as razors and blades, or printers and ink cartridges, or cell phones and airtime. Basic machines cost $500. Materials, like blades, ink, or airtime, are expensive.

"Right now a 40 lb. bag of gypsum to mix with super glue for making models costs $1,700. And you need lots of it."[25]

However, patents from the 1970s and 1980s are due to expire in 2014, and the processes and materials will not be proprietary any more. People will be able to open-source to make their own products. It is expected that much manufacturing will soon be done regionally to satisfy local needs.

Inside a 3-D Printer:
The printing system includes a parts chamber, a laser, and computerized controls. The parts chamber includes a platform for building, a powder cartridge and a leveling roller. A thin layer of building material is spread across the platform; the laser traces a two-dimensional cross section of the part, sintering the material together. The platform then descends and the leveling roller pushes materials from the powder cartridge across the platform, and the next cross section is sintered to the previous one.

24 Fortune Magazine, December 9, 2013
25 Confidential industry interviewee

Economic Impacts of Additive Manufacturing

3-D printing is predicted to contribute $550 billion a year to the U.S. economy by 2025.[26] It will profoundly change the way products are designed, developed, and produced in five specific ways.[27]

1. Accelerated product development cycles

Speeding the production of prototypes reduces development time from weeks to days or hours. It gets prototypes into customers' hands sooner for faster feedback. Advances in printer resolution, higher definition coloration and broader use of materials, such as elastomers, make the final product experience more realistic and tangible. Making prototypes without tooling reduces product launch risk and costs. Companies can launch parts or finished products while traditional production tools are still being manufactured; and when they order tools they can use additive manufacturing techniques to save even more time and money.

2. New manufacturing strategies

In 2011, only 25% of the 3-D printing market involved direct manufacture of end products. With 60% annual growth since then, it has become the fastest growing manufacturing segment.[28] Costs continue to fall while capabilities increase, so a greater variety of parts can be produced economically this way. Boeing uses 3-D printers to make 200 parts for ten different types of aircraft. Medical device makers use them to create hip replacements custom fitted to each patient's physical measurements.

Characteristics to help determine which manufacturing methods to use include:

- Components with a high labor cost, and time consuming processes such as assembly and secondary machining processes
- Complex tooling requirements or relatively low volumes with high tooling costs
- High obsolescence or scrap rates

Production may also move closer to end customers given lower labor costs and less intensive capital equipment and infrastructure needs. The digital nature of 3-D printing may also make it possible to produce complex parts in remote areas with lower costs for electricity and labor.

The cost of printing materials is still uncertain. On one hand, patents on materials will expire in 2014 and 2015, making some inputs less costly. On the other hand, many printers use proprietary or licensed printing equipment. Once universal standards are developed, prices should decline significantly.

3. Shifting sources of profit

Outsourcing of basic manufacturing enabled companies like Nike to concentrate on design. 3-D printing may likewise reduce the costs and complexity of manufacturing, so companies can differentiate their products in other ways, such as customized design or longer life cycles. Reducing reliance on hard tooling that enables making thousands of identical items lets companies offer personalized design at lower cost to a broad range of consumers. Mass customization can be a disruptive marketing capability. It will also make it easier for suppliers to manage inventories of spare parts that can be created on demand, which

26 Disruptive Technologies: Advances that will transform life, business, and the global economy. May 2013, on mckinsey.com

27 3-D Printing takes shape. McKinsey Quarterly. Cohen, Sergeant and Somers. January 2014

28 Ibid

will eliminate the need for large regional warehouses and create a new market for small fabricators at convenient sites such as airports, hospitals and shopping malls. Retailers could let customers tailor toys and building materials. If they own those machines, they will have a new value chain and access to consumer-direct data.

4. New Capabilities

Design know-how is a crucial capability for manufacturing companies. Engineers can't design machines without knowing the benefits and challenges of casting, forging, milling, turning and welding. While there is much knowledge about design for manufacturing, there is not for design for 3-D printing. This is an open opportunity for competitive advantage. Technical challenges of shape distortion, speed optimization and unusual new materials are another opportunity for expertise. Plastics are fairly simple; metals are more difficult. Gels and slurries for printing living tissue or advanced batteries are very difficult. Hiring engineers with experience in additive manufacturing is crucial for companies wishing to remain competitive.

5. Disruptive Competitors

As costs drop, market entry barriers fall. Lowering tooling costs means it will be cheap to manufacture, even for low-volume high-mix and niche segments. Products can go directly from the computer screen to commercialization. Highly customized or collaboratively designed products can be created and sold online by "pop-up shops." They can gain consumer insights and create customer relationships that leave traditional manufacturers in the dust. Initially customers will be willing to pay a premium for bespoke design, complex geometry and rapid delivery.[29] But overtime, that can evolve to make design or even ownership of customer networks more important than the making of things. Consideration also needs to be given to potential regulatory and ethical challenges, such as 3-D printing of firearms.

Instead of regulation or restriction, there is hope that, as with music and movies, software businesses will share their source codes and be compensated for the services they provide. So the spread of digital fabrication tools is now leading to a corresponding practice for open-source hardware.

Advances in 3-D printing will provide greater competition with reduced costs and increased precision for complex components. The U.S. is not alone in developing additive manufacturing; other countries are creating regional programs through the international Fab Lab Foundation Network (FabLab.nl, Belgium, Luxembourg, Netherlands) to support the sourcing of specialized materials around the world. Digital fabrication is more than 3-D printing. It is an evolving suite of capabilities to turn data into things and things into data.

29 3-D Printing takes shape. McKinsey Quarterly, January 2014

3-D What-ifs . . .

Extremists building self-reproducing weapons of mass destruction

Digital fabrication used to produce weapons of individual destruction

Security hazards: replicating padlock keys and police handcuff keys

Patent protection works only if there is a barrier to entry to using the intellectual property and if the infringement can be identified

"Gray Goo" doomsday scenario, where a self-reproducing system multiples out of control and consumes the world's resources—a form of biological warfare

The Foundry – Subtractive Manufacturing

A foundry is a factory or workshop for casting metal into shapes. Metals are melted to a liquid and poured into molds or casts. The metal solidifies as it cools, resulting in parts made to the specified shape and size. Most commonly used metals are aluminum and cast iron, bronze, brass, steel, magnesium, and zinc. New metal mixtures, called alloys, provide castings with better characteristics for strength and durability.

Foundries produce castings that are close to the final product shape, i.e., "near-net shape" components. Castings are produced by pouring molten metal into molds with cores used to create hollow internal sections. After the metal has cooled sufficiently, the casting is separated from the mold and undergoes cleaning and finishing techniques.

Metal Production Processes[30]

Name/Synonyms	Description
Bulk ferrous metal production "Iron & Steel making," "Integrated Steelworks"	The production of bulk molten metal from raw ores and metal scrap. The molten metal can then be used for: • Continuous casting • Production of billet, plate, and sheet • Production of pig iron • Supply to a foundry process
Bulk nonferrous metal production Refiners/Smelters	The production of nonferrous metals from raw ores and metal scrap, with refining and purification by chemical, thermal, electrolytic and other methods. Products consist of extruded bar, rod, wire, slab, billet, and ingots.
Ferro-alloy and ingot production	Production of certified grades of metal alloys and metal additions (in the form of nuggets, granules, etc.) for use by foundries as raw materials
Foundry Casting	Production of "near-net shape" products by pouring molten metal into molds. The molten metal is produced from scrap, pig iron, ingots and alloys. Associated processes include mold/core preparation and finishing of cast components.
Forging	Production of dense metal products from ingot or bar stock using heat and pressure.
Wrought iron working	Commercially pure iron (>99%) worked by hammering, squeezing, rolling or by hand to make high quality or intricate products. Mainly a historical production technique limited to specialty items today.
Fabrication	Assembly of metal sheet, plate, etc. to make a finished product. May involve cutting, grinding, welding, shaping, etc.
Machining	Removal of unwanted metal by grinding, drilling, cutting, turning, to produce the required shape to the required dimensional tolerance.
Finishing	Polishing, coating, painting

Figure 2

30 www.castingstechnology.com/public/documents

Cast Metals and Foundry Products

The metals cast by foundries can be subdivided into several main groups as shown below.

Different Metals Used for Casting Production[31]

Main Group	Subsets	Further Divisions and Alloy Constituents
Ferrous	Iron	Grey: containing > 95% iron with carbon, silicon and manganese. Ductile: iron with carbon, silicon and magnesium. Malleable: constituents as grey iron. Cast in chill condition, graphite aggregated through heat treatment (mainly historic). Alloy: containing up to 30% each of chromium and/or nickel to provide additional hardness and heat-treat ability.
	Steel	Carbon steel: contains carbon levels up to 1.7% (typically 0.1 to 0.5%) and manganese up to 1.6%. Low alloy steel: a low carbon (0.35% maximum) iron alloy containing 3 to 5% chromium and 2 to 8% nickel. Stainless steel: iron base alloy containing up to 30% chromium and/or up to 40% nickel. Corrosion resistance increases with Cr/Ni content.
Nonferrous	Aluminum	Various alloys usually containing silicon, copper and/or magnesium.
	Copper	Pure copper: > 99% pure Brass: an alloy of copper and zinc (up to 45%), sometimes with up to 2% lead and 1% tin. Bronze: an alloy of copper and tin (up to 12%). Variations: leaded bronze (9 to 22% lead), gun metal (3 to 5% lead and 2 to 8% zinc), aluminum bronze (with 6 to 9% aluminum, 0 to 5% nickel, 0.5 to 5% iron), phosphor bronze.
	Zinc	Zinc-based alloys with up to 4% aluminum and trace amounts of copper, magnesium, etc.
	Super alloys	Nickel or cobalt-based alloys in combination with chromium, iron, manganese, molybdenum, etc.
	Magnesium	Magnesium alloyed with aluminum, zinc and thorium. Other metals can be added in trace amounts.
	Titanium	Pure titanium: > 99% pure α/β alloys with aluminum, vanadium, zinc, molybdenum and zirconium.

Figure 3

31 www.castingstechnology.com/public/documents

The Foundry Process Consists of Many Steps[32]

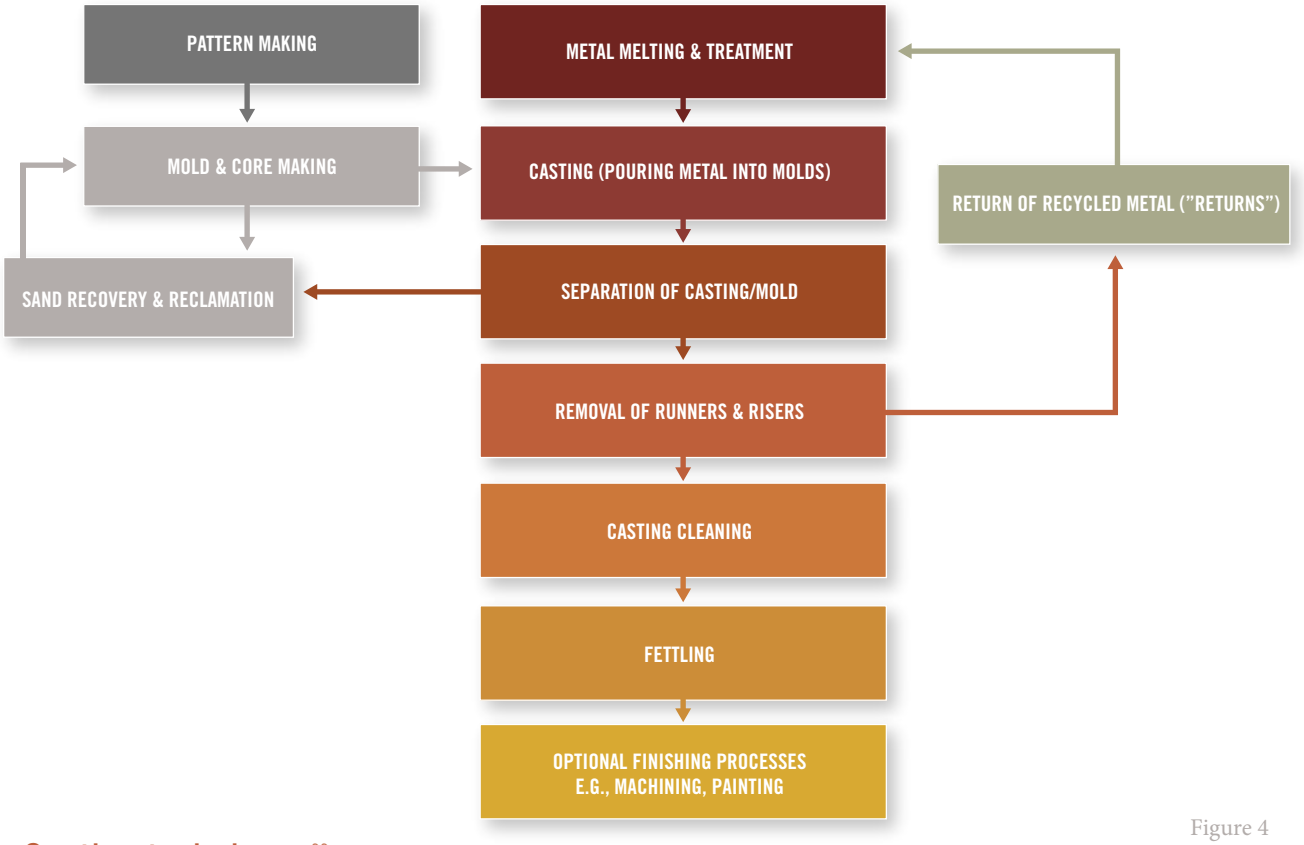


Figure 4

Casting techniques[33]

Although sand casting is the predominant production technique, other methods are used as well.

Metal molds are used for certain types of production including centrifugal casting techniques and die-casting. Centrifugal (spun) casting involves pouring the metal into a rotating mold. It is used for making pipes, rolls, and cylinder liners. Die-casting is commonly used for production of aluminum and zinc castings.

Metal Melting: Molten metal is prepared in a variety of furnaces, the choice of which is determined by the quality, quantity and throughput required.

- **Electric induction furnaces** are the most common type used for batch melting of ferrous, copper and super alloys. This method involves the use of an electrical current surrounding a crucible that holds the metal charge. Furnace sizes range from < 100 kg up to 15 tons. For production of super alloys and titanium, melting may be undertaken in a vacuum chamber to prevent oxidation.
- **Cupolas** are used solely by iron foundries for continuous production of molten iron. The cupola consists of a shaft in which a coke bed is established. Metal, coke and limestone are alternately charged into the furnace from the top. Molten metal trickles through the coke bed picking up essential carbon, while impurities react with the limestone to form waste slag. Both metal and slag are continuously tapped out at the bottom.

32 www.castingstechnology.com/public/documents
33 Ibid

- **Electric arc furnaces** are still used by a few ferrous foundries, mainly to produce steel castings, although most have been replaced by induction furnaces. Furnace capacities range from three tons to one hundred tons. The design involves the use of a holding bath into which electrodes are inserted, and the heat generated by creating a charge between the electrodes causes the metal to melt.
- **Rotary furnaces** are relatively uncommon but are used in some iron foundries. The furnace consists of a horizontal cylindrical steel shell mounted on rollers and lined with refractory material. The furnace is fired from one end using gas or oil and the furnace body is slowly rotated during melting.
- **Gas-fired shaft and resistance furnaces** are used for melting aluminum. They provide a continuous melting and tapping capability, useful at high production facilities. Resistance furnaces are employed for melting small batches.
- **Gas and oil-fired crucible furnaces** are used for small batch melting of copper and aluminum alloys, although oil-fired units are less common now and tend to be limited to smaller foundries. Unlike the larger furnaces where molten metal is tapped into a ladle for casting, the crucible is lifted out (or pops out) of the heating chamber and the molten metal can be poured directly into the mold.

Casting and Separation

- Molten metal is poured into molds using various types of ladles, or in high volume production, automated pouring furnaces. Metal is poured into the "runner" (a channel into the mold cavity) until the "runner bush" is full. The "riser" provides an additional reservoir of feed metal to counteract the shrinkage that occurs as the casting begins to cool.
- When the metal has cooled sufficiently for the casting to hold its shape, it is separated from the mold by mechanical or manual methods.

Casting a Sand Mold

Where sand molds are used, the process is often referred to as shakeout or knockout, and large amounts of dust may be generated. The industry recycles a large proportion of mold and core, making sand internally for reuse. This involves processing to remove tramp metal and returns the sand to a usable condition for mold or core production.

Finishing

A range of finishing processes include:

- Cleaning to remove residual sand, oxides and surface scale, often by shot or tumble blasting
- Heat treatment, including annealing, tempering, normalizing and quenching (in water or oil) to enhance mechanical properties
- Grinding to remove excess metal or surface blemishes, (e.g., flash resulting from incomplete mold closure or burrs left from riser cut-off), or by sawing or arc air (oxy-propane) cutting
- Rectifying defects by welding
- Machining
- Testing to check for defects
- Priming, painting or application of a rust-preventative coating

WELDING:
"The craft of fusing metal is getting more respect from manufacturers."[34]

For most of the past 30 years, a career in welding offered limited growth potential. In 1988, there were 570,000 welders in the U.S. and by 2012 there were only 360,000. The recent growth of U.S. manufacturing, combined with the oil and gas boom of the past few years, has driven demand for skilled welders past capacity. The American Welding Society predicts there will be a shortage of 290,000 welding professionals by 2020. The Manufacturing Institute of the National Association of Manufacturers says small and medium manufacturers are in direct competition with major corporations in seeking skilled welders. GE hired 55 in 2013; Caterpillar is hiring several hundred over the next couple years. Hobart is adding 52 welding booths to its capacity.

U.S. manufacturers say the shortage is costing them money. "We have welding jobs and can't find people to fill them . . . we're turning down business because we don't have the manpower."

Lack of skilled welders has extended the time it takes manufacturers to delivery orders. "That's costing us about $2 million a year." (Company revenue is $14 million.)

Hobart Institute of Welding Technology in Troy, Ohio, is one of the top programs in the nation. Since 1930, they have taught students how to figure out cosigns, tangents, the distance of a line, the degree of an angle, and the circumference of a circle—all skills required of welders striving to make a perfect weld that makes the metal stronger. This is crucial for welding pipeline across rough terrain or running pipe into a refinery at unusual angles. Hobart's program requires a high school diploma or GED and tuition costs $25,000. Students practice for 1,000 hours and learn to work with advanced materials and complicated alloys such as aluminum, titanium and stainless steel. They graduate in nine months, 83% have job offers when they leave, and their average starting pay is $17.00 an hour, or $36,000 a year.

34 BusinessWeek, March 24-April 6, 2014. Welders, America Needs You, pp. 19-21

U.S. & GLOBAL METALS & MACHINERY MANUFACTURING OPPORTUNITIES

Defense – The ordnance market includes weapons, ammunition, combat vehicles and tools for every area of defense. Forged metal components are used in everything from gun triggers to mortar shells and submarine drive shafts. This segment is projected to fall 9.5% over the coming years due to decreased military spending. The industry uses forged valves and fittings such as flanges, stems, tees, elbows, reducers and saddles.

Oil & Gas – Oil field applications include drill bits, rock cutter bits, drilling hardware, crankshafts and numerous other parts and pieces. This industry is projected to grow, with increasing demand in the "Energy Coast" of Texas, Louisiana, and Alabama, as well as the Bakken region of North Dakota, Montana and Lower Canada. The Bakken shale region is 200,000 square miles, where hydraulic fracturing or "fracking" is being used to get at an estimated 2.1 billion barrels of oil. Currently, the Bakken area is behind Texas and ahead of Alaska in oil production.

Alternative Energy Sources – Wave and wind turbine blades require metal alloys and composites. The U.S. Department of Energy's National Renewable Energy Laboratory estimates there are more than 900 gigawatts of offshore wind capacity along the Pacific Coast. "That's about the same as the Country's installed power capacity."[35] The Oregon wind farm, valued at $200 million, will consist of five Siemens turbines 15 miles off the coast. It will be connected to the grid via an underwater cable in 2017.

Infrastructure – The U.S. operates 21st century firms, applications and national security on 1940s and 50s infrastructure that needs to be replaced.

- Roads
- Bridges
- Energy Grids
- Energy Pipe and Trunk Lines

Transportation – Increasing NAFTA trade and interstate trade requires highway and rail support that is fast and fuel-efficient.

- Rail
- Light rail
- Marine cargo vessels
- Lightweight freight trucks
- Electric vehicles
- Rail and marine containers

Market Sectors

Machinery manufacturing is the second smallest market segment at a small fraction of the total market, as depicted below.

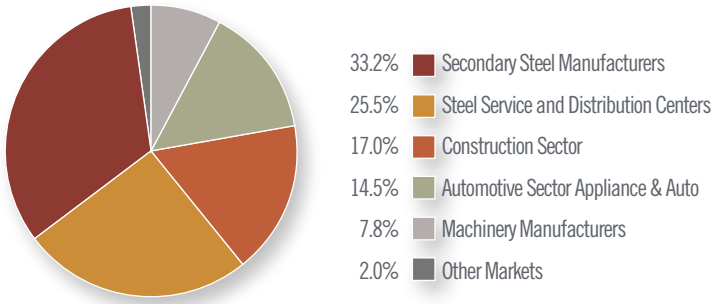


Figure 5– IBISworld.com 2013

35 Casting Wind Turbines Out to Sea. Bloomberg BusinessWeek, Focus on Energy, page 48. March 3, 2014

Product Segments

As shown in Figure 6, "pipes and tubing" is currently a small segment; but it is predicted to grow thanks to increasing demand from the gas and oil industry, along with upgrades in water transport. More than 50% of product segmentation comes from basic shapes, sheets and bars.

Major industrial machinery manufacturers include ABB Group, Honeywell International, Inc., Emerson Electric Company, Eaton Corporation, Rockwell Automation, Hubbell Inc., ITT Corporation, and IDEX Corporation. The outlook for this sector is modest growth. The aging of equipment and reduced investment spending during the recent recession have led to pent-up demand. It has also led to increased spending on maintenance, repair and replacement parts.[36]

Major end-user markets for industrial machinery include agriculture, construction, mining, and energy. Both U.S. and international demand for machinery for all those segments, except farm machinery, has been increasing since 2012.[37]

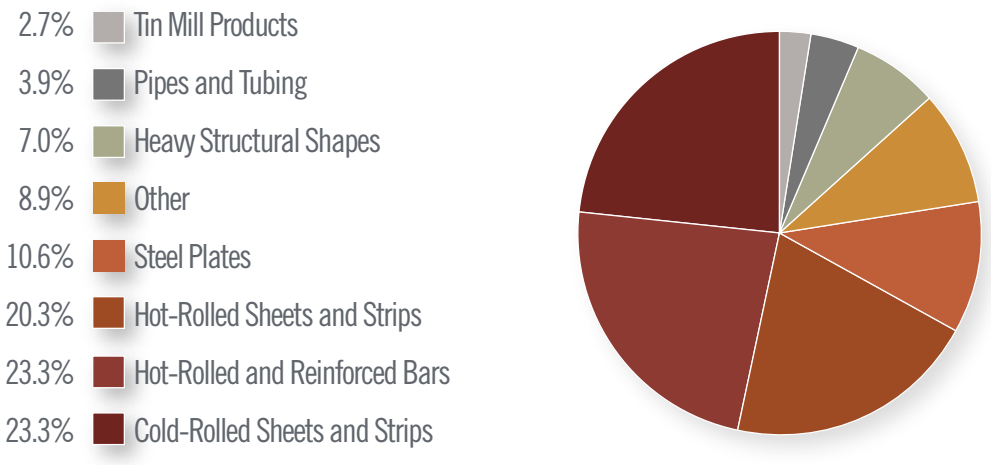


Figure 6 - IBISworld.com 2013

U.S. Market

The U.S. market ranks third in global steel production, with output only 12.3% of China's. The Great Lakes region is home to nearly half of all U.S. iron and steel production; but it has only 30% of the companies in iron and steel manufacturing. Ohio has the most companies at 9.9%. This is due to years of automotive production, two mines in Michigan, and Great Lakes waterways providing transport for coke and iron ore as well as access to markets in the U.S. and Canada.[38]

The industry is not highly concentrated, with the four largest players accounting for only 45% of revenue. More than 100 smaller companies were acquired or went out of business during the recession. Consolidation is expected to increase over the next five years as U.S. producers face increasing global competition and rising materials costs.

36 Standard & Poor's Industry Survey, Industrial Machinery. March 2013
37 Zack's Investment Research. Machinery Industry Outlook. January 2013
38 IBISWorld Industry Report 33111, November 2012

U.S. Metals Manufacturing Geography

The Southeast and Mid-Atlantic regions are major iron and steel manufacturing areas due to pig iron production. Pennsylvania is the largest producer with 9.9% of industry businesses.

U.S. iron and steel manufacturing is showing signs of recovery after years of decline. Until 2007, 45% of U.S. steel was produced in blast furnaces. By 2012, that dropped to 39% of production as manufacturers moved to electric arc furnaces. They basically recycle scrap metal to avoid the rising cost of iron ore and coking coal.

Steel faces competition from other materials such as aluminum, lighter weight steel alloys, and carbon fiber. While more expensive, they provide greater fuel efficiency and add less weight. China, India, and Brazil are expected to outpace the U.S. in steel production over the next five years.

Metals & Machinery Manufacturing Industries By NAICS Code[39]

NAICS Code	Industry	Location Quotient[40]
331	Iron & Steel Manufacturing	1.9
3315	Ferrous & Nonferrous Metal Foundry Products	4.53
332	Fabricated Metals, Light Metals, Composites, Copper Rolling, Drawing, Extruding	.25
33271	Machine Shop Services	1.17
325	Plastics & Polymers	.23
333	Agriculture, Construction & Mining Machinery	.82

Figure 7

A location quotient (LQ), is a way to quantify how concentrated a particular industry is compared to the national average. It indicates what makes a region unique based on relative employment data. An LQ greater than one (1) is above the national average. As shown in Figure 7, Metal Foundry Products in the Portland region are nearly five times the national average, and Iron and Steel Manufacturing is twice the national average. Fabricated Metals and Plastics & Polymers, important sources for additive and subtractive manufacturing, are way below the national average.

Ferrous: Iron & Steel

Nonferrous: Aluminum, Copper, Titanium, Nickel, Magnesium, & Alloys

39 www.bls.gov

40 U.S. Bureau of Labor Statistics, 2014

Metals & Materials Manufacturing Sectors[41]

Stamping and forging are the most predominant forms of metal products and services sectors, as shown in Figure 8.

Figure 8 – IBISworld.com, 2013

Making With Metal

All ferrous metals are magnetic and have poor corrosion resistance, while nonferrous metals are typically non-magnetic and have more corrosion resistance. An overview of common manufacturing metals is provided in Appendix C.

Metal stamping – Forming processes such as blanking, punching, piercing, forming and drawing are performed on sheet metal using a machine or stamping press. Production is done in one step or a series of stages.

Ferrous and nonferrous forgings – The process by which metals are heated and shaped by applying compression using a hammer or press. Iron, steel, and aluminum forgings include cold forgings, ferrous forgings, gun forgings, hammer forgings, horseshoes, press forgings and upset forgings.

Custom roll formed products – Mass production, batch production and jobbing (one-off products) are made from processed metals. Higher demand from automobile manufacturers has increased output, especially for lightweight aluminum roll products for fuel-efficient cars. This segment also includes powder metallurgy and metal crowns for closures on food and chemical storage containers.

Tubular bending and coating – Tube fabrication, forming and bending is a sub-industry with growing demand from the oil and gas industry for pipelines and below-sea applications, water use, HVAC installations and industrial and residential construction and furniture. All of those forms of manufacturing are used in the industry, which is segmented into five major sectors shown in the chart below.

U.S. Metals Manufacturing Geography

The entire industry is highly concentrated in the Great Lakes region, which has 34.2% of U.S. companies and generates 32% of industry revenue. California is the single greatest producer due to demand from neighboring Mexico.

41 IBISWorld.com/reports/us/industry. February 2014

Leading U.S. Players & Market Share in Nonferrous Metals Manufacturing

- Alcoa Inc., New York, New York – 9.2%
- Precision Castparts Corp., Portland, Oregon – 7.1%
- Other – 83.8%

Figure 9 - IBISworld.com, 2013

Iron & Steel (Ferrous) Manufacturing (NAICS 3111) – Growing International Competition

The last recession led to a reduction in demand as manufacturing and construction industries fell. As demand and prices declined, revenue plunged 50% in 2009. They recovered in 2010-11, though slowly. Prices have risen, but demand is predicted to be slow through 2014 due to weak economic performance in the U.S. and U.K. Weak performance has led to consolidation in the domestic market, and international competition is on the rise. While U.S. revenues are predicted to increase 4.7% through 2017 due to increasing prices, real growth will be minimal compared to competing nations. Domestic demand comes from primary metals manufacturing, mostly for construction and the automobile industry, as well as mining, industrial manufacturing, electric and gas utilities and oil pipelines, which are expected to grow from 2014 on, presenting a potential market opportunity.

Leading U.S. Players & Market Shares in Ferrous Metal Manufacturing

- Arcelor Mittal – 15.0%
- Nucor Corp. – 11.8%
- U.S. Steel – 11.5%
- Steel Dynamics – 6.9%
- AK Steel Holding Corp. – 5.2%
- Other – 51.8%

Figure 10 - IBISWorld.com, 2013

Nonferrous Metal Rolling & Alloying (NAICS 33149) – U.S. and International Trade Opportunity

This industry produces semi-fabrications of sheet, wire, plate, foil and extruded products from nonferrous metals, except copper and aluminum, for rolling into finished products. Manufacturers roll, draw, extrude, and alloy metal, and recover nonferrous metals and alloys from scrap. Inputs include copper, zinc and lead, electric power and inorganic chemicals. It provides product for iron and steel manufacturers, mining, oil and gas machinery manufacturers, batteries, automobiles and trucks, and aircraft engine and parts manufacturers. International trade is a key growth area with increasing competition.

The oil and gas and mining machinery sectors are a major user of nonferrous metals. U.S. production of oil and gas is increasing dramatically, requiring parts for drilling, extracting and distributing oil and natural gas. Companies in those sectors are developing and expanding production of high-margin energy products. These sectors provide good opportunities for Pacific Northwest manufacturers to expand into the Bakken region and the Louisiana energy coast, where oil and natural gas production demands are enormous. U.S. players can expect higher margins and lower production costs, making them more competitive in the international market.[42]

42 IBISWorld, 2014

Leading U.S. Players & Market Share in Rolling & Alloying

- Allegheny Technologies Inc., Pittsburgh, Pennsylvania – 11.5%
- Precision Castparts Corp., Portland, Oregon – 8.6%
- Carpenter Technology Corp., Reading, Pennsylvania – 7.3%
- Horsehead Holding Corp., Pittsburgh, Pennsylvania – 1.8%
- RTI International Metals Inc., Pittsburgh, Pennsylvania – 1.3%
- Other – 69.5%

Figure 11 – IBISworld.com, 2013

Metals manufacturing involves eight different metallurgy specialties.

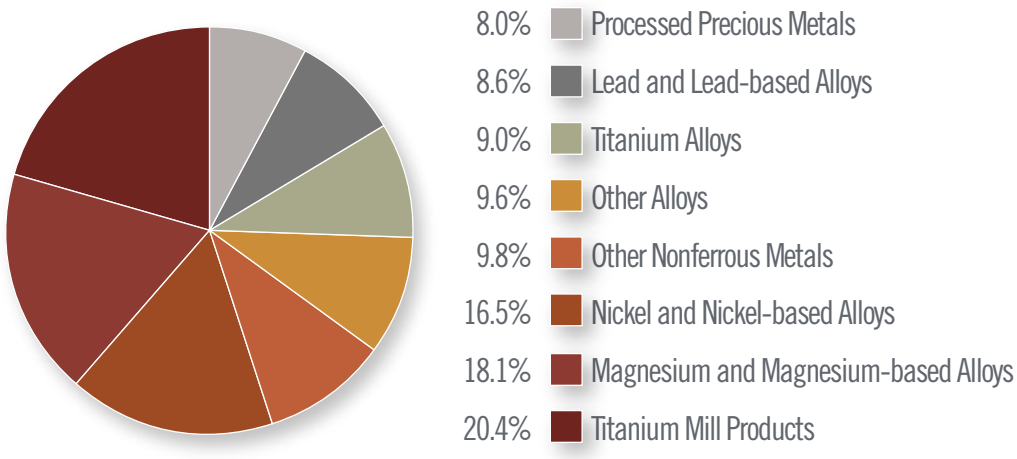


Figure 12 – IBISworld.com, 2013

Metal manufacturers supply every industrial market from mining to consumer products, and it is a $22.3 billion industry.

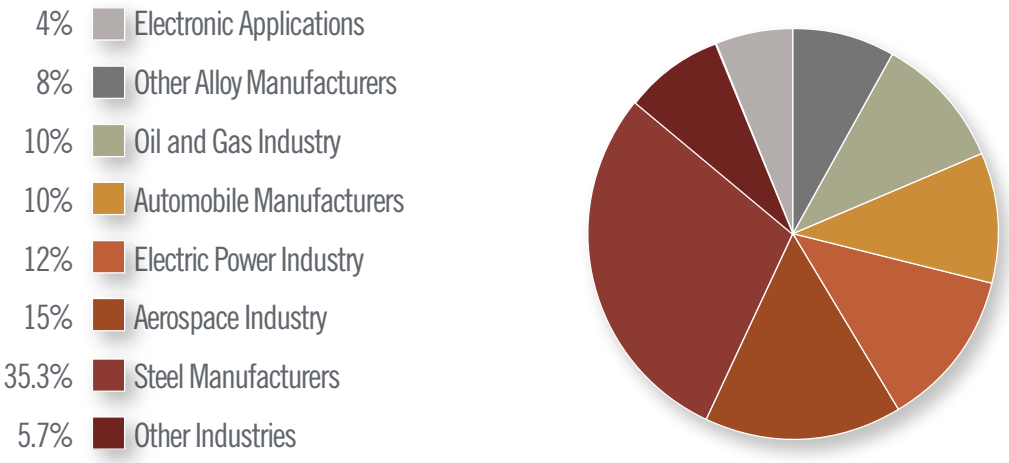


Figure 13 – IBISworld.com, 2013

Metal Stamping & Forging Regions

The same regions contributing significantly to metals manufacturing are also the biggest providers of stamping and forging, with Pennsylvania (13.0%) dominating the industry, followed by New York (8.8%), Ohio (7.2%), California (5.1%), Texas (5.0%), Massachusetts (4.8%), Illinois (4.1%), and Alabama (4.0%).

Metal Stamping & Forging (NAICS 33211) – A Declining Industry

These manufacturers produce forgings, metal custom roll forming products, stamped and spun products, and powder metallurgy products. Forging is the process of shaping metal. Stamping is a method for forming sheet metal into shapes using a press. Powder metallurgy blends and compresses fine powdered materials into desired shapes. Demand comes from machinery manufacturing; aircraft, engine and parts manufacturing; and turbine and automobile manufacturing. Inputs include aluminum, metal pipes and tubing, nonferrous metal rolling and alloying, paint manufacturing, steel rolling and drawing, and small hardware manufacturing (nuts, bolts, screws, etc.).

Major players are Alcoa, Inc. and Precision Castparts Corp., and increasing industrial demand is expected to drive industry growth.

Automobile Manufacturing – Auto production includes various forged components, and demand for autos is expected to grow in 2014.

Machinery Manufacturing – Demand is expected to increase in 2014 for stamped and forged metal parts used in agricultural machinery and the manufacture of engines and turbines.

Aircraft, Engine and Parts Manufacturing – Aerospace parts require the most complex and technically advanced metals, as applications are required to become lighter yet stronger. Demand is expected to increase during 2014.

Overall, this industry is predicted to shrink over the next ten years because:

- The number of business are declining as consolidation increases
- Forging and stamping techniques have had few technological advances
- The industry's contribution to the overall economy is declining
- Aerospace & defense, computers & electronics, and metals & machinery manufacturing industries are putting more resources and expectations into additive manufacturing

Competition from aluminum, titanium, and advanced alloys allow firms to use materials that are lighter, greater in strength, more tolerant of temperature extremes, and more resistant to corrosion.

Leading U.S. Players & Market Share in Metal Stamping & Forging

- Alcoa Inc., New York, New York – 9.2%
- Precision Castparts Corp., Portland, Oregon – 7.1%
- Allegheny Technologies Inc., Pittsburg, Pennsylvania – 3.7%
- Other – 80%

Figure 14 – IBISworld.com, 2013

The largest percentage of metal-stamped products represents demand from automakers and industrial machinery manufacturers.

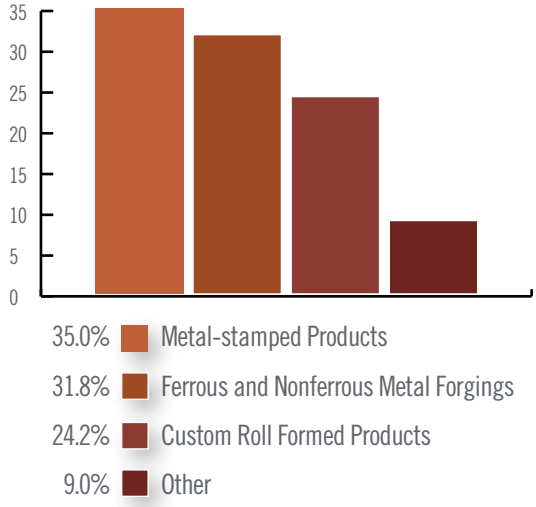


Figure 15 – IBISworld.com, 2013

Aerospace and agricultural markets play a great part in demand for stamped and forged products.

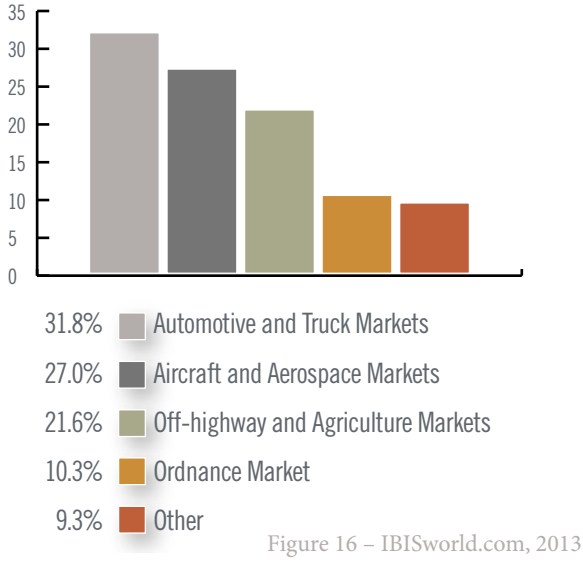


Figure 16 – IBISworld.com, 2013

33231 Structural Metal Product Manufacturing (NAICS 33231) – New Building Will Drive Growth But Exports Pressure Profits

Metal products include fabricated structural metal products, prefabricated metal buildings, panels, sections, and metal plate work: steel and concrete reinforcing bars (rebar), fabricated bar joists, and structural panels for bridges and ships. Suppliers include aluminum manufacturing, copper rolling, drawing and extruding, iron and steel manufacturing, and metal pipe and tube manufacturing. Parts and products are used for residential and commercial building construction, infrastructure (bridge and tunnel) construction, shipbuilding, automobiles, and HVAC manufacturing.

Leading U.S. Players & Market Share in Structural Metal Products

- Nucor Corp., Charlotte, North Carolina – 9.2%
- Alcoa Foundation, Pittsburgh, Pennsylvania – 8.5%
- Commercial Metals Co./CMC Americas/CMC International, Irving, Texas – 3.5%
- NCI Group Inc., Houston, Texas – 2.9%
- Gerdau AmeriSteel Corp., Las Vegas, Nevada – 2.4%
- Hirschfield Industries Inc., Irving, Texas – 1.3%
- Other – 72.2%

Figure 17 – IBISworld.com, 2013

As shown in Figure 18, construction and infrastructure industry needs provide the largest demand for structural metal products.

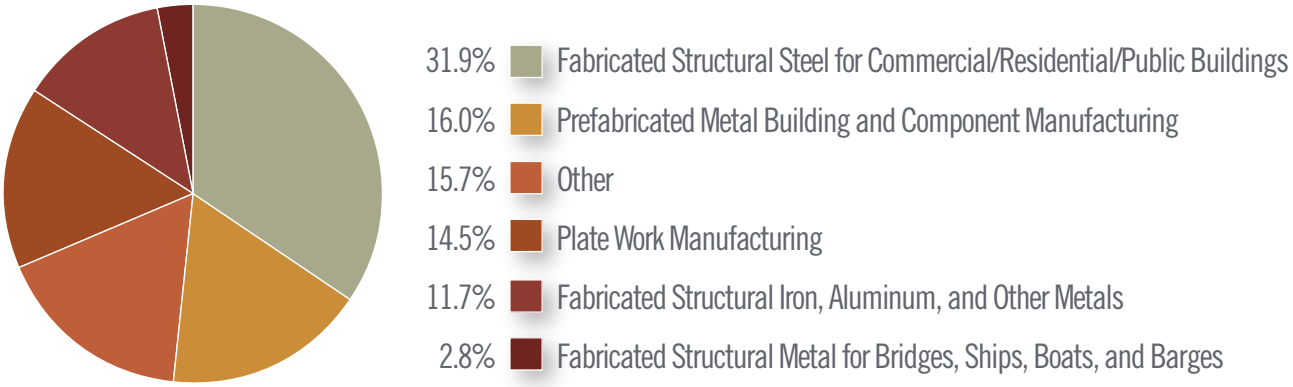


Figure 18 – IBISworld.com, 2013

Metal Tube & Pipe Manufacturing (NAICS 33121) – Oil & Gas Extraction and Pipelines Will Increase Demand; Two Major Players Are Regional Firms

Producers supply products for oil drilling and gas extraction, industrial construction, HVAC, and appliances manufacturing, as well as auto and light truck manufacturing. Inputs are iron and steel, ferrous and nonferrous metal foundry products, and paint/coatings. Imports are strong, but U.S. competitiveness is improving[43] due to increased demand from the domestic oil and gas sector. Metal pipes and tubes are built to withstand high-pressure extraction work and high-risk pipeline distribution. Natural gas extraction and distribution is growing rapidly in the U.S. In addition, demand is growing for water and wastewater applications to replace existing infrastructure, and from increased automobile production. New companies are expected to enter the market to meet these growing demands.

Leading U.S. Players & Market Share in Pipe & Tube Manufacturing

- Tenaris S.A., a global corporation with U.S. locations in Kentucky and Georgia – 24.8%
- **Northwest Pipe Company, Vancouver, Washington – 4%**
- **Oregon Steel Mills (Evraz Group S.A.), Portland, Oregon – 4%**
- Webco Industries, Inc., Sand Springs, Oklahoma – 3.5%
- RathGibson (PCC Energy Group), Janesville, Wisconsin – 2.9%
- American Cast Iron Pipe Co., Birmingham, Alabama – 2.5%

Figure 19 – IBISworld.com, 2013

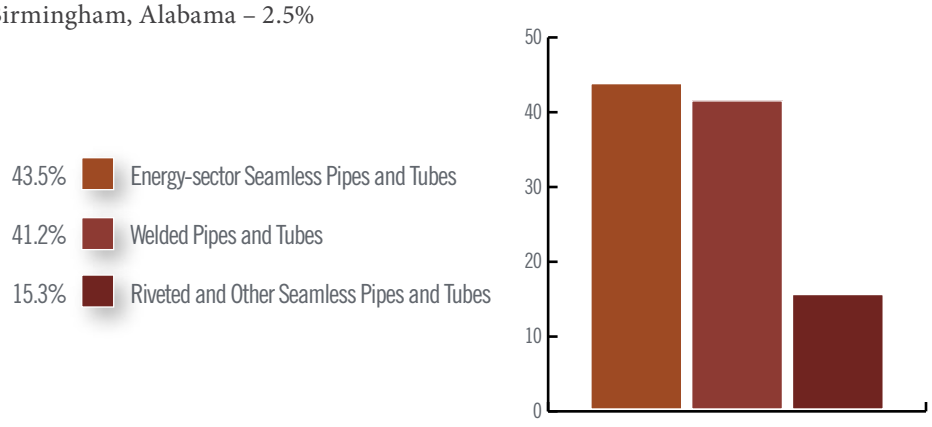


Figure 20 – IBISworld.com, 2013

43 IBISWorld.com Industry Outlook

Machine Shop Services (NAICS 33271) – Solid Demand is Coming from Increased Investments for Infrastructure and Oil and Gas Extraction

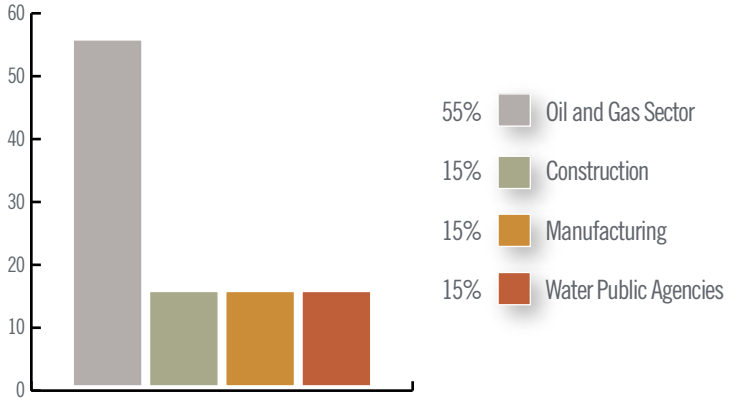


Figure 21 – IBISworld.com, 2013

As shown in Figure 21, oil & gas producers are by far the largest buyers of metal pipes and tubes.

Machine shops cut raw materials into shapes and sizes using milling machines, lathes, grinders and drill presses. Computer Numerical Control (CNC) milling is common. Turning is used to produce cylindrical components; other processes include broaching, fastening, planning, and grinding to remove burrs and then adding shine and gleam with anticorrosive finishing applications, paint or coatings. All forms of metal fabrication involve machining, as do plastics and composite materials. Supplies used include aluminum; rolled, drawn and extruded copper; metal pipes and tubes; stamping and forging; metalworking machinery; and hardware. Demand comes from metal stampers and forgers, industrial machinery manufacturers, the oil and gas industry, engine and turbine manufacturers, and wind turbine manufacturers.

Increased manufacturing in general is expected to increase growth. Additional demand is coming from aerospace for satellites and unmanned aerial vehicles, as well as for wind turbines, oil and gas machinery and equipment, and medical devices. The impact of additive manufacturing on this industry has yet to be determined; but industry experts predict there will always be a need for local machining, although the industry may consolidate and shrink.

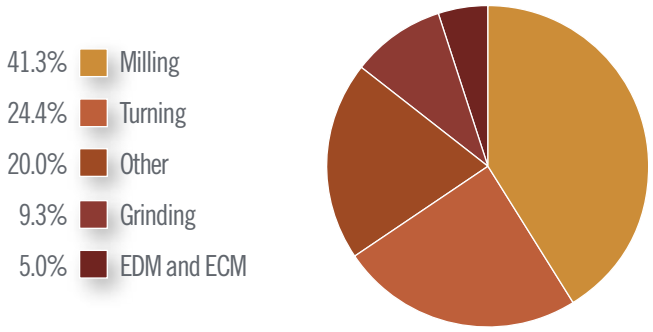


Figure 22 – IBISworld.com, 2013

This sector is made up of thousands of small, medium, and large companies, so there are no major players with significant market share. There are more than 600 companies in the greater Portland region alone, as depicted on the GIS Map on page 35 of this report.

Metal Plating & Treating (NAICS 33281)

- 30.0% Other Markets
- 27.6% Heavy Machinery and Civilian Vehicle Markets
- 16.1% Defense Markets
- 14.9% Commercial Airline Markets
- 11.4% Medical Markets

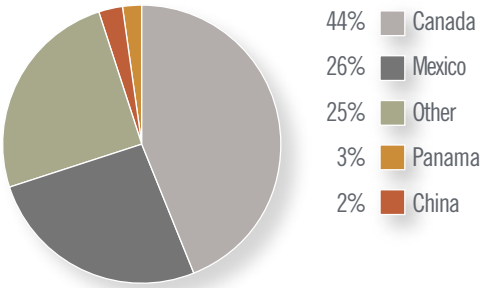
Figure 23 – IBISworld.com, 2013

INTERNATIONAL TRADE & U.S. EXPORTS

Exports are predicted to grow moderately due to increased demand from Latin American markets, such as Venezuela and Colombia.

Metals & Alloys

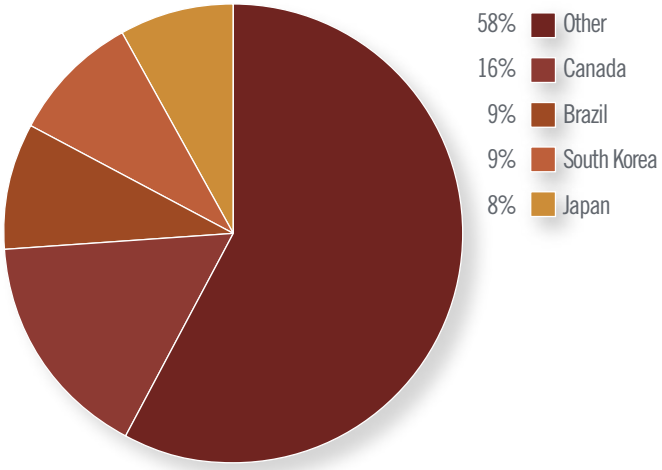
EXPORTS TO . . .



Total $16.5 Billion

YEAR: 2013

IMPORTS FROM . . .



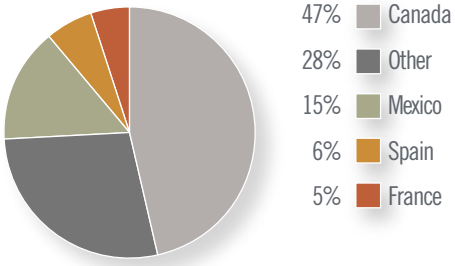
Total $37.3 Billion

YEAR: 2013

Figure 24 Source: USITC

Manufactured Metal Products & Machinery

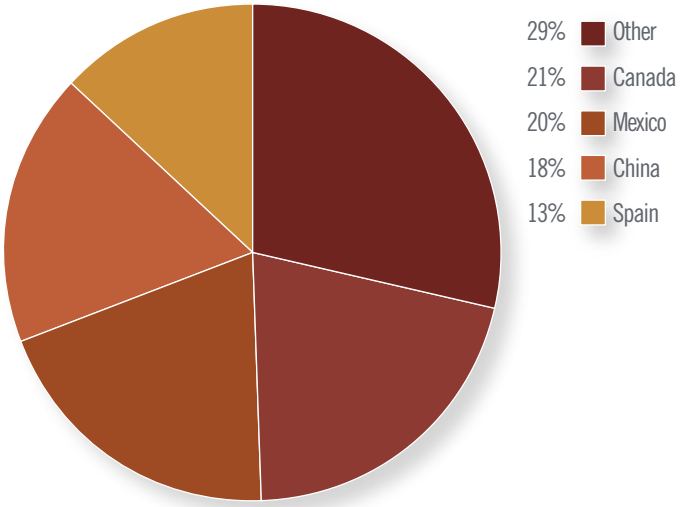
EXPORTS TO . . .



Total $163 Million

YEAR: 2013

IMPORTS FROM . . .



Total $516.8 Million

YEAR: 2013

Figure 25 Source: USITC

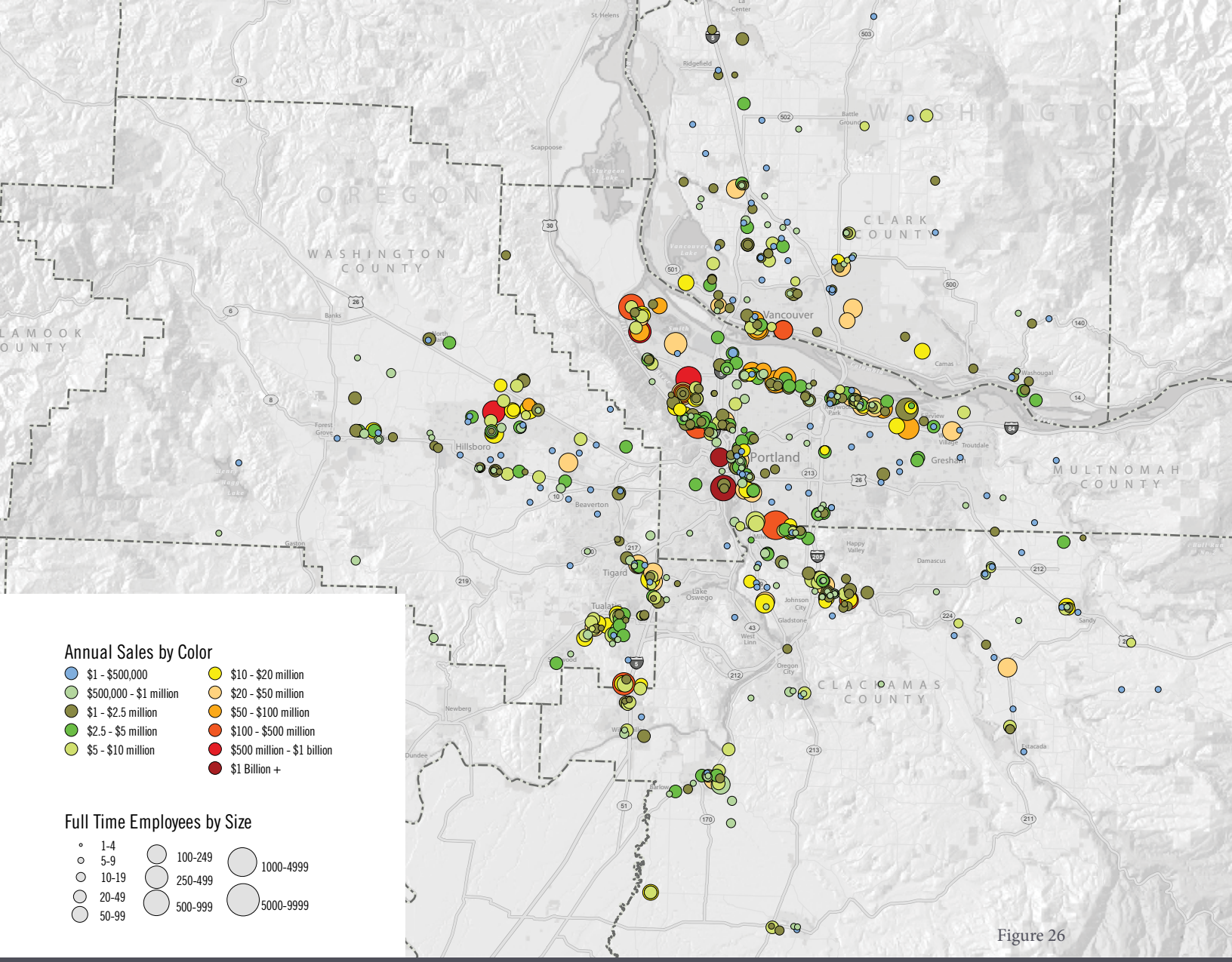


Figure 26

REGIONAL METALS MANUFACTURING GIS MAP

As shown in Figure 26, there are nearly 600 small, medium, and large metals manufacturing companies in the Greater Portland region. They range from small machine shops with a few employees to major producers supplying Boeing, Gunderson Rail, Daimler, and other aerospace, defense, transportation, infrastructure, and industrial machinery manufacturers. The list of companies depicted on the map is provided in Appendix A.

MAJOR REGIONAL METALS SUPPLIERS

Precision Castparts Corporation[44]

Founded in 1953, Portland, Oregon, based Precision Castparts Corporation (PCC) is a global manufacturer of complex metal components and products. The company produces castings, forgings, nickel and specialty alloys, seamless pipes, refiner plates, fasteners, and other related products that are primarily used for aerospace, industrial manufacturing, energy, chemical processing, oil and gas, and pollution control industries. The company divides its operations into three principal business segments: investment cast products, forged products, and fastener products. PCC participates within the metal stamping and forging industry via its forged products segment, which operates through several of the company's subsidiaries, including Texas-based Wyman-Gordon and Hackney Ladish Inc. (acquired in 2008) and New Jersey-based McWilliams Forge Company (acquired in 2007). These companies and the broader forged products segment manufacture titanium, nickel and steel forgings and forged pipe fittings for commercial, aerospace and defense, and energy infrastructure applications. PCC also produces various jet engine components, including titanium and nickel-based fan discs, compressor discs, turbine discs, seals, spacers, shafts, hubs and cases.

In fiscal year 2014, PCC's forged products segment is estimated to generate $3.9 billion in U.S. revenue, with $846.9 million in operating income. This figure represents estimated growth of 10% from 2012, marking an annualized growth rate of 5.7% over the past five years.[45] Sales of forged products increased in 2013 as the aerospace industry renewed previously canceled orders, which were discontinued because of the recessionary environment. Revenue also rebounded strongly over the prior two years, contrasting with performance in fiscal 2010, when the recession severely cut company shipments. However, PCC is expected to rebound faster than many other industry companies due to its size, product integrity, and ability to fulfill an array of customer requests. In 2012 alone, PCC acquired eight companies, further solidifying its position as the number one manufacturer in the metal stamping and forging industry. The company's industry dominance allows them to attract new business from clients whose previous contractors were forced out of business during the recession. In fiscal 2013, PCC acquired two additional companies, Texas Honing, Inc. in services, and Titanium Metals Corporation, a manufacturer.

44 IBISWorld, 2013
45 PCC website and financial reports

ESCO

Expert in metallurgy and metals manufacturing, ESCO makes highly engineered parts that are essential for mining, infrastructure, oil and gas, and industrial machinery. It is the world's first foundry to use Argon-Oxygen Decarburization (ACD) to purify steel. ESCO's sophisticated computer-aided design system is integrated with its computer-aided manufacturing system to ensure products meet precise specifications. The 100 year-old Portland, Oregon, company sources materials and parts from Mexico, Slovakia, China, and India. ESCO's global supply chain management system requires superior supplier performance and on-time delivery. Suppliers are monitored using supplier-quality engineering and statistical process controls. It manufactures on a just-in-time basis to provide online inventory access for its customers.[46]

In 2014, the privately held company acquired Stabiltec Downhole Tools, a manufacturer of specialty drilling tools, to be able to better serve the growing oil and gas industry.

ATI/WAH CHANG

Headquartered in Pittsburgh, Pennsylvania, Allegheny Technologies Inc. is one of the world's largest specialty metals and components producers. The Wah Chang division, headquartered in Albany, Oregon, produces reactive and refractory metals, powdered metals and alloys, including zirconium, hafrium, niobium, tantalum, titanium, vanadium, and zirconium. It manufactures components and cutting tools. Their mill, in business since 1956, makes ingots, slabs, billets, bars, rods, tubes, extrusions, wire, sheet, foil, chemicals and powders, castings, forgings, and bar. They also produce near net shape and custom shapes. They are suppliers to the aerospace and defense, oil and gas, energy, automotive, construction, mining, electronics and medical, and food equipment and appliance industries, among others. The publicly traded company has facilities in the U.S., Europe, and Asia.

PCC STRUCTURALS

Founded in 1949 by Oregon Saw Chain as an investment casting operation[47] and headquartered in Clackamas, Oregon, PCC Structurals is a spin-off from Precision Castparts Corp. It produces super alloys, aluminum and titanium castings for jet aircraft engines, airframes, industrial gas turbine engines, the defense industry, medical prostheses and other industrial uses. The company has twelve facilities in the U.S. and France, and manufactures the largest investment castings in the world. It provides design and engineering services, in-house rapid prototyping, modeling analysis, materials testing, heat treating, welding, and finish processing such as machining, coating, and painting. The company uses lean manufacturing techniques.

BLOUNT International

Founded in 1947 as part of Oregon Saw Chain, the company spun out in 1957 and was renamed Omark Industries. In 1980 the company was listed on the American Stock Exchange, and in 1985 it was purchased by Blount Inc., an Alabama manufacturer of chain saw equipment for the construction industry. In 1995 it was renamed Blount International and has since become a worldwide manufacturing company that manufactures for the forestry, agriculture, lawn and garden, and farm and ranch industries. They are a major supplier to Husqvarna. In 2002 the publicly traded company moved its headquarters to Portland, Oregon. Blount has grown through acquisitions and developed a world-wide distribution network including Canada, Brazil, and China.

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46 ESCO website

47 Investment casting is a technique for making small, accurate castings in refractory alloys using a mold formed around a pattern of wax or similar material, which is then removed by melting.

Voices & Views

"Most companies here are 35 or fewer people . . . There's a big need for networking that allows buyer industries to have a resource list and supplier companies to network with potential customers. [Manufacturing] events like PDC's are important."

"We source steel products from distributors here with value-added services. Other stuff we buy local, but through distributors, [including] fasteners made in Asia, chain made in Asia, bearings made in Asia, drives and electric panels from U.S. markers, and motors from U.S. companies."

"We source lots of technical services that work locally, machine repair and software."

"Here's the theme: Higher tech comes from [U.S.] companies that design and manufacture. The rest is all imports."

Best Practices Shared By Successful Regional Suppliers

"Leverage successful relationships in industry and geography."

"Offer Value-Added Services."

"Do not try to bolt on a menu of services to your existing business. Think about your value proposition and how it relates to the outcome the customer is seeking. Bose offers "sound"; it does not sell speakers. That expands the idea of what you can do, such as working with other contractors to provide whole systems, not just parts and pieces. How can you configure your business to provide what your customer really values?"

"It's not enough to know what your machine does; you need deeper and wider knowledge embedded into your culture."[48]

"Most small and medium suppliers do not have the internal resources to provide every skill in-house. Share connections with other suppliers to deliver a full range of services . . . even if they come through you and not from you."

"Don't sell products, sell business outcomes and problem solutions." Rolls Royce sells "power by the hour" – the downtime risk related to engine failure. That is a bottom-line benefit.

"What can you offer in terms of customization, logistics, unique information services, inventory management, or special shipping arrangements that enhance your product and service differentiation? Is there data from your processes that can enhance theirs?"

Specifically:

Can the components you make be not just shipped on time, but sorted or sequenced to meet the needs of particular assembly processes that reduce plant handling and inspection at the customer's end? Can you offer guarantees?

- Consult with clients on design, performance requirements, quality parameters, and production techniques; and engineer custom-designed solutions.

Generally:

- Stay engaged. "Don't sell something and walk away." Transactions are not relationships. Build trust by following up: "How did it go? What could be better? Do you need help?" Those three questions can generate repeat orders and cement long-term relationships.
- Provide connections to product-related experts and services that expand your relevance and provide broader support for customers

48 Journal of the Global Accounting Alliance. The Benefits of Value-Added Services. December 16, 2013

Workforce Voices & Views

"Have respect for your workforce. It's a partnership between management and machinists."

"Manufacturing is a variable cost business based on fluctuating demand. Workforce has to be built on that. How do we help companies with a flexible pool? That's a manufacturing industry problem."

". . . need apprenticeship programs for integrated learning."

"Exposing students to theoretical knowledge through context is necessary. Dollars shrank and tech evaporated from U.S. high schools."

"OSU College of Engineering is growing fast; and mechanical engineering is growing fastest of all. It is doubled in size since 2004 and they are adding faculty."

"Washington State [University Vancouver] and Clark College are applicable for mechatronics and fluid and electric power. They teach programmable logic controls at Clark. Good employees have technical capabilities and understand design and engineering."

"Workers here need communication skills, problem solving, conceptualization, math and science . . . experimentation is necessary . . . work ethic, computer literacy to run machines."

Sample Occupations in Machinery Manufacturing[49]

Position	% of Manufacturing Employment 2012
Tool & Die Makers	33.2%
Mechanical Engineers	20.5%
Welders, Cutters, Solderers, Brazers	15.4%
Team Assemblers	10%
Computer Controlled (CNC) Machine Tool Operators, Metal & Plastic	7%
Machine Setters, Operators, Tenders	6.5%
Engine & Machine Assemblers	5%
Other	2.4%

Figure 27

49 Ibid

FINDINGS & IMPLICATIONS

It is a regional asset to have broad and deep capabilities in an industry with companies at every level of a robust supply chain. But given how disruptive additive manufacturing may be, it also indicates a major economic risk if a lot of smaller companies suddenly go under because they have been unable to keep up with change, or if there are just too many of them to absorb a smaller portion of traditional work. Ideally there would be mergers and acquisitions to make bigger, stronger suppliers. That could mean consolidation; or, it could mean a lot of dead and dying businesses and higher unemployment. That is a big conundrum no one has the answer to right now. There is speculation from all sides: McKinsey, Harvard Business Review, industry "experts," and the manufacturing trade associations are all proposing various scenarios. The GIS map on page 35 is a visual depiction of the need for that awareness.

"Manufacturing competence is based on consistent repetition. We're very good at what we do and who we do it for. Why it works is of secondary importance. There's no time to change. Just make the donuts."

Monitoring industry and technology trends is a crucial part of business and economic sustainability, and a place where economic development professionals can play an active role in three crucial areas:

1. Helping new and small regional manufacturers understand how important it is to adapt to manufacturing process changes, such as the implementation of lean product development and manufacturing techniques that can increase their quality and productivity.

2. Assisting small and medium regional manufacturers in assessing and reacting to the rapid transition to additive manufacturing.
   - How is it likely to affect their business?
   - What they can do to adapt and participate, rather than be left behind?

3. Providing support for developing a better-trained, more technically capable workforce.

Simply put, additive manufacturing is the ability to print three-dimensional objects. The technology has existed for 30 years, and quality and cost can vary enormously. A basic low-quality printer can cost under a hundred dollars. An industrial printer can cost a million dollars or more. Lack of standards and common terminology are minor speed bumps considering the technology's rapid expansion.

Manufacturing jobs are crucial to the economic vitality of this region's economy because they pay significantly more, on average, than other jobs.[50]

Supporting existing businesses is the most productive route to increasing manufacturing jobs. Nationally, no more than 2% of annual state job gains can be attributed to business relocations; 95% of new jobs come from the expansion of existing businesses (42%) and the birth of new [companies] (56%).[51]

Portland's manufacturing employment fared better than the U.S. average during the recession; however, the Greater Portland region's employment in durable goods manufacturing slowed in 2013 compared to 2012.[52]

The Association of Manufacturing Technology rated the Portland region as "dense" in existing manufacturing innovation infrastructure in 2012. That rating was based on a combination of assets including Manufacturing Extension Partnerships (Impact Washington and Oregon Manufacturing Extension Partnership [OMEP]); manufacturing companies, universities and community colleges, vocational and technical schools, and private innovation centers, such as the Oregon Metals Initiative.[53]

To maintain that reputation for innovation and to strengthen the ecosystem in which the region's manufacturers operate, economic development professionals, universities, and government entities need to work together and work closely with industry associations and regional businesses, to insure that research and development, capital investment, and workforce education are prepared to meet the challenges of the Second Industrial Revolution.

50 2012 Value of Jobs Manufacturing report, Portland Business Alliance

51 Brookings Institution, Job Creation on a Budget. January 2011

52 A check-up on the Portland-Region's Economic Health, 2013. Portland Business Alliance

53 The Manufacturing Mandate: Key to American Economic Power. The Association of Manufacturing Technology, 2012

RESOURCES & REFERENCES

1. 3-D Printing Takes Shape. Cohen, Sargeant and Somers. McKinsey Quarterly, January 2014
2. 2013 Employment Projections, Washington State Employment Security Department
3. Accelerated Advanced Manufacturing with New Research Centers. Brookings-Rockefeller. February 2011
4. Advanced Manufacturing Cluster Inventory Phase report, PDC July 2010
5. Strategic Justification of Advanced Manufacturing Technology, V.B. Kreng. Journal of Advanced Manufacturing Vol. 52, Issue 9, p. 1103. February 2011
6. Advanced Materials Manufacturing Pilot Study. Washington State University, 2010
7. Advanced Materials Manufacturing Sustainability and Workforce Development Pilot Study. Washington State University Extension Energy Program 2010
8. Bringing It All Together. SSTI 17th Annual Conference, Sept. 2013, Portland, OR
9. Brookings Institution Global Cities Initiative Export Nation, September 2013
10. Brookings Institution Policy Discussion: Manufacturing U.S. Prosperity. Gene Spurling, National Economic Council, July 25, 2013
11. Business Oregon Computers & Electronics Export Data, 2013
12. Business Roundtable, David Thomas. *www.brt.org/trade* 2013
13. Business Week, Smaller, faster, lighter, cheaper. Micro Batteries. Technology, pg. 34, July 22-26, 2013
14. CIA World Fact Book, Exports 2013
15. Council of Supply Chain Professionals
16. Creating New International Sales Opportunities, Business Oregon, 2012
17. Disruptive Technologies. McKinsey Global Institute, May 2013
18. Export Business Development Strategies, U.S. Commercial Service, International Trade Administration, 2012
19. Export Nation, Brookings Institution, 2012
20. Export.gov Market Reports: Turkey, October 2013
21. *Fabricated: The New World of 3D Printing* by Hod Lipson and Melba Kurman. 2013
22. Focus on the Future of the Renewable Materials Industry, Deloitte
23. Game Changers: Five opportunities for U.S. growth and renewal. McKinsey Global Institute, July 2013
24. Greater Portland Export Initiative Business Plan, Greater Portland, Inc. 2012
25. Greater Portland Metropolitan Export Plan, Brookings Institution, 2012 and 2013
26. Greater Portland Export Initiative Regional Westside Freight Access and Logistics Analysis. DKS Associates, October 1, 2013
27. Greater Portland/Vancouver Metropolitan Region Workbook, 2013-2014
28. Help Wanted in Portland Tri-County 2011 Job Vacancy Survey
29. IBISWorld Iron and Steel Manufacturing in the U.S., 2013; Aerospace & Defense Manufacturing in the U.S., 2013; Computers & Electronics Manufacturing, 2013; Metals Manufacturing in the U.S., 2013

30. Impact Washington Manufacturing Report & SW Survey Results, 2011

31. Marks' Standard Handbook for Mechanical Engineers, Manufacturing Processes. Chuck Fennell, Dalton Foundries and Rajiv Shivpuri, The Ohio State University. McGraw-Hill Professional Press, 2006

32. Industrial Research Institute, *http://www.iriweb.org*

33. Innovation in Global Industries: U.S. Firms Competing in a New World. Macher, Jeffrey T. and Mowery, David C. National Research Council of the National Academies. 2008

34. Job Creation on a Budget: How Regional Clusters Can Add Jobs, Bolster Entrepreneurship, and Spark Innovation. Brookings-Rockefeller, January 2011

35. Jobs Alone Do Not Explain The Importance of Manufacturing. Brookings 2013

36. Jobs Through Exports, Jim Lucchesi, Export-Import Bank of the U.S. 2012

37. Manufacturing & Logistics National Report, Conexus IN 2012

38. Manufacturing Economic and Workforce Data at a Glance. SW Washington Workforce Development Council, August 2012

39. Manufacturing Workforce Survey Reports, Columbia-Willamette Collaborative, Nov. 2012

40. National Strategic Plan for Advanced Manufacturing, National Science & Technology Council, Feb. 2012

41. Navigating the Product Mindset – High Tech Industry Report, UL. V13, 2012

42. Novel Practices for Advancing Manufacturing. Defense Materials Manufacturing and Infrastructure Standing Committee, Division on Engineering and Physical Sciences. National Research Council of the National Academies Press. 2013

43. Occupational Employment and Wage Estimates. WA State Employment Security Department, June 2012

44. Office of the U.S. Trade Representative, 2013

45. Oregon Economy Review and Forecast, State of Oregon; *www.oregon.gov*, 2012

46. Oregon Employment Department, September 2013 and January 2014

47. Oregon Metals Initiatives Annual Report, 2012

48. PC Magazine Encyclopedia, 3D Printing

49. Portland Business Alliance Check-up on the Portland-Region's Economic Health, 2013

50. Portland Metro's Manufacturing Sector, Paying Dividends, 2012

51. Portland, Oregon/Vancouver, Washington Regional Comprehensive Economic Development Strategy (CEDS) 2012

52. Producing Prosperity: Why America Needs A Manufacturing Renaissance. Pisano & Shih, 2012

53. Remaking the Industrial Economy. Nguyen, Stuchtey and Zils. McKinsey Quarterly, February 2014

54. Report to the President on Capturing Domestic Competitive Advantage in Advanced Manufacturing, President's Council of Advisors on Science & Technology, July 2012

55. Standard & Poor's Industry Surveys, 2013

56. Sustainable Nanomanufacturing – Creating the Industries of the Future. National Nanotechnology Initiative's Signature Initiative, July 2010

57. The Internet of Things and the Future of Manufacturing, McKinsey Quarterly, 2010

58. The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies. Erik Brynjolfsson, Andrew McAfee. W.W. Norton & Co. New York. 2014

59. Top 10 Manufactured Products in America's Export Industry. Business Insider.com. March 8, 2012

60. U.S. Census Bureau American Community Survey, 2011, 2012; and Business & Industry Statistics, July 2013

61. U.S. Commercial Service, 2012 and 2013

62. U.S. International Trade: Trends and Forecasts. Congressional Research Service, October 19, 2012. *www.ustr.gov*

63. Washington State Manufacturing and The Global Market, AWB Institute, 2010

64. We Forge the Future, Manufacturing Portland. Business Oregon, Portland Development Commission, Greater Portland Inc, Manufacturing 21 Coalition. 2012

65. What Employers Need: Workforce Challenges Among Fabricated Metal Manufacturers in Marion, Polk and Yamhill Counties. 2013

66. White House Plan for Advanced Manufacturing Technologies, Washington, DC. 2012

67. White Papers on Advanced Manufacturing Questions, National Science and Technology Policy Institute, Washington, DC. 2010

68. Why 3D Printing Can Make the World a Better Place. Bloomberg BusinessWeek, p.8, May 20, 2013

69. Why Does Manufacturing Matter? Which Manufacturing Matters? Brookings Institution 2012

70. WorkSource Oregon Labor Market Information 2013

APPENDIX A: Regional Metals & Machinery Companies On GIS Map

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
2001 Machining	3920 SE View Acres Rd	Portland	OR	97267	33272101	< $500,000
4 B Precision Product Inc	10281 S Kraxberger Rd	Canby	OR	97013	33271002	$500,000-1 Million
A & B Sheet Metal Inc	5410 NE 109th Ave	Portland	OR	97220	33232204	$500,000-1 Million
A & C Foundry	6720 NW Saint Helens Rd	Portland	OR	97210	33151304	$500,000-1 Million
A & G Products	7360 SW Bonita Rd # D	Portland	OR	97224	33271002	< $500,000
A B Finishing Tech	6724 NE 46th Ave	Portland	OR	97218	33281317	$500,000-1 Million
A G Machine Works	18191 SE Tickle Creek Rd	Boring	OR	97009	33271002	$500,000-1 Million
A-1 Automotive Machine Shop	1831 N Killingsworth St	Portland	OR	97217	33271002	< $500,000
A-1 Metal Spinning & Mfg Co	5147 SE 12th Way	Gresham	OR	97080	33211911	< $500,000
AAA Precious Metals Inc	9908 SE Ash St	Portland	OR	97216	42394011	$10-20 Million
Aarons Custom Metal Fab Inc	4709 NE 148th Ave #1	Portland	OR	97230	332312	$500,000-1 Million
Abba Industries INC/Rc Plath	36339 Industrial Way	Sandy	OR	97055	33271002	$500,000-1 Million
Accro Rule	1018 SE Woodward St	Portland	OR	97202	33351403	< $500,000
Accukraft Vinyl Coatings	2660 SE 39th Loop # F	Hillsboro	OR	97123	33281203	$1-2.5 Million
Accushape Inc	4344 Sw Chesapeak Ave	Portland	OR	97239	33151304	$2.5-5 Million
Ace Tank & Fueling Equip Co	7510 NE Killingsworth St	Portland	OR	97218	33242006	$1-2.5 Million
Acme Welding Corp	637 SE Salmon St	Portland	OR	97214	81149058	< $500,000
ADC	6451 NE Colwood Way	Portland	OR	97218	33271002	$2.5-5 Million
Adolf's Pattern Shop Inc	425 NE 80th Ave	Portland	OR	97213	33151304	$500,000-1 Million
Advanced Letterpress	727 SE Hawthorne Blvd	Portland	OR	97214	33351401	$1-2.5 Million
Advanced Powder Coating Inc	8969 SE 58th Ave	Portland	OR	97206	33281219	$2.5-5 Million
Advanced Surfaces	85 N 26th Ave	Cornelius	OR	97113	33281202	$1-2.5 Million
Advantage Northwest	1777 SE Brookwood Ave	Hillsboro	OR	97123	33271002	< $500,000
Agc Heat Transfer	9109 SE 64th Ave	Portland	OR	97206	33241001	$10-20 Million
AIC Inc	17555 63rd Ave	Lake Oswego	OR	97035	33261804	$1-2.5 Million
Aimico Precision Tooling	15865 SE 114th Ave	Clackamas	OR	97015	33351413	$500,000-1 Million
Alaskan Copper & Brass Co	2440 SE Raymond St	Portland	OR	97202	33111004	$20-50 Million
All Star Machine Inc	16077 SE Evelyn St	Clackamas	OR	97015	33271002	$500,000-1 Million
Allied Screw Machine	27526 SE Highway 212	Boring	OR	97009	33271002	$500,000-1 Million
Allied Technologies Intl Inc	20190 SW Avery Ct	Tualatin	OR	97062	33271002	$2.5-5 Million
Almar Tool & Cutter	4715 NE 136th Ave	Portland	OR	97230	33351709	$2.5-5 Million
Aloha Welding Inc	2630 SE 39th Loop # E	Hillsboro	OR	97123	33231210	$1-2.5 Million
Alpha Fencing Co	128 NE 127th Ave	Portland	OR	97230	33261805	< $500,000
Alpine Machine Svc Inc	1284 S Alpine	Cornelius	OR	97113	33271002	$500,000-1 Million
Amada America Inc	35900 Industrial Way # 404	Sandy	OR	97055	33232205	< $500,000
American Fence Co	9940 SE Oak St	Portland	OR	97216	33261805	$2.5-5 Million
American Flagpole Pacific	1332 NE Broadway St	Portland	OR	97232	42339015	$2.5-5 Million
American Machine & Gear	2300 NW Nicolai St	Portland	OR	97210	33271002	$1-2.5 Million
American Machine & Gear Inc	2770 NW Industrial St	Portland	OR	97210	33361201	$5-10 Million
American Metal Cleaning Inc	9940 N Vancouver Way	Portland	OR	97217	33281324	< $500,000
American Precision Industries	2480 NW 229th Ave	Hillsboro	OR	97124	33271002	$10-20 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
American Steel LLC	525 Sequioa Pkwy	Canby	OR	97013	42351036	$500,000 - 1 Million
Ammcon Corp	21450 NW West Union Rd	Hillsboro	OR	97124	33271002	$5-10 Million
Anderson Forge & Machine	18500 SW Pacific Hwy	Tualatin	OR	97062	33211107	$5-10 Million
Anderson Quality Spg Mfg Inc	125 S Hazel Dell Way	Canby	OR	97013	33261304	$5-10 Million
Apex Anodizing	7116 SE 92nd Ave	Portland	OR	97266	33281301	$1-2.5 Million
Apex Industries Inc	12670 SW Hall Blvd # 2	Portland	OR	97223	32619916	$20-50 Million
Apex Powder Coating	7200 SE 92nd Ave	Portland	OR	97266	33281219	$500,000-1 Million
Apollo Mechanical Contractors	26055 SW Canyon Creek Rd	Wilsonville	OR	97070	33232204	$5-10 Million
Archers Precision Inc	12700 SW Hall Blvd # A	Portland	OR	97223	33232204	$2.5-5 Million
Architectural Castings	4701 SE 24th Ave # H	Portland	OR	97202	33151112	$1-2.5 Million
Architectural Iron Prod Inc	10701 SE Foster Rd	Portland	OR	97266	33232312	< $500,000
Argo Safety Railings Inc	9915 SW 31st Ave	Portland	OR	97219	33232204	$500,000-1 Million
Arrow Machine Works	2340 NW 29th Ave	Portland	OR	97210	33271002	$5-10 Million
Ascentec	19535 SW 129th Ave	Tualatin	OR	97062	33312014	$20-50 Million
Ascentec Engineering	18500 SW 108th Ave	Tualatin	OR	97062	33271002	$5-10 Million
Astro Tool Corp	21615 SW Tualatin Valley Hwy	Beaverton	OR	97006	33221629	$2.5-5 Million
Automatic Machining	416 SW Cedar St # C	Hillsboro	OR	97123	33271002	$1-2.5 Million
Axcelis Technologies	10260 SW Nimbus Ave # M1	Portland	OR	97223	33324201	$1-2.5 Million
B & B Machine	10405 NE Sandy Blvd	Portland	OR	97220	33271002	$500,000-1 Million
B & B Metal Inc	11309 NE Holman St	Portland	OR	97220	33149104	$2.5-5 Million
B & L Doors & Windows	1735 SE Powell Blvd	Portland	OR	97202	32191806	< $500,000
B & M Enterprises	1360 SE 179th Ave	Portland	OR	97233	33232204	< $500,000
B & R Machine Inc	17252 Pilkington Rd	Lake Oswego	OR	97035	33271002	$500,000-1 Million
Baker Corp	6400 SE 101st Ave # X1	Portland	OR	97266	56299104	$1-2.5 Million
Balzer Pacific Equipment Co	2136 SE 8th Ave	Portland	OR	97214	33312008	$20-50 Million
Barr Castings Co	8981 SE 76th Dr	Portland	OR	97206	33152306	$1-2.5 Million
Bartlett Enterprises	1900 NE 25th Ave # 11	Hillsboro	OR	97124	33271002	$2.5-5 Million
BBC Steel Corp	2001 S Township Rd	Canby	OR	97013	33231210	$5-10 Million
BCS Machining	8900 SW Burnham St # E21	Portland	OR	97223	33271002	< $500,000
Bearing Service Co	1040 NW Everett St	Portland	OR	97209	81111102	$500,000-1 Million
Beaver Heat Treating Corp	2700 NW Front Ave	Portland	OR	97210	33281101	$2.5-5 Million
Beaver Metal Finishing Co	3019 SE Park Ave	Milwaukie	OR	97222	33281317	< $500,000
Becker Precision	7732 SW Tournament Ct	Wilsonville	OR	97070	33271002	< $500,000
Began Tank Truck	7605 NE 21st Ave	Portland	OR	97211	33232317	$2.5-5 Million
Beko's Welding Inc	1100 SW Berg Pkwy	Canby	OR	97013	33231210	$1-2.5 Million
Bel Air Machine & Performance	14181 Fir St	Oregon City	OR	97045	33271002	$500,000-1 Million
Beltservice Corp	13327 N Woodrush Way	Portland	OR	97203	42383008	$20-50 Million
Bend Bronze	30820 SE Heiple Rd	Estacada	OR	97023	33151304	< $500,000
Benz Spring Co	4330 SW Macadam Ave	Portland	OR	97239	33261304	$1-2.5 Million
Bestco Inc	21475 NW Mauzey Rd # 101	Hillsboro	OR	97124	33351410	$1-2.5 Million
Betts Spring Co	4334 NE Columbia Blvd	Portland	OR	97218	33261304	$2.5-5 Million
Blackline Inc	2425 NW St Helens Rd	Portland	OR	97210	33281317	$1-2.5 Million
Blaser Die Casting	11555 NE Sumner St	Portland	OR	97220	33151112	$1-2.5 Million
Blount International	3901 SE Naef Rd	Portland	OR	97267	33311205	$20-50 Million
BMP America	1100 SW Palatine Hill Rd	Portland	OR	97219	33351401	< $500,000

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Bob's Design Engineering Inc	3325 SW 229th Ave	Beaverton	OR	97007	33271002	$5-10 Million
Bobcat Of Portland	7000 SW Sandburg St	Portland	OR	97223	33312009	$20-50 Million
Bodycote Testing Group Inc	12003 NE Ainsworth Cir # 105	Portland	OR	97220	33281101	$2.5-5 Million
Bold Ideas	2000 SE 4th Ave	Canby	OR	97013	33271002	$1-2.5 Million
Boring Machine Works	12443 SE 282nd Ave	Boring	OR	97009	33271002	$500,000-1 Million
Brun Metals Co LLC	29441 NW West Union Rd	North Plains	OR	97133	33232312	$2.5-5 Million
Buntrock Industries Inc	12055 NE Glenn Widing Dr # 203	Portland	OR	97220	33151112	< $500,000
Burns & Son Inc	5005 NE 14th Ave	Portland	OR	97211	33281305	$500,000-1 Million
Buss Precision Mold Co	13581 SE Ambler Rd	Clackamas	OR	97015	33351410	$1-2.5 Million
C & L Custom Tooling	10736 SE Highway 212	Clackamas	OR	97015	33351410	< $500,000
C & M Precision Spindle Inc	19730 SW Cipole Road #7	Tualatin	OR	97062	42383046	$5-10 Million
C Power Industries Inc	33671 S Dickey Prairie Rd	Molalla	OR	97038	33351728	$1-2.5 Million
Calstrip Northwest Inc	4033 NW Yeon Ave	Portland	OR	97210	33111007	$10-20 Million
Cambridge Precision Machining	7350 SW Landmark Ln # 110	Portland	OR	97224	33271002	$1-2.5 Million
Canam Chains	15151 SE Industrial Way	Clackamas	OR	97015	33211107	$5-10 Million
Canron Western Constructors	4600 NE 138th Ave	Portland	OR	97230	33231210	$20-50 Million
Carter Machine & Tool	2436 SE 12th Ave	Portland	OR	97214	33351709	$500,000-1 Million
Cartesian Research Inc	37680 Ruben Ln	Sandy	OR	97055	33271002	< $500,000
Cartwright Co	18366 S Norman Rd	Oregon City	OR	97045	33271002	$500,000-1 Million
Cascade General Inc	5555 N Channel Ave # 71	Portland	OR	97217	33661102	$20-50 Million
Cascade Precision Inc	35700 SE Bluff Rd	Boring	OR	97009	33271002	$2.5-5 Million
Cascade Window	23555 NE Halsey St	Wood Village	OR	97060	32619923	$20-50 Million
Casting House Nw LLC	1001 SE Water Ave	Portland	OR	97214	33151112	$1-2.5 Million
Celestica	18870 NE Riverside Pkwy	Portland	OR	97230	33441303	$1-2.5 Million
Central Machine Works Inc	8009 N Kerby Ave	Portland	OR	97217	33299910	$500,000-1 Million
Clock Associates	1629 SE 11th Ave	Portland	OR	97214	33324106	$500,000-1 Million
Clyde/West Inc	13805 NE Sandy Blvd	Portland	OR	97230	33312008	$10-20 Million
CNC Machining	6051 SE Frances St	Hillsboro	OR	97123	33271002	< $500,000
CNC Precision Mfg	13735 SW Galbreath Dr	Sherwood	OR	97140	33271002	$500,000-1 Million
Color Technology	2455 NW Nicolai St	Portland	OR	97210	33281312	$5-10 Million
Columbia Forge & Machine Works	8524 N Crawford St	Portland	OR	97203	33211107	$5-10 Million
Columbia Gear Works	14629 NE Halsey St	Portland	OR	97230	33271002	< $500,000
Columbia Steel Casting Co Inc	10425 N Bloss Ave	Portland	OR	97203	33312008	$20-50 Million
Columbia Structural Tubing	8735 N Harborgate St	Portland	OR	97203	33111011	$10-20 Million
Columbia Wire & Iron Works Inc	5555 N Channel Ave # 10	Portland	OR	97217	33231210	$1-2.5 Million
Commercial Honing Co	3453 NW Luzon St	Portland	OR	97210	33271002	$500,000-1 Million
Comp Tool	34800 SE Smith Rd	Corbett	OR	97019	33351413	< $500,000
Connect Works	13100 SW Hart Road	Beaverton	OR	97008	33351504	< $500,000
Consolidated Metco Inc	10448 SE Highway 212	Clackamas	OR	97015	33152301	$10-20 Million
Construction Products Nw	10700 Beaverton Hillsdale #533	Beaverton	OR	97005	33231210	< $500,000
Cornell Pump Co	16261 SE 130th Ave	Clackamas	OR	97015	33391101	$100-500 Million
Cornerstone Fencing	10100 SE Main St	Milwaukie	OR	97222	42339013	$2.5-5 Million
Crane Pro Svc Inc	13233 NE Whitaker Way	Portland	OR	97230	33312010	$2.5-5 Million
Cranston Machinery Co Inc	2251 SE Oak Grove Blvd	Oak Grove	OR	97267	33324310	$10-20 Million
CRB Manufacturing Inc	9801 SE Lawnfield Rd	Clackamas	OR	97015	33271002	$5-10 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Creative Products	4850 SW 139th Ave	Beaverton	OR	97005	33271002	< $500,000
Curran Coil Spring Inc	9265 SW 5th St	Wilsonville	OR	97070	33261304	$5-10 Million
Custom Cast Corp	31103 SW French Prairie Rd	Wilsonville	OR	97070	33152301	$1-2.5 Million
Custom Spring Products Inc	2625 SE 39th Loop # B	Hillsboro	OR	97123	33261304	$1-2.5 Million
Cylinder Head Specialties	8222 SE 6th Ave	Portland	OR	97202	33271002	$500,000-1 Million
Daitron Inc	27750 SW 95th Ave # 100	Wilsonville	OR	97070	33324201	$5-10 Million
Daniel's Iron Design LLC	31830 NW Commercial St	North Plains	OR	97133	33232312	< $500,000
Dave's Machining	27526 SE Highway 212	Boring	OR	97009	33271002	$500,000-1 Million
Davis Tool Inc	3740 NW Aloclek Pl	Hillsboro	OR	97124	33221629	$10-20 Million
Delta Industries Inc	16142 NE Mason St	Portland	OR	97230	33391101	$1-2.5 Million
Dependable Pattern Works	737 SE Market St	Portland	OR	97214	33299919	$2.5-5 Million
Design Metals	5311 NE 109th Ave	Portland	OR	97220	33232302	$5-10 Million
Dexter Design & Development Co	5285 NE Elam Young Pkwy # A800	Hillsboro	OR	97124	33271002	$1-2.5 Million
Dickman Enterprises Inc	10800 SE Orient Dr	Boring	OR	97009	33271002	< $500,000
Die Masters Inc	2305 SE Palmblad Rd # C	Gresham	OR	97080	33351403	$500,000-1 Million
Digital Craft PDX	3512 SE 160th Ave	Portland	OR	97236	326199	< $500,000
Dimensional Machine & Cad Inc	18155 SW Baseline Rd # C	Beaverton	OR	97006	33399914	< $500,000
Double J Machine Inc	15425 SE Piazza Ave	Clackamas	OR	97015	33271002	$500,000-1 Million
DS Association Inc	160 SW Spring St	Hillsboro	OR	97123	33299602	$1-2.5 Million
Dura Industries Inc	4466 NW Yeon Ave	Portland	OR	97210	33281312	$1-2.5 Million
Dutchman Tool & Machine Works	7937 NE Alberta St	Portland	OR	97218	33271002	$1-2.5 Million
Duyck Machine Inc	4200 NW Visitation Rd	Forest Grove	OR	97116	33271002	$1-2.5 Million
DVC Machine	1284 S Alpine St	Cornelius	OR	97113	33271002	$500,000-1 Million
Dyadic Iron Works	623 SE 12th Ave	Portland	OR	97214	33232312	< $500,000
Eagle Foundry Co	23123 SE Eagle Creek Rd	Eagle Creek	OR	97022	33151304	$20-50 Million
Eagle Precision Sheet Metal	761 N Holladay St	Cornelius	OR	97113	33232204	$2.5-5 Million
East Side Plating Inc	8400 SE 26th Pl	Portland	OR	97202	33281312	$5-10 Million
Eaton Cooper Bussmann Trnsprtn	10955 SW Avery St # A	Tualatin	OR	97062	33281312	$5-10 Million
EBARA Technologies Inc	15247 NW Greenbrier Pkwy	Beaverton	OR	97006	33391102	$5-10 Million
EBARA Technologies Inc	5289 NE Elam Young Pkwy # G80	Hillsboro	OR	97124	33391102	$5-10 Million
EBARA Technologies Inc	6199 NW Casper Pl	Hillsboro	OR	97124	33391102	$10-20 Million
Ebony Iron Works	2401 NW 22nd Ave	Portland	OR	97210	33231210	$2.5-5 Million
Eckelman Machining & Aircraft	2074 NW Aloclek Dr # 425	Hillsboro	OR	97124	33271002	< $500,000
Electro-Chem Metal Finishing	4849 SE 26th Ave	Portland	OR	97202	33281301	$2.5-5 Million
Emmert Machine & Fabrication	9446 SW Tigard St	Portland	OR	97223	33271002	$500,000-1 Million
Enoch Manufacturing Co	14242 SE 82nd Dr	Clackamas	OR	97015	33272101	$5-10 Million
Enterprise Fabricators Co	4001 SE Roethe Rd	Portland	OR	97267	33231210	$500,000-1 Million
Entro	3601 NW John Olsen Pl	Hillsboro	OR	97124	54133011	$1-2.5 Million
Eric Canon Metalworks	1923 Elm St	Forest Grove	OR	97116	33152901	< $500,000
Ers	7325 NE 55th Ave	Portland	OR	97218	33271002	$2.5-5 Million
ESCO Corp	2141 NW 25th Ave	Portland	OR	97210	33211908	$100-500 Million
Evergreen Machine Works	7525 NE 33rd Dr	Portland	OR	97211	33271002	$500,000-1 Million
Evraz Oregon Steel Mills	14400 N Rivergate Blvd	Portland	OR	97203	33231210	$100-500 Million
Excel Finishing Inc	1765 Red Soils Ct	Oregon City	OR	97045	33281312	$500,000-1 Million
Excel Machine	5031 SE El Centro Ct	Portland	OR	97267	33271002	$500,000-1 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
F & C Machine	2235 Yew St # 3	Forest Grove	OR	97116	33271002	$500,000-1 Million
F & F Grinding Inc	9442 N Ramsey Blvd	Portland	OR	97203	33281207	$2.5-5 Million
Fabworks LLC	20226 SE Veneer Ln	Sandy	OR	97055	33231210	$2.5-5 Million
Facial North America	6020 N Cutter Cir	Portland	OR	97217	33272201	$1-2.5 Million
Far East Import & Export	3836 NE Columbia Blvd	Portland	OR	97211	33271002	$1-2.5 Million
FEI Co	5350 NE Dawson Creek Dr	Hillsboro	OR	97124	33451601	$500m - $1 Billion
Ferguson Enterprises Inc	4120 NE Columbia Blvd	Portland	OR	97211	33291102	$5-10 Million
Finishing First Inc	12970 SW Hall Blvd	Tigard	OR	97223	33281312	$1-2.5 Million
Finishline Coating	2889 SE Silver Springs Rd	Portland	OR	97222	33281219	$500,000-1 Million
FMC Technologies Inc	10245 SW Todd St	Portland	OR	97225	33313202	$2.5-5 Million
Fought & Co	14255 SW 72nd Ave	Tigard	OR	97224	33231210	$10-20 Million
Freightliner	6936 N Fathom St	Portland	OR	97217	44111008	$500m - $1 Billion
G & G Parts & Machine	10381 S Mulino Rd	Canby	OR	97013	33271002	$500,000-1 Million
G B Products	2233 NE 244th Ave # D2	Wood Village	OR	97060	33272101	Less Than $500,000
G N Machine Inc	21414 NE Sandy Blvd	Fairview	OR	97024	33271002	< $500,000
G-4 Precision	15865 SE 114th Ave	Clackamas	OR	97015	33271002	$500,000-1 Million
Gardner-Stussi Tool & Die	6635 N Baltimore Ave # 125	Portland	OR	97203	33271002	$500,000-1 Million
Gary's Machine Shop Svc	565 W Main St	Molalla	OR	97038	33271002	$500,000-1 Million
Gauge Tech Systems	19275 SW Anderson St	Aloha	OR	97007	33351907	< $500,000
Gauge-Rite Products	911 NW Jackson St	Hillsboro	OR	97124	33312014	$500,000-1 Million
Gebhardt Machine Works Inc	3360 SE 21st Ave	Portland	OR	97202	33271002	$500,000-1 Million
Geometric Machining Inc	8900 SW Burnham St # 10	Tigard	OR	97223	33211908	$500,000-1 Million
Georgia-Pacific Corp	505 NE 3rd Ave	Canby	OR	97013	32191801	$2.5-5 Million
Gilbertson Machine Shop Inc	731 SE Yamhill St	Portland	OR	97214	33271002	$1-2.5 Million
Gladstone Machine Inc	15451 SE Keeley Ct	Clackamas	OR	97015	33271002	$1-2.5 Million
Gray's Automotive Machine Shop	8975 SW Burnham St	Tigard	OR	97223	33271002	< $500,000
Green Street Details Inc	8900 NE Vancouver Way	Portland	OR	97211	33251015	$2.5-5 Million
Greg Fahlgren Machining	30983 SW Boones Ferry Rd	Wilsonville	OR	97070	33271002	$500,000-1 Million
Grinding Specialties	30623 SW Boones Ferry Rd # B	Wilsonville	OR	97070	33281207	$500,000-1 Million
Gte Metal Erectors Inc	24530 S Cass Rd	Canby	OR	97013	33299910	$2.5-5 Million
Gva-Northwest LLC	4434 SE Division St	Portland	OR	97206	33391102	$1-2.5 Million
H & H Machine Works Inc	9819 SE Foster Rd	Portland	OR	97266	33271002	$500,000-1 Million
H Hirschberger Co Inc	1714 NW Northrup St	Portland	OR	97209	33131802	$5-10 Million
H W Metal Products Inc	19480 SW 118th Ave	Tualatin	OR	97062	33231210	$10-20 Million
Hardchrome Inc	1152 NW Commerce Ct	Estacada	OR	97023	33281317	$500,000-1 Million
Harris Rebar	2727 NW 35th Ave	Portland	OR	97210	33231210	$2.5-5 Million
Hegar 4 Products	3677 SE Edison St	Portland	OR	97222	33271002	$500,000-1 Million
Hegar Manufacturing	15600 SE For Mor Ct # 1	Clackamas	OR	97015	33521010	$1-2.5 Million
Helser Industries	10750 SW Tualatin Rd	Tualatin	OR	97062	33232204	$10-20 Million
Helzer Machine Inc	15865 SE 114th Ave # N	Clackamas	OR	97015	33271002	$500,000-1 Million
Hessel Custom	80 SE Madison St	Portland	OR	97214	33271002	$500,000-1 Million
Hillcore Machine Inc	646 N Thompson St	Portland	OR	97227	33271002	$1-2.5 Million
Hilltop Machine	6600 NE M L King Blvd	Portland	OR	97211	33271002	$500,000-1 Million
HKK Chain Co	9730 SW Hillman Ct # 630	Wilsonville	OR	97070	33211102	$1-2.5 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Hoffman Instrumentation Supply	6110 NW Croeni Rd # 170	Hillsboro	OR	97124	33312014	$5-10 Million
Hogan Fab Inc	5722 SE Johnson Creek Blvd	Portland	OR	97206	33231210	$5-10 Million
Horiba Stec Inc	10110 SW Nimbus Ave # B11	Tigard	OR	97223	33441302	$1-2.5 Million
Hot Stuff Custom Works	37827 SE Lusted Rd	Boring	OR	97009	33281219	$1-2.5 Million
Howser Steel Inc	8235 N Kerby Ave	Portland	OR	97217	33231210	$2.5-5 Million
Ideal Industries Inc	5405 SE Alexander St # C	Hillsboro	OR	97123	33271002	$500,000-1 Million
Ideal Steel Inc	4567 NE 190th Ln	Portland	OR	97230	33111008	$10-20 Million
Imperial Steel Craft Inc	5455 SE Alexander St	Hillsboro	OR	97123	33231210	$1-2.5 Million
Independent Marine Propeller	8675 N Crawford St	Portland	OR	97203	33661102	$1-2.5 Million
Induction Specialties	7937 NE Alberta St	Portland	OR	97218	33271002	$500,000-1 Million
Industrial Machine Svc	7515 NE 13th Ave	Portland	OR	97211	33271002	$1-2.5 Million
Industrial Metal Works Inc	1800 Main St	Oregon City	OR	97045	33231210	$1-2.5 Million
Innovative Machining Inc	7715 NE 33rd Dr # G	Portland	OR	97211	33271002	$500,000-1 Million
Inserta Fittings Co	3707 24th Ave	Forest Grove	OR	97116	33291902	$1-2.5 Million
Integrated Metal Components	18355 SW Teton Ave	Tualatin	OR	97062	33232204	$5-10 Million
Interstate Manufacturing	8319 SE Otty Rd	Happy Valley	OR	97086	33232202	$2.5-5 Million
Intl Custom Making & Trade	15879 SW Wintergreen St	Portland	OR	97223	33271002	< $500,000
Ionbond LLC	25749 SW Canyon Creek Rd # 400	Wilsonville	OR	97070	33281203	$10-20 Million
Ipd LLC	13124 NE Airport Way	Portland	OR	97230	33312009	$1-2.5 Million
Iron Eagle Trailers	21414 NE Sandy Blvd # B3	Fairview	OR	97024	33621404	$2.5-5 Million
Isley Welding Svc	5555 N Channel Ave	Portland	OR	97217	81149058	$1-2.5 Million
J & J Mechanical	10812 SE Highway 212	Clackamas	OR	97015	33281217	$500,000-1 Million
J & P Wire Products	5565 SE International Way	Milwaukie	OR	97222	33261804	$1-2.5 Million
J B's Quality Metal Finishing	12777 NE Whitaker Way	Portland	OR	97230	33281317	< $500,000
J C Custom Machining & Design	5575 SE Alexander St # 300	Hillsboro	OR	97123	33351413	$1-2.5 Million
J L Custom Inc	414 Beavercreek Rd # 712	Oregon City	OR	97045	33271002	$500,000-1 Million
J V Northwest Inc	390 S Redwood St	Canby	OR	97013	33324106	$20-50 Million
James E Mathis Inc	14500 S Brunner Rd	Oregon City	OR	97045	33232302	< $500,000
James Forkner Sales & Mktng	17118 SW Cambridge Dr	Beaverton	OR	97007	33281317	$500,000-1 Million
Jamieson Tool & Design Inc	5285 NE Elam Young Pkwy # B300	Hillsboro	OR	97124	33351410	$500,000-1 Million
Janco LLC	1828 NW Pettygrove St # A	Portland	OR	97209	33271002	$1-2.5 Million
Jd Cross Enterprises Inc	4511 NE 135th Ave	Portland	OR	97230	33232204	$500,000-1 Million
Jim Calcagno Studio & Foundry	27400 SE Highway 212	Boring	OR	97009	33151304	< $500,000
John K Mildrexler Paint & Wall	11579 SW Davies Rd # 2903	Beaverton	OR	97007	33281202	$500,000-1 Million
Jones Heavy Equipment Products	4441 NE 148th Ave	Portland	OR	97230	33312008	$2.5-5 Million
JTD Inc	9800 SW Tigard St	Tigard	OR	97223	33221629	$1-2.5 Million
K O Custom Fab	18625 SE Bakers Ferry Rd	Boring	OR	97009	33231210	$2.5-5 Million
KACH Machine Works Inc	3838 N Ballast St	Portland	OR	97217	33271002	$1-2.5 Million
Kebco Mold & Design	1635 SE Tualatin Valley Hwy #5	Hillsboro	OR	97123	33351410	< $500,000
Kenny's Machine	120 Metzler St	Molalla	OR	97038	33271002	< $500,000
Kervin Brothers Ornmntl Iron	2727 NW 35th Ave	Portland	OR	97210	33232312	< $500,000
Kinetics Inc	10085 SW Commerce Cir	Wilsonville	OR	97070	32599816	$100-500 Million
Komatsu America Corp	8520 NE Alderwood Rd	Portland	OR	97220	33312007	$1-2.5 Million
Kraftliner Steel Dies Inc	254 S Pine St	Canby	OR	97013	33351403	$500,000-1 Million
Ky-Ro Inc	18209 SW Boones Ferry Rd	Tigard	OR	97224	33231206	$1-2.5 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
L A Casting Co	24116 NW Moreland Rd	North Plains	OR	97133	33151112	$1-2.5 Million
L B Foster Co	5335 Meadows Rd # 355	Lake Oswego	OR	97035	33651004	$500,000-1 Million
L-M Equipment Co Inc	8705 SE 13th Ave	Portland	OR	97202	33312014	$2.5-5 Million
Labarre Machine	4100 SE Milwaukie Ave	Portland	OR	97202	33271002	$500,000-1 Million
Lacey Harmer Co	4270 NW Yeon Ave	Portland	OR	97210	33399922	$5-10 Million
Landmark Equipment	7625 NE Killingsworth St	Portland	OR	97218	33312009	$2.5-5 Million
Larry's Engine Rebuilding	4860 SE 82nd Ave	Portland	OR	97266	33271002	< $500,000
LASH Quality Molds & Sculpture	4702 NE 102nd Ave	Portland	OR	97220	33351410	< $500,000
Le Tourneau Technologies	1701 NW Sundial Rd	Troutdale	OR	97060	33231210	$5-10 Million
Leadtek	27555 SW Boones Ferry Rd	Wilsonville	OR	97070	33149103	$5-10 Million
Lexica Inc	15075 SW Koll Pkwy # B	Beaverton	OR	97006	33441902	< $500,000
Lfr Machining Inc	1982 NE 25th Ave # 6	Hillsboro	OR	97124	33271002	< $500,000
Life Time Gate Co	18155 SW Teton Ave	Tualatin	OR	97062	33299910	$1-2.5 Million
Lighthouse Precision Machining	15717 S Eaden Rd	Oregon City	OR	97045	33271002	< $500,000
Lightning Machine Works	1377 NE 25th Ave	Hillsboro	OR	97124	33271002	< $500,000
Lignomat	4430 NE 148th Ave	Portland	OR	97230	33324912	$1-2.5 Million
Lts Fabrication LLC	6530 SE 96th Ave	Portland	OR	97266	33232312	$500,000-1 Million
Lundeen Steel	42331 SE Wildcat Mountain Dr	Sandy	OR	97055	33231210	< $500,000
Lynch Co Inc	4706 SE 18th Ave	Portland	OR	97202	33232204	$10-20 Million
M & J Mfg	12747 NE Whitaker Way	Portland	OR	97230	33271002	$500,000-1 Million
M & W Building Supply Co	22175 Pacific Hwy E	Canby	OR	97013	33232204	$5-10 Million
M B Machine Inc	12425 SE 282nd Ave	Boring	OR	97009	33271002	< $500,000
M K Tooling	4720 NE 135th Ave	Portland	OR	97230	33271002	< $500,000
Macadam Aluminum & Bronze Co	1255 N Columbia Blvd	Portland	OR	97217	33152304	$1-2.5 Million
Machine Products Inc	1629 SE 11th Ave	Portland	OR	97214	33331846	$500,000-1 Million
Machine Sciences Corp	10165 SW Commerce Cir # G	Wilsonville	OR	97070	33271002	$5-10 Million
Machine Works LLC	1455 NW Northrup St	Portland	OR	97209	33271002	$500,000-1 Million
Machined Components	1004 NE 4th Ave	Canby	OR	97013	33271002	< $500,000
Macro Manufacturing Co	9625 N Ramsey Blvd	Portland	OR	97203	33271002	$1-2.5 Million
Madden Fabrication	2550 NW 25th Pl	Portland	OR	97210	33231210	$2.5-5 Million
Maiden Foundry	16600 362nd Ave	Sandy	OR	97055	33151304	$10-20 Million
Manutek Inc	1150 NW Commerce Ct	Estacada	OR	97023	33271002	$1-2.5 Million
Mar-Dustrial Sales Inc	4865 N Lagoon Ave	Portland	OR	97217	33231206	$5-10 Million
Marine Machine Works	9732 N Taft Ave	Portland	OR	97203	33271002	< $500,000
Marks Brothers Inc	28055 SE Dee St	Boring	OR	97009	33231210	$2.5-5 Million
Marks Metal Technology Inc	10300 SE Jennifer St	Clackamas	OR	97015	33231210	$10-20 Million
Martin Machine Shop	2640 SE 180th Pl	Gresham	OR	97030	33271002	< $500,000
Masic Industries	627 SE Division Pl	Portland	OR	97202	33281317	$1-2.5 Million
Mason Oregon Inc	3150 NW 31st Ave # 4a	Portland	OR	97210	33231205	$500,000-1 Million
Master Machine & Fabrications	38855 SW Laurelwood Rd	Gaston	OR	97119	33271002	$500,000-1 Million
Matrix Industries	16650 SW Shaw St	Beaverton	OR	97007	33232317	$2.5-5 Million
Mc Dermott Fence	9205 SE Clackamas Rd # 21	Clackamas	OR	97015	33261805	$500,000-1 Million
Mc Dowell Welding & Pipe Inc	4000 NW Saint Helens Rd	Portland	OR	97210	33231206	$10-20 Million
Mc Guire Bearing Co	947 SE Market St	Portland	OR	97214	33152902	$20-50 Million
Mc Kernan Machine & Tool	3111 SE 13th Ave	Portland	OR	97202	33271002	< $500,000
Meacon Corp	3990 SE International Way	Portland	OR	97222	33451202	$2.5-5 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Met-Tek Inc	15651 SE 125th Ct	Clackamas	OR	97015	33281101	$5-10 Million
Metal Enterprises Inc	2425 NW 23rd Pl	Portland	OR	97210	33231206	$1-2.5 Million
Metro Mold	6039 NE Holladay St	Portland	OR	97213	33351410	$500,000-1 Million
Metro Precision Machine	11055 SW Avery St	Tualatin	OR	97062	33351713	< $500,000
Metu-Streimer	740 N Knott St	Portland	OR	97227	33232202	$20-50 Million
Microlonamerica	2870 NE Hogan Dr # 504	Gresham	OR	97030	33351906	< $500,000
Midori Cascade	21550 NW Nicholas Ct # E	Hillsboro	OR	97124	33271002	$500,000-1 Million
Mill Machinery LLC	31670 S Highway 213	Molalla	OR	97038	33312014	$5-10 Million
Miller Engineering & Mfg	16088 SE 106th Ave	Clackamas	OR	97015	33271002	$1-2.5 Million
Mobile Metal Finishing	20345 SW Skiver Dr	Aloha	OR	97007	33281312	< $500,000
Moehnke Machinery	24695 S Barlow Rd	Aurora	OR	97002	33271002	$500,000-1 Million
Molalla Machine Inc	203 Kennel Ave	Molalla	OR	97038	33271002	$500,000-1 Million
Moore Business Machine Svc	9600 SW 74th Ave	Portland	OR	97223	33271002	$500,000-1 Million
Moore Machining Svc	30101 SW Weaver Dr	Newberg	OR	97132	33271002	$500,000-1 Million
Morning Star Fence	10701 SE Foster Rd	Portland	OR	97266	33232312	< $500,000
Morrison Engineering & Mach	19850 SW 129th Ave	Tualatin	OR	97062	33271002	$1-2.5 Million
Moventas	8823 N Harborgate St	Portland	OR	97203	33211107	$5-10 Million
My Machine Works Inc	3335 Sw Nelson Road	Gaston	OR	97119	33271002	< $500,000
N & T Mold Engineering Co	2820 SE 39th Loop # D	Hillsboro	OR	97123	33351410	$500,000-1 Million
Nanometrics Inc	2925 NW Aloclek Dr	Hillsboro	OR	97124	33324201	$2.5-5 Million
Newnes Machine LTD	15527 SW Willamette St	Sherwood	OR	97140	33271002	$500,000-1 Million
Norsam Technologies Inc	5285 NE Elam Young Pkwy # A200	Hillsboro	OR	97124	33312014	$1-2.5 Million
Northwest Automated Machining	802 SE 199th Ave	Portland	OR	97233	33271002	$2.5-5 Million
Northwest Automatic Machining	29119 SE Lusted Rd	Gresham	OR	97080	33271002	$500,000-1 Million
Northwest Copper Works Inc	1303 N River St	Portland	OR	97227	33299910	$5-10 Million
Northwest Door & Supply	10550 SW Manhasset Dr	Tualatin	OR	97062	32191806	$5-10 Million
Northwest Fourslide Inc	13945 SW Galbreath Dr	Sherwood	OR	97140	33211912	$5-10 Million
Northwest Industrial Machining	21550 Northwest Nicholas Court Suite A	Hillsboro	OR	97124	33271002	$500,000-1 Million
Northwest Innovators	12400 SE Carpenter Dr	Clackamas	OR	97015	33281219	$1-2.5 Million
Northwest Lasercut Inc	13021 NE David Cir	Portland	OR	97230	33351403	$1-2.5 Million
Northwest Machine Works Inc	1145 SE 2nd Ave	Canby	OR	97013	33271002	$1-2.5 Million
Northwest Machining Concepts	16011 SE Evelyn St	Clackamas	OR	97015	33271002	< $500,000
Northwest Pipe Co	12005 N Burgard Way # A	Portland	OR	97203	33121003	$50-100 Million
Northwest Structural Svc Inc	18201 SW Boones Ferry Rd	Portland	OR	97224	33231210	$2.5-5 Million
Nu Tech Machining Inc	20437 NE Sandy Blvd	Fairview	OR	97024	33271002	$1-2.5 Million
NW Sustainable Building Prods	6906 SE Johnson Creek Blvd	Portland	OR	97206	33261805	$500,000-1 Million
Olympic Foundry Inc	6530 NE 42nd Ave	Portland	OR	97218	33151304	$1-2.5 Million
Oregon Auto Spring Svc Inc	920 SE Stark St	Portland	OR	97214	33261304	$2.5-5 Million
Oregon Feralloy Partners	14400 N Rivergate Blvd	Portland	OR	97203	33151304	$5-10 Million
Oregon Iron Works	9700 SE Lawnfield Rd	Clackamas	OR	97015	33271002	$20-50 Million
Oregon Machine Works	1101 SE 2nd Ave	Canby	OR	97013	33271002	$500,000-1 Million
Oregon Metal Slitters Inc	7227 N Leadbetter Rd	Portland	OR	97203	33111008	$50-100 Million
Oregon Plating Co Inc	436 SE 6th Ave	Portland	OR	97214	33281312	$1-2.5 Million
Oregon Screw Machine Products	9291 SE 64th Ave	Portland	OR	97206	33272101	$2.5-5 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Ostrom Glass & Metal Works	2170 N Lewis Ave	Portland	OR	97227	33299910	$1-2.5 Million
P & A Metal Fab Inc	13009 SE 130th Av	Clackamas	OR	97015	33232204	$10-20 Million
P & J Machine Shop Inc	3345 SE 22nd Ave	Portland	OR	97202	33271002	$1-2.5 Million
Pacific Agents	PO Box 1673	Lake Oswego	OR	97035	33111007	$1-2.5 Million
Pacific Belting Inc	6400 SE 101st Ave # 2d	Portland	OR	97266	33392204	$2.5-5 Million
Pacific Machinery & Tool Steel	3445 NW Luzon St	Portland	OR	97210	42351036	$100-500 Million
Pacific Paper Box & Bindery	2117 NE Oregon St	Portland	OR	97232	33351401	$2.5-5 Million
Pacific Swiss & Mfg Inc	15423 SE Piazza Ave	Clackamas	OR	97015	33272101	$1-2.5 Million
Pacific Trail Mfg Inc	6532 SE Crosswhite Way	Portland	OR	97206	33312014	$2.5-5 Million
Paramount Supply Co	816 SE Ash St	Portland	OR	97214	33291906	$2.5-5 Million
Parks Metal Products Inc	19460 SW Shaw St	Aloha	OR	97007	33281312	$5-10 Million
Pattern Craft Inc	5771 SE International Way	Portland	OR	97222	33351413	$500,000-1 Million
Paul Brong Machine Works Inc	421 NE 12th Ave	Portland	OR	97232	33271002	$2.5-5 Million
PCC Structurals Inc	4600 SE Harney Dr	Portland	OR	97206	33151201	$100-500 Million
Peak Solutions LLC	4640 SW Macadam Ave, Suite 120	Portland	OR	97239	326199	$1-2.5 million
Peco	4707 SE 17th Ave	Portland	OR	97202	33641301	$20-50 Million
Peerless Pattern Works	3325 NW Yeon Ave	Portland	OR	97210	33299919	$1-2.5 Million
Pella Vinyl Portland	18600 NE Wilkes Rd	Portland	OR	97230	33232115	$50-100 Million
Peninsula Iron Works	6618 N Alta Ave	Portland	OR	97203	33271002	$2.5-5 Million
Pentagon EMS	570 NE 53rd Ave	Hillsboro	OR	97124	33271002	$10-20 Million
Perfectech	46255 SE Wildcat Mountain Dr	Sandy	OR	97055	33271002	< $500,000
Performancepro Pumps	5976 SE Alexander St # F	Hillsboro	OR	97123	33391102	$1-2.5 Million
Peterson Cat	4421 NE Columbia Blvd	Portland	OR	97218	33311103	$50-100 Million
PGM Recycling	31810 S Ona Way	Molalla	OR	97038	33231106	$1-2.5 Million
Pierce Pacific Mfg Inc	4424 NE 158th Ave	Portland	OR	97230	33312008	$50-100 Million
Pioneer Metal Finishing	18240 SW 100th Ct	Tualatin	OR	97062	33281317	$2.5-5 Million
Pioneer Metal Finishing	19005 SW 125th Ct	Tualatin	OR	97062	33281312	$10-20 Million
Pioneer Pump Inc	310 S Sequioa Pkwy	Canby	OR	97013	33391102	$2.5-5 Million
Pneumatic Tube Products Co	14945 SW 72nd Ave # C	Portland	OR	97224	33312014	$2.5-5 Million
POFCO	12805 SE Capps Rd	Clackamas	OR	97015	33211912	$1-2.5 Million
Poly Production	5701 NE 105th Ave # F	Portland	OR	97220	33271002	< $500,000
Portland Bolt & Mfg Co Inc	3441 NW Guam St	Portland	OR	97210	33272202	$10-20 Million
Portland Die & Stamping Co Inc	4805 SE 26th Ave	Portland	OR	97202	33211912	$2.5-5 Million
Portland Foundry	7715 NE 21st Ave	Portland	OR	97211	33151304	$2.5-5 Million
Portland Pattern Inc	2305 NW 30th Ave	Portland	OR	97210	33299919	$2.5-5 Million
Portland Precision Mfg Co	16327 NE Cameron Blvd	Portland	OR	97230	33271002	$2.5-5 Million
Portland Service Station Supl	737 NE 25th Ave	Portland	OR	97232	33351907	$1-2.5 Million
Portland Sheet Metal Works Inc	10101 SE Brittany Ct	Clackamas	OR	97015	23822030	$1-2.5 Million
Powder Tech Inc	PO Box 3221	Tualatin	OR	97062	33281219	$2.5-5 Million
PPG Industries Inc	2130 NE Argyle St	Portland	OR	97211	33281203	$2.5-5 Million
Precision Castparts Corp	4650 SW Macadam Ave # 300	Portland	OR	97239	33151112	> $1 Billion
Precision Components Inc	6110 NE Cherry Dr	Hillsboro	OR	97124	33272101	$500,000-1 Million
Precision Die Cutting	27595 SW 95th Ave # 760	Wilsonville	OR	97070	33351401	$1-2.5 Million
Precision Equipment Inc	8440 N Kerby Ave	Portland	OR	97217	33271002	$2.5-5 Million
Precision Powder Coating Inc	11719 SE 40th Ave	Portland	OR	97222	33281219	$2.5-5 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Premier Gear & Machine Works	1700 NW Thurman St	Portland	OR	97209	33271002	$2.5-5 Million
Premier Tool & Die Co	2909 SE Oak Grove Blvd	Oak Grove	OR	97267	33351403	< $500,000
Presicion Rebar & Acces Inc	1712 N Pier 99 St	Portland	OR	97205	33231210	$2.5-5 Million
Pro-Met Machining	2441 NW Eleven Mile Ave	Gresham	OR	97030	33271002	$2.5-5 Million
Proco Manufacturing	10950 SW 5th St # 260	Beaverton	OR	97005	33271002	$1-2.5 Million
Product Manufacturing Inc	555 SW 2nd Ave	Canby	OR	97013	33271002	$500,000-1 Million
Production Sawing	18205 SW Boones Ferry Rd	Tualatin	OR	97224	33351719	$500,000-1 Million
Production Tool & Mfg Co	16240 SW 72nd Ave	Tigard	OR	97224	33271002	$2.5-5 Million
Proto Rapid	15865 SE 114th Ave # G	Clackamas	OR	97015	33271002	$500,000-1 Million
Proturn Inc	14192 Fir St # 100	Oregon City	OR	97045	33271002	$5-10 Million
QBF Inc	10005 SW Herman Rd	Tualatin	OR	97062	33299910	$5-10 Million
Qpm Aerospace	17383 NE Sacramento St	Portland	OR	97230	33999936	$10-20 Million
Quality Tank & Construction Co	16911 SE 362nd Dr	Sandy	OR	97055	33242006	$5-10 Million
R & D Mfg Inc	160 SW Freeman Ave	Hillsboro	OR	97123	33271002	$500,000-1 Million
R & J Metal Fabricators	PO Box 17245	Portland	OR	97217	33231210	$2.5-5 Million
R & S Mfg Inc	7200 SE 92nd Ave # B	Portland	OR	97266	33232104	$2.5-5 Million
R & T Machine LLC	5701 NE 105th Ave # G	Portland	OR	97220	33271002	$500,000-1 Million
R B Designs	12025 NW Thompson Rd	Portland	OR	97229	33271002	< $500,000
R C Plath Co	36339 Industrial Way	Sandy	OR	97055	33211911	< $500,000
R H Brown Co	5 NE Hancock St	Portland	OR	97212	33392204	$1-2.5 Million
R M Engineering	2889 SE Silver Springs Rd	Portland	OR	97222	33281203	< $500,000
Ran-Bro Tool Co	31678 NW Hillcrest St	North Plains	OR	97133	33351410	$1-2.5 Million
Rapid Made	2828 SW Corbett Ave	Portland	OR	97201	326199	$500,000-1 million
Rd F & P	707 N Holladay St	Cornelius	OR	97113	33231210	$10-20 Million
Real Mechanical	6050 SE Foster Road #100	Portland	OR	97206	33231210	< $500,000
Rees Manufacturing	1192 N Fremont St	Cornelius	OR	97113	33271002	< $500,000
River City Pattern Inc	9828 SE Empire Ct	Clackamas	OR	97015	33271002	$2.5-5 Million
Robb Shoemaker Co	4207 SE Woodstock Blvd	Portland	OR	97206	33271002	< $500,000
Robertson Grating Products Inc	18129 SW Boones Ferry Rd	Portland	OR	97224	33232309	$1-2.5 Million
Rockmore International Inc	10065 SW Commerce Cir	Wilsonville	OR	97070	33351504	$10-20 Million
Rogers Machinery Co	14600 SW 72nd Ave	Tigard	OR	97224	33391201	$20-50 Million
Rolok Products	4800 N Channel Ave	Portland	OR	97217	33232204	$10-20 Million
Rope Master Skookum	6160 S Whiskey Hill Rd	Hubbard	OR	97032	33299910	$5-10 Million
Rose City Rebar	5512 NE 105th Ave # A	Portland	OR	97220	33231203	$1-2.5 Million
Rose City Steel	1412 SE Stark St	Portland	OR	97214	33111007	$10-20 Million
Rose City Steel	1810 SE 10th Ave	Portland	OR	97214	33231210	$2.5-5 Million
Roy Manufacturing	3113 N Mississippi Ave	Portland	OR	97227	33211915	$1-2.5 Million
Royal Oak Metal Craft Inc	2135 NW 29th Ave	Portland	OR	97210	33231210	$1-2.5 Million
S & M Steel Fab Inc	10850 SW 5th St # B	Beaverton	OR	97005	33231210	$5-10 Million
S D Machine Svc Inc	1970 Sylvan Way	West Linn	OR	97068	33271002	< $500,000
S L Machine	PO Box 24	Estacada	OR	97023	33271002	< $500,000
S V Mfg Inc	2624 SE 162nd Ave	Portland	OR	97236	33271002	$1-2.5 Million
Sachse Alloy Svc	7715 NE 21st Ave	Portland	OR	97211	33151304	< $500,000
SAPA Anodizing Inc	5325 NE Skyport Way	Portland	OR	97218	33281301	$50-100 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Sapa Extrusions Inc	7933 NE 21st Ave	Portland	OR	97211	33131801	$50-100 Million
Sapa Profiles Inc Tda	9124 SE 64th Ave	Portland	OR	97206	33131801	$10-20 Million
Sause Marine Svc Inc	31626 Oregon 213	Molalla	OR	97038	33231210	$1-2.5 Million
Schnitzer Steel	3935 NW Aloclek Pl	Hillsboro	OR	97124	423930	$50-100 Million
Schnitzer Steel	12005 N Burgard Way #C	Portland	OR	97203	423930	$500 Million-1 Billion
Schnitzer Steel	299 SW Clay St #350	Portland	OR	97201	423930	> $1 Billion
SDS Machining	14910 SE Morning Way # 102	Clackamas	OR	97015	33271002	$1-2.5 Million
Seepex Inc	12498 SE Ashley St	Clackamas	OR	97015	33391102	$1-2.5 Million
Service Steel Inc	5555 N Channel Ave # 2	Portland	OR	97217	33111008	$50-100 Million
Seubert Machining	1075 NW Park Ave	Estacada	OR	97023	33271002	$5-10 Million
Sieckmann Metal Fab Inc	27625 SE Paul Bunyan Ln	Eagle Creek	OR	97022	33231210	$1-2.5 Million
Simonds International	2700 SE Tacoma St	Portland	OR	97202	33221634	$5-10 Million
Simplicity Tool Co	10330 NE Marx St	Portland	OR	97220	33441902	$2.5-5 Million
Six Moon Designs	16228 SW Ellerson St	Beaverton	OR	97007	33351728	< $500,000
Skutt Ceramics Inc	6441 SE Johnson Creek Blvd	Portland	OR	97206	33399405	$10-20 Million
Small Parts Mfg Co Inc	4401 NE M L King Blvd	Portland	OR	97211	33271002	$5-10 Million
Smithco Manufacturing Inc	7911 NE 33rd Dr # 130	Portland	OR	97211	33271002	$500,000-1 Million
SMTNW Inc	16398 SW 72nd Ave	Portland	OR	97224	33312014	$5-10 Million
Sonsray Machinery	1745 NE Columbia Blvd	Portland	OR	97211	33312009	$10-20 Million
Spark Machining & Tools	11135 SW Industrial Way	Tualatin	OR	97062	33271002	$500,000-1 Million
Spectrum Prototype	3685 NW John Olsen Pl	Hillsboro	OR	97124	33271002	$500,000-1 Million
Spegel Machining	35795 NW Zion Church Rd	Cornelius	OR	97113	33271002	$500,000-1 Million
Stack Metallurgical Svc	5938 N Basin Ave	Portland	OR	97217	33281101	$5-10 Million
Stanley Hydraulic Tools	3810 SE Naef Rd	Oak Grove	OR	97267	33399103	$10-20 Million
Star 13 Inc Machine Shop	9860 SE Empire Ct # A	Clackamas	OR	97015	33271002	$500,000-1 Million
Starbright Finishes	13929 Fir St # F	Oregon City	OR	97045	33281312	< $500,000
Starley Manufacturing Inc	15796 SE 114th Ave	Clackamas	OR	97015	33271002	< $500,000
STB Coatings	5717 NE 105th Ave # D	Portland	OR	97220	33281219	$1-2.5 Million
Steel Masters Inc	2660 SE 39th Loop # A	Hillsboro	OR	97123	33271002	$500,000-1 Million
Steel Tek Industries	17070 SW Sunset Blvd	Sherwood	OR	97140	33232204	$2.5-5 Million
Stellar Industrial Supply	12831 NE Whitaker Way	Portland	OR	97230	33351401	$2.5-5 Million
Steve Machining	8945 NW Roy Rd	Cornelius	OR	97113	33271002	$500,000-1 Million
Strassel Jim Fabrication Repr	53830 NW South Rd	Gaston	OR	97119	33271002	$500,000-1 Million
Stratford Gate Systems Inc	12318 SE Capps Rd	Clackamas	OR	97015	33261807	$1-2.5 Million
Strom Manufacturing Inc	5285 NE Elam Young Pkwy	Hillsboro	OR	97124	33271002	$2.5-5 Million
Suburban Grinding Inc	13025 SW Herman Rd	Tualatin	OR	97062	33281207	$5-10 Million
Sulzer Pumps US Inc	2800 NW Front Ave	Portland	OR	97210	33391102	$5-10 Million
Sumitomo Electric Carbide Inc	7230 NW Evergreen Pkwy	Hillsboro	OR	97124	33351709	$10-20 Million
Summit Inc	2324 NE 82nd Ave	Portland	OR	97220	33111006	< $500,000
Summit Stainless Steel LLC	4732 NE 190th Ln	Portland	OR	97230	33111006	$2.5-5 Million
Sun & Moon Garden Art	15209 SE East Ave	Portland	OR	97267	33232302	< $500,000
SUN Edison	7832 N Leadbetter Rd	Portland	OR	97203	33341409	$1-2.5 Million
Sunset Manufacturing Co	19355 SW Teton Ave	Tualatin	OR	97062	33271002	$2.5-5 Million
Sunset Precision Concepts Inc	13445 NW Milburn St	Beaverton	OR	97005	33351412	< $500,000

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Suri Iron Inc	1803 N Killingsworth St	Portland	OR	97217	33211107	$1-2.5 Million
Swan Island Sheet Metal Works	5748 NE Columbia Blvd	Portland	OR	97218	33232204	$1-2.5 Million
T & P Machine	54660 E Highway 26	Sandy	OR	97055	33271002	< $500,000
TECHNICAL Finishes & Coatings	9120 SE 64th Ave	Portland	OR	97206	33281317	$1-2.5 Million
Temco Metal Products	10240 SE Mather Rd	Clackamas	OR	97015	33639018	$20-50 Million
Thompson Metal Fab Inc	3000 SE Hidden Way # 40	Portland	OR	97217	33231210	$50-100 Million
Thortex Advance Metal Tech	15045 NE Mason St	Portland	OR	97230	33281101	$20-50 Million
Thortex Ink	15045 NE Mason St	Portland	OR	97230	33911312	$5-10 Million
Tice Industries	2219 N Vancouver Ave	Portland	OR	97227	33251015	$2.5-5 Million
Tiger Drylac USA Inc	16520 SW 72nd Ave	Portland	OR	97224	33281219	$1-2.5 Million
Tobert White Machine Inc	22165 SE Mark Rd	Damascus	OR	97089	33271002	$500,000-1 Million
Todd Littlehales LLC	1709 SE Powell Blvd	Portland	OR	97202	33231210	$2.5-5 Million
Tokai Carbon USA Co	4495 NW 235th Ave	Hillsboro	OR	97124	33281204	$5-10 Million
Transco Industries Inc	5534 NE 122nd Ave	Portland	OR	97230	33231210	$20-50 Million
Trek Inc	7875 SW Hunziker St	Portland	OR	97223	33211908	< $500,000
Treske Precision Machining Inc	14140 SW Galbreath Dr	Sherwood	OR	97140	33271002	$10-20 Million
Triax Metal Products Inc	1880 SW Merlo Dr	Beaverton	OR	97006	33232204	$20-50 Million
Trillium Machine Inc	36535 Industrial Way	Sandy	OR	97055	33271002	$1-2.5 Million
Triple T Machining Inc	11243 Beutel Rd	Oregon City	OR	97045	33271002	$500,000-1 Million
Tube Forgings Of America Inc	5200 NW Front Ave	Portland	OR	97210	33211107	$1-2.5 Million
Tufcoat Propowder	19700 SW 124th Ave	Tualatin	OR	97062	33281219	$1-2.5 Million
Turk Manufacturing Inc	1500 NE 48th Ave	Hillsboro	OR	97124	33271002	$5-10 Million
TVT Die Casting & Mfg Inc	7330 SW Landmark Ln	Portland	OR	97224	33152301	$5-10 Million
Ultimizers Inc	28380 SE Stone Rd	Boring	OR	97009	33331846	$1-2.5 Million
Ulven Forging Inc	6160 S Whiskey Hill Rd	Hubbard	OR	97032	33211107	$10-20 Million
Uni Source	8040 NE 33rd Dr	Portland	OR	97211	33111011	$50-100 Million
Unique Metalcraft	28494 SE Glover Rd	Eagle Creek	OR	97022	33231210	< $500,000
United Pipe Bending & Fab Inc	10534 NE Marx St	Portland	OR	97220	33299602	$2.5-5 Million
Universal Machine	7500 NE 11th Ave	Portland	OR	97211	33271002	$500,000-1 Million
Universal Precision Products	1775 NW Cornelius Pass Rd	Hillsboro	OR	97124	33272101	$2.5-5 Million
Us Metal Works Inc	36370 Industrial Way	Sandy	OR	97055	33231210	$10-20 Million
Usher Precision Mfg Inc	3863 24th Ave	Forest Grove	OR	97116	33211908	$2.5-5 Million
Vanport Marine	2711 NE Columbia Blvd	Portland	OR	97211	336611	$2.5 - 5 Million
Versa Steel Inc	1618 NE 1st Ave	Portland	OR	97232	33231210	$500,000-1 Million
Versa-Tech Metal Fab Inc	12920 NE Whitaker Way	Portland	OR	97230	33232317	$5-10 Million
Vigor Industrial Marine LLC	5555 N Channel Ave # 71	Portland	OR	97217	33661102	$100 - 500 Million
Voith Paper Fabric & Roll Syst	6633 NE 59th Pl	Portland	OR	97218	31599034	$2.5-5 Million
W W Machine Shop	926 SE Grand Ave	Portland	OR	97214	33271002	$500,000-1 Million
Wade Manufacturing Co	9995 Sw Avery St	Tualatin	OR	97062	33311103	$2.5-5 Million
Wagner-Smith Co	19020 SW Cipole Rd # B	Tualatin	OR	97062	33312009	$5-10 Million
Webster Industries Inc	9620 SW Herman Rd	Tualatin	OR	97062	33211102	$1-2.5 Million
West Coast Cart Co	15429 SE Piazza Ave	Clackamas	OR	97015	33261815	$1-2.5 Million
Western Integrated Tech	8900 N Ramsey Blvd	Portland	OR	97203	33399601	$10-20 Million
Western Machine Works Inc	12005 N Burgard Way	Portland	OR	97283	33271002	$5-10 Million
Western Metrology Inc	9425 SW Commerce Cir # B22	Wilsonville	OR	97070	33324201	$1-2.5 Million
Western Well Supply	21075 SW Tualatin Valley Hwy	Beaverton	OR	97006	33351709	$1-2.5 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
WGBM Associates Inc	10422 NE Killingsworth St	Portland	OR	97220	33324308	$1-2.5 Million
Willamette Manufacturing Inc	PO Box 156	Tualatin	OR	97062	33231210	$500,000-1 Million
Willamette Pattern Works Inc	2336 SE 9th Ave	Portland	OR	97214	33324303	$2.5-5 Million
William D Elliott Bending	7547 SE Altman Rd	Gresham	OR	97080	33281101	< $500,000
Williams Manufacturing Inc	9820 SE Empire Ct	Clackamas	OR	97015	33271002	< $500,000
Williams Tool & Die	9300 SW Norwood Rd	Tualatin	OR	97062	33351410	< $500,000
Wolf Industries Inc	6541 SE Johnson Creek Blvd	Portland	OR	97206	33271002	< $500,000
Wolf Steel Foundry	6160 S Whiskey Hill Rd	Hubbard	OR	97032	33151304	$5-10 Million
Wright Manufacturing LLC	7474 SE Johnson Creek Blvd	Portland	OR	97206	33231210	$2.5-5 Million
XZERES Corp	9025 SW Hillman Ct # 3126	Wilsonville	OR	97070	33232318	$1-2.5 Million
A-1 Precision Inc	8014 NE 19th Ct	Vancouver	WA	98665	33271002	$1-2.5 Million
Advance Welding Inc	1509 NE 106th St # A	Vancouver	WA	98686	81149058	$500,000-1 Million
Aloomold	34712 NE Washougal River Rd	Washougal	WA	98671	33271002	< $500,000
Alpha Omega Tool & Die	13206 NE Fourth Plain Rd # A1	Vancouver	WA	98682	33271002	< $500,000
Artistic Iron	1354 Down River Dr	Woodland	WA	98674	33232312	< $500,000
Asco Machine Inc	7916 NE 19th Ct	Vancouver	WA	98665	33271002	$2.5-5 Million
Avos Inc Wrought Iron Engrng	11812 NE Highway 99	Vancouver	WA	98686	33232312	$1-2.5 Million
Azure Machinery Inc	2850 NE 65th Ave	Vancouver	WA	98661	33312014	$2.5-5 Million
B & J Metal Fab	31211 NW Paradise Park Rd	Ridgefield	WA	98642	33232204	$1-2.5 Million
Bart's Enterprises	1327 Coal Creek Rd	Longview	WA	98632	33271002	$1-2.5 Million
Biec International	1111 Main St # 600	Vancouver	WA	98660	33281203	$1-2.5 Million
Blue Luca	3652 Old Lewis River Rd	Woodland	WA	98674	33232312	< $500,000
Bob's Mow & Machine	1501 NW Sluman Rd	Vancouver	WA	98665	33271002	< $500,000
Bodycote IMT Inc	4605 NW Pacific Rim Blvd	Camas	WA	98607	33281101	$10-20 Million
Bowers Steel	9702 SE 12th St	Vancouver	WA	98664	33231210	$1-2.5 Million
Burke Industrial Coatings	600 S 74th Pl # 108	Ridgefield	WA	98642	33281203	$1-2.5 Million
Cascade Aluminum	4102 NE 72nd Ave	Vancouver	WA	98661	33131802	$2.5-5 Million
Chrome Industrial Repair Inc	11901 NE 56th Cir	Vancouver	WA	98682	33271002	$1-2.5 Million
Clark College-Machine Tech	1933 Fort Vancouver Way	Vancouver	WA	98663	33271002	$500,000-1 Million
Claude's Accurate Machining	14413 NE 10th Ave # A112	Vancouver	WA	98685	33271002	$500,000-1 Million
Cleveland Enterprises Inc	3207 NE 65th St	Vancouver	WA	98663	33231210	$1-2.5 Million
Cobalt Designworks LLC	1930 D St	Vancouver	WA	98663	33232312	< $500,000
Columbia Machine Inc	107 S Grand Blvd	Vancouver	WA	98661	33271002	$50-100 Million
Columbia Metal Works Inc	4200 NW Fruit Valley Rd	Vancouver	WA	98660	33231210	$1-2.5 Million
Computer Controlled Machining	3417 NE 109th Ave	Vancouver	WA	98682	33271002	< $500,000
Consolidated Metco Inc	5701 SE Columbia Way	Vancouver	WA	98661	33152301	$100-500 Million
Crown Plating Inc	4221 NE St Johns Rd # G	Vancouver	WA	98661	33281317	< $500,000
Crs	919 SE Grace Ave	Battle Ground	WA	98604	33231210	$2.5-5 Million
D Z & Family Machine Works	400 2nd St	Woodland	WA	98674	33271002	< $500,000
Davis Development & Mfg Inc	9500 NE 72nd Ave	Vancouver	WA	98665	33271002	$500,000-1 Million
Decorative Metal Svc	1200 W 8th St	Vancouver	WA	98660	33232302	$500,000-1 Million
Deno's Custom Coatings	1400 SE 192nd Ave	Vancouver	WA	98683	33281203	$1-2.5 Million
Diversified Welding Works	8009 NE 19th Ct	Vancouver	WA	98665	33521010	$1-2.5 Million
DJ Fence Svc	9919 NE St Johns Rd	Vancouver	WA	98686	33261805	$500,000-1 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Donamo Co	1413 N 20th St	Washougal	WA	98671	33281317	$500,000-1 Million
Dullum Industries	13315 NE Kerr Rd # A	Vancouver	WA	98682	33271002	$500,000-1 Million
Eastside Steel Inc	6402 NE 127th Ave	Vancouver	WA	98682	33231210	$5-10 Million
EDT Corp	1006 NE 146th St # J	Vancouver	WA	98685	33324106	$2.5-5 Million
Elliot Attachaments Inc	244 Milwaukee Pl # 2	Kelso	WA	98626	33232204	$500,000-1 Million
Eminic Manufacturing	7000 NE 40th Ave	Vancouver	WA	98661	33271002	$1-2.5 Million
Eridu Designs	17005 NE Grantham Rd	Amboy	WA	98601	33231206	$1-2.5 Million
ESCO Corp	2141 NW 25th Ave	Vancouver	WA	98660	33211908	$1-2.5 Million
Fabral Inc	116 Y St	Vancouver	WA	98661	33232204	$500,000-1 Million
Fabrication Products Inc	4201 NE Minnehaha St	Vancouver	WA	98661	33232204	$5-10 Million
Farwest Steel Reinforcing	3703 NW Gateway Ave	Vancouver	WA	98660	33231210	$10-20 Million
Fenceman	2808 NE Burton Rd	Vancouver	WA	98662	33232312	$1-2.5 Million
France Special Tool	30111 NE Timmen Rd	Ridgefield	WA	98642	33351413	$1-2.5 Million
Gillaspie Manufacturing Inc	12800 NE 95th St	Vancouver	WA	98682	33211912	$1-2.5 Million
Gilmour Machinery	14812 NE 379th St	La Center	WA	98629	33312014	$1-2.5 Million
Graham Steel Corp	3000 SE Hidden Way # 40a	Vancouver	WA	98661	33231210	$5-10 Million
Grating Fabricators Inc	3001 SE Columbia Way # 3	Vancouver	WA	98661	33232309	$1-2.5 Million
Greigs Custom Machine	672 Walker Rd	Kelso	WA	98626	33271002	$500,000-1 Million
Harris Metal Fab & Welding	19217 NE 219th St	Battle Ground	WA	98604	33231210	< $500,000
Herko Tool & Machine	2719 E 5th St	Vancouver	WA	98661	33271002	< $500,000
Hi Tech Metal Fab Inc	2301 SE Hidden Way # 100	Vancouver	WA	98661	33231210	$5-10 Million
Hyak Electrowork	600 SE 45th Pl	Vancouver	WA	98661	33312014	$2.5-5 Million
IMW Inc	5561 S 1st Cir	Ridgefield	WA	98642	33351709	< $500,000
Jan Well Machining & Hardware	1909 E 5th St	Vancouver	WA	98661	33271002	$1-2.5 Million
Kalama Precision Machine	1629 S Cloverdale Rd	Kalama	WA	98625	33271002	< $500,000
Kap Machine Shop	21514 NE 29th Ave	Ridgefield	WA	98642	33271002	< $500,000
Kaso Plastics	5720-C NE 121st Avenue, Ste. 110	Vancouver	WA	98682	326199	$20-50 Million
Kirkpatrick's Inc Machine Shop	86 Port Way	Longview	WA	98632	33271002	< $500,000
Laclede Chain Mfg Co	603 SE Victory Ave # 170	Vancouver	WA	98661	33211102	$2.5-5 Million
Lakey Enterprises	3608 NE 163rd St	Ridgefield	WA	98642	33351504	< $500,000
Lam Research Corp	222 NE Park Plaza Dr # 112	Vancouver	WA	98684	33441302	$20-50 Million
Last Cast Custom Jigs	2245 32nd Ave	Longview	WA	98632	33351409	$1-2.5 Million
Liedtke Tool & Gage Inc	3801 NE 102nd St	Vancouver	WA	98686	33271002	$500,000-1 Million
Life Last	1301 NE 144th St # 125	Vancouver	WA	98685	33281203	$1-2.5 Million
M & M Mfg Co	2208 Laframbois Rd	Vancouver	WA	98660	33299910	$2.5-5 Million
M & M Mfg Co	3315 NE 112th Ave # 14	Vancouver	WA	98682	33299910	$1-2.5 Million
Mac Chain	1855 Schurman Way	Woodland	WA	98674	33392204	$5-10 Million
Manufacturing Resources Inc	32809 NE Sako Dr	Battle Ground	WA	98604	33271002	< $500,000
Mechanically Inclined LLC	138 Cowlitz Gdns	Kelso	WA	98626	33271002	$1-2.5 Million
Mellema Manufacturing	1413 Lincoln Ave	Vancouver	WA	98660	33271002	$1-2.5 Million
Micro Dimensions Inc	5617 S 6th Way	Ridgefield	WA	98642	33271002	$1-2.5 Million
Micro Machining LLC	1213 NE 314th Ave	Washougal	WA	98671	33271002	$500,000-1 Million
Micropump Inc	1402 NE 136th Ave	Vancouver	WA	98684	33391102	$20-50 Million
Molecular Inc	247 Schutt Rd	Castle Rock	WA	98611	33281203	$500,000-1 Million

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Mr Powder KOTE	11406 NE Rosewood Ave # L	Vancouver	WA	98662	33281219	< $500,000
Murphy Ironworks Inc	9709 NE 222nd Ave # A	Vancouver	WA	98682	33232312	< $500,000
Northwest Pipe Co	5721 SE Columbia Way # 200	Vancouver	WA	98661	33121003	$100-500 Million
Northwest Stamping Precision	1216 NW 79th Cir	Vancouver	WA	98665	33211912	$1-2.5 Million
Norwesco Inc	3860 Grant St	Washougal	WA	98671	32619910	$2.5-5 Million
Nw Manufacturing Svc	12510 NE Highway 99 # A	Vancouver	WA	98686	33999936	< $500,000
Oramac Inc	8100 NE St Johns Rd # C104	Vancouver	WA	98665	33312014	$5-10 Million
Orbit Industries LLC	778 S 27th St	Washougal	WA	98671	33231210	$2.5-5 Million
P & V Precision Grinding Inc	12607 NE 95th St	Vancouver	WA	98682	33281207	$500,000-1 Million
Pacific Die Casting	4107 NW Fruit Valley Rd	Vancouver	WA	98660	33151112	$1-2.5 Million
Pacific Die Casting Corp	5712 NW Fruit Valley Rd	Vancouver	WA	98660	33152301	$5-10 Million
Pacific Machine & Development	5600 NE 78th St	Vancouver	WA	98665	33271002	$2.5-5 Million
Pacific Northwest Plating	7001 NE 40th Ave	Vancouver	WA	98661	33281317	$1-2.5 Million
Pacific Precision Mfg Inc	2850 NE 65th Ave # B	Vancouver	WA	98661	33271002	$500,000-1 Million
Pentair Valves & Controls	22120 NE 209th Ave	Battle Ground	WA	98604	33291102	$5-10 Million
Performance Prototypes	12401 Ne 60th Way A-8	Battle Ground	WA	98682	33271002	$500,000-1 Million
Phyl-Mar Swiss Products Inc	3136 Evergreen Way	Washougal	WA	98671	33271002	$1-2.5 Million
Portable Fab & Machine	12004 NW 36th Ave	Vancouver	WA	98685	33271002	$500,000-1 Million
Precision Rebar & Accessories	1712 NE 99th St	Vancouver	WA	98665	33231210	$2.5-5 Million
Pro-Coat Inc	PO Box 2284	Vancouver	WA	98668	33281219	< $500,000
Pro-Tech Industries	14113 NE 3rd Ct	Vancouver	WA	98685	33131802	$20-50 Million
Ps Fab	20600 NE 72nd Ave	Battle Ground	WA	98604	33131802	$500,000-1 Million
Quality Machine	8704 NE 55th Ave	Vancouver	WA	98665	33271002	< $500,000
R & D Machine LLC	3109 NE 65th St # B	Vancouver	WA	98663	33271002	$500,000-1 Million
R & L Mfg	19215 SE 34th St. Suite 106	Camas	WA	98607	33271002	$1-2.5 Million
R D Olson Mfg Inc	1807 Baker Way	Kelso	WA	98626	33231210	$20-50 Million
R S Machine	6133 NE 63rd St	Vancouver	WA	98661	33271002	< $500,000
R2 Manufacturing Inc	3108 NE 65th St # A	Vancouver	WA	98663	33271002	< $500,000
Rail Pro	2700 NE Andresen Rd # G2b	Vancouver	WA	98661	33232312	$1-2.5 Million
Rapid Protocasting	14413 NE 10th Ave # A109	Vancouver	WA	98685	33151304	$1-2.5 Million
Roemer Electric Steel Foundry	523 7th Ave	Longview	WA	98632	33151304	$5-10 Million
Salmon Creek Machine	14503 NW Mccann Rd	Vancouver	WA	98685	33271002	$1-2.5 Million
Schroeder's Machine Works Inc	8010 NE 19th Ct	Vancouver	WA	98665	33271002	$1-2.5 Million
Schurman Machine Inc	23201 NE 10th Ave	Ridgefield	WA	98642	33271002	$2.5-5 Million
Screen Technology Group	33008 NE Washougal River Rd	Washougal	WA	98671	33232110	$1-2.5 Million
Skinner & Family Vending	35206 NE Gable Ave	La Center	WA	98629	33271002	$1-2.5 Million
Sky Comm Inc	2116 NW 140th St	Vancouver	WA	98685	33231211	$1-2.5 Million
Skyline Steel	9 International Way	Longview	WA	98632	33111006	$10-20 Million
Skytech Machine Inc	10505 NE Maitland Rd	Vancouver	WA	98686	33271002	< $500,000
Somarakis Inc	552 Hendrickson Dr	Kalama	WA	98625	33271002	$5-10 Million
Sonsray Machinery	6407 NE 117th Ave # B	Vancouver	WA	98662	33312009	$10-20 Million
Southridge Steel Fabricators	17800 NW 31st Ave	Ridgefield	WA	98642	33231210	< $500,000
Spare Parts Mfg & Repair	3004 NE 112th Ave # C	Vancouver	WA	98682	33271002	< $500,000
Specialty Motors Mfg	641 California Way	Longview	WA	98632	33231303	$500,000-1 Million
Spence Co	1044 Oak Point Rd	Longview	WA	98632	33231206	< $500,000

Company Name	Address	City	ST	Zip	NAICS Code	Sales Volume
Steel Erectors Northwest Inc	PO Box 224	Brush Prairie	WA	98606	33231210	$1-2.5 Million
Steelscape Inc	222 W Kalama River Rd	Kalama	WA	98625	33111007	$20-50 Million
Stewart Precison	3315 NE 112th Ave # 65	Vancouver	WA	98682	33271002	< $500,000
Swift Machining	1414 E St # 2	Washougal	WA	98671	33271002	< $500,000
Thermal Coatings Intl Inc	680 S 28th St # C	Washougal	WA	98671	33351712	$1-2.5 Million
Thompson Metal Fab Inc	3000 SE Hidden Way	Vancouver	WA	98661	33231210	$50-100 Million
Three Rivers Indl Machine	2201 Talley Way	Kelso	WA	98626	33271002	$1-2.5 Million
Tidland Hydraulics Inc	3408 NE Corbin Rd	Vancouver	WA	98686	33271002	$500,000-1 Million
Tigerstop	12909 NE 95th St	Vancouver	WA	98682	33312014	$5-10 Million
Trucut Die Inc	4601 NE 78th St # 260	Vancouver	WA	98665	33351401	< $500,000
Tubes N' Hoses NW	13106 NE Fourth Plain Blvd	Vancouver	WA	98682	33299607	$500,000-1 Million
Unlimited Fence	4604 NW 209th St	Ridgefield	WA	98642	33261805	< $500,000
Vancouver Iron & Steel Inc	1200 W 13th St	Vancouver	WA	98660	33151112	$20-50 Million
Vancouver Powder Coating	3406 NW 128th St	Vancouver	WA	98685	33281219	$500,000-1 Million
Waite Specialty Machine Inc	1356 Tennant Way	Longview	WA	98632	33271002	$10-20 Million
Waite Specialty Machine Works	1160 Industrial Way	Longview	WA	98632	33271002	$5-10 Million
Wayron LLC	1201 Baltimore St	Longview	WA	98632	33271002	$10-20 Million
Weissert Tool & Design Inc	540 Washougal River Rd	Washougal	WA	98671	33351410	$1-2.5 Million
Western Fabrication	2203 Talley Way	Kelso	WA	98626	33231210	$10-20 Million
Williams Precision Machine	1695 13th Ave S	Kelso	WA	98626	33271002	$1-2.5 Million

APPENDIX B: Metals Used In Manufacturing Machinery

Ferrous Metals (from Iron)

- Low carbon steel – Good formability, good weld-ability, low cost. Used in chains, stamping, rivets, nails, wire, pipe, and where very soft "plastic" steel is needed.
- Medium carbon steel – Well-balanced properties, fair formability. Percent of carbon determines use:
  - Lowest percent is in lead screws, gears, worms, spindles, shafts and machine parts
  - Next highest is used for crankshafts, gears, axles, mandrels, tool shanks, heat-treated machine parts
  - "Tool Steel" is used for drop hammer dies, screws, screwdrivers and arbors
  - Highest carbon percent is in tough, hard steel: anvil faces, band saws, hammers, wrenches, cable wire
- High carbon steel – Low toughness, formability, high hardness and wear resistance, fair formability. Five strengths depending on carbon percentage.
  - Lowest: Metal punches, rock drills, shear blades, cold chisels, rivet sets, hand tools
  - Hard high-tensile strength for springs, cutting tools
  - Drills, taps, milling cutters, knives, cold cutting dies, wood working tools
  - Files, reamers, knives, tools for cutting wood and brass
  - Keen-edge cutting tools with high-wear resistance: razors, saws
- Stainless steel – Good corrosion resistance, appearance and mechanical properties.
- Austenitic Steel – Good mechanical and corrosion resistance, high hardness and yield strength, excellent ductility and usually non-magnetic. For kitchen sinks, roofing, cladding, gutters, doors and windows; food processing equipment; heat exchangers, ovens; chemical tanks.
- Ferritic (iron oxide) Steels – Good ductility, weld-ability and formability; reasonable thermal conductivity, corrosion resistance, bright surface appearance. For auto trim, catalytic converters, radiator caps, fuel lines, cooking utensils, architectural and domestic appliance trims.
- Martensitic Steels – Corrosion resistance combined with excellent mechanical properties, produced by heat treatment to develop maximum hardness, strength and resistance to abrasion and erosion. For cutlery, surgical instruments, wear plates, garbage disposal shredder lugs, industrial knives, steam turbine vanes, fasteners, shafts and springs.

Nonferrous Metals

- Aluminum, pure or alloyed with small amounts of copper, manganese, silicone and magnesium added to produce low density, good electrical conductivity; nonmagnetic, noncombustible, ductile, malleable, corrosion resistant. Easily formed, machined or cast. Used for window frames, aircraft parts, automotive parts, kitchenware.
- Brass – 65% Copper 35% Zinc alloy. Reasonable hardness; casts, forms and machines well; good electrical conductivity and acoustic properties. For electrical fittings, valves, forgings, ornaments, musical instruments.
- Copper, pure – Excellent ductility, thermal and electrical conductivity. For electrical wiring, tubing, kettles, bowls, pipes, printed circuit boards.
- Lead, pure – Heaviest common metal, ductile, malleable, good corrosion resistance. For pipes, batteries, roofing, protection against X-rays.
- Magnesium, pure or used with nonferrous alloys; alloyed with aluminum to improve mechanical, fabrication and welding characteristics; lightest metallic material (two-thirds that of aluminum); strong, most machine-

able metal, easily cast; good corrosion resistance. For automobile parts, portable electronics, appliances, power tools, sporting goods, aerospace equipment.

- Nickel/Nickel-based alloys work with large amounts of other elements such as chromium – very good corrosion resistance, often beyond stainless steel, good high temperature and mechanical performance, fairly good conductor of heat and electricity. For preparing alloys and plating, as an undercoat in decorative chromium plating, and to improve corrosion resistance. Applications include electronic lead wires, battery components, heat exchangers in corrosive environments.
- Titanium – Easily alloyed with aluminum, nickel, chromium. Low density, low coefficient of thermal expansion, high melting point. Excellent corrosion resistance, nontoxic and biologically compatible with human tissue and bones. High strength, stiffness, good toughness. Used in aerospace structures and other high-performance applications. Good for chemical and petrochemical applications; marine environments, biomaterial applications.
- Zinc – Pure or most commonly alloyed zinc with small amounts of copper, aluminum and magnesium to make brass for use in die-casting; excellent corrosion resistance, lightweight, reasonable conductor of electricity, mostly for galvanizing iron; many lightweight auto applications.

Metals commonly used in Computers & Electronics:

- Aluminum
- Copper
- Iron and steel
- Terne: coated metals such as carbon steel and stainless steel with a zinc/tin alloy to reduce corrosion
- Zinc

Metals commonly used in Aerospace & Defense:

Corrosion-resistant metals including: titanium and titanium alloys, nickel-based alloys and super alloys. Materials of particular interest include: Nickel-based super alloys; thermal barrier coatings; modern carbon composite materials; thermal and night vision sensor materials; radiation-hardened electronics; high-precision optics, glasses and plastics; solar panels; paints; ceramic armor materials and munitions all requiring tight control of material properties, composition and chemistry. Carbon fiber is not a metal; it consists of thin, strong crystalline filaments of carbon used as a strengthening material, especially in resins and ceramics. It is replacing metal in many parts and components because of its lightweight strength.

- Aluminum
- Copper
- Grain-oriented electrical steel
- Hafnium
- Magnesium
- Nickel-based alloys
- Niobium alloys
- Stainless and specialty steels
- Titanium and titanium alloys
- Zirconium

APPENDIX C: Education Resources

Competitive National Examples of Education & Training

Virginia Polytechnic Institute and State University's College of Materials Science and Engineering has a state-of-the-art advanced materials foundry for metal casting on campus. It has a 4,500 sq. ft., $1.7 million facility with an induction furnace capable of melting aluminum, copper, bronze, iron and steel, along with molding equipment and rapid prototyping.

Pennsylvania State University has the Center for Innovative Materials Processing through Direct Digital Deposition, a laboratory and a university-wide initiative to become a world-class facility for additive manufacturing technology. The university broke ground on a new 10,000 sq. ft. facility in January 2013.

Regional Examples of Education & Training

Clark College Mechatronics Lab, Vancouver, Washington

Clark College has the only Mechatronics Lab on the West Coast offering two-year degrees. State-of-the-art electrical and mechanical equipment provides hands-on learning. Coursework includes soft skills training as well as project management, business models and technical writing. The average student is 35 years old and the program graduates 12 students per year on average—many of whom have job offers before graduation. The four-year-old program works with an Industrial Advisory Council of local companies to ensure it meets business needs.

Business courses integrate social skills training with the manufacturing program:

- Team building
- Corporate structure and business models
- Project management and lean manufacturing, 5S, JITI, etc.
- Overall entrepreneurship and business spirit, including funding and finance
- College level writing and communications
- Technical writing
- Conflict resolution
- Leadership

The curriculum includes systems thinking relevant to semiconductor processes for WaferTech and Intel. Students receive mechanical training for use with v-belts, pulleys, chain and gear drives, bearings and lubricants, laser alignment, and vibration. They learn how to bend and thread pipe and calculate pressure drops. They work with copper, plastic, and galvanized metal, and learn hydraulics, pneumatics and directional valves, as well as manual and electrical controls. Safety is embedded in the courses and there is a stand-alone course on safety at the request of the Industrial Advisory Committee.

Students learn about programmable logic controls on custom machines from Siemen's (Germany) and Allen Bradley (U.S.). Process control trainers teach level, flow, pressure, and temperature management.

The program is designed to match students with jobs. During students' second year, they work in a realistic technology environment. SMC machines are "Troub200," meaning they are controllable by the teacher who can make something go wrong so the students have to figure out and fix the problem. SMC is the world leader for pneumatic components. Their machines mimic production environments to teach students how to increase knowledge with real-world examples.

Companies also bring employees to be trained on site in a four-year apprenticeship program. Clark College is starting a new certification and degree program for millwrights who are industrial maintenance technicians that design, build, or repair mills and mill machinery. Manufacturing companies need them for troubleshooting and repair. Program masteries include:

- ElectroMechanical Oscillation (EMO)
- PLC programming with code modifications
- Gant charts
- Presentation of reports to actual prospective employers
- Introduction to rapid prototyping taught at WSUV

Portland Community College (PCC)
PCC offers manufacturing-related courses and programs in Machine Manufacturing Technology, Mechanical Engineering Technology, Electrical Engineering, Solar Voltaic Manufacturing, Microelectronics and Computer-Aided Design and Drafting (CADD), and Electrical Trades. PCC is reported[54] to be investing in electrochemical machining equipment that removes material by accelerating corrosion instead of grinding.

Oregon Institute of Technology (OIT)
OIT's Wilsonville, Oregon, campus offers bachelor and master degree programs in Electronics, Mechanical Engineering, Manufacturing Engineering, Renewable Energy Engineering, and Embedded Systems Engineering. The Embedded Systems courses are relevant for industrial applications such as avionics equipment, medical equipment, and printers.

Washington State University Vancouver (WSUV)
WSUV offers degrees in Electrical and Mechanical Engineering. Curricula include focus on aerospace and military systems, microelectronics, control systems, and power generation and distribution. Course subject matter includes integrated circuit design and testing, electronic devices and materials, micro- and nano-technology, design and manufacturing, and mechatronics, as well as computer-aided engineering and manufacturing, micromachining, and rapid prototyping.

Oregon State University (OSU)
Research faculty focuses on interdisciplinary materials science, such as thin film, as well as advanced electronics. Funding comes from the National Science Foundation, the Office of Naval Research, and the Department of Energy. Students can earn degrees in Structural and Mechanical Behavioral of Materials, Electroceramic Materials, Polymer Materials, Electronic Materials, and Nano-processing of Materials.

The university is reported[55] to have built the machine that evaluates metal grinding belts, an automated test device for comparing different belts and providing operational feedback to the machine operator to reduce materials waste. It was mentioned in confidential interviews with regional businesses that there is not enough focus on metals research, which is a need in the region. However, it was also mentioned that, as PSU reportedly wants to focus on sustainable energy versus metallurgy, OSU will be increasing its investment in metallurgy.

Portland State University (PSU)
PSU currently offers degrees in Electrical & Computer Engineering, Engineering & Technology Management, Mechanical & Materials Engineering, and Systems Engineering. The Mechanical & Materials Engineering program focuses on mechanical engineering design. The curriculum includes courses on aerospace, energy conversion and utilization, chemical processing, electromechanical systems, controls, manufacturing and materials, and mechanical design.

The programs engage students in solving problems faced by industry and government in the Portland metropolitan area, the state of Oregon, and Southwest Washington.

54 Confidential interview
55 Confidential interview

APPENDIX D: Industry Organizations, Associations, Publications & Conferences

Aluminum Association, Inc – A trade association for U.S. producers of primary aluminum, recyclers, and semi-fabricated aluminum products.

American Electroplaters & Surface Finishers Society – The AESF is an international society that advances the science of surface finishing for the benefit of industry and society.

American Galvanizers Association – The AGA association members represent the after-fabrication, hot-dip galvanizing industry throughout the United States, Canada, and Mexico.

American Iron and Steel Institute – The AISI promotes steel as the material of choice and works to enhance the competitiveness of the North American steel industry and its member companies.

American Mold Builders Association – American Mold Builders Association is the leading industry trade organization serving U.S. mold builders.

American Society for Metals International – Society of materials engineers and scientists dedicated to advancing industry, technology, and applications of metals and materials.

American Welding Society (AWS) – AWS was founded in 1919 as a nonprofit organization with a goal to advance the science, technology and application of welding and related joining disciplines.

Association for Forming & Fabricating Technologies of the Society of Manufacturing Engineers – Focuses on the technologies and processes that efficiently make products from metal sheet, coil, plate, tube, or pipe stock.

Association of Iron and Steel Engineers – A technical organization in the steel industry dedicated to the advancement of technical and engineering phases of the production and processing of iron and steel.

Association for Manufacturing Excellence – An organization for the exchange of knowledge in enterprise excellence.

Association for Manufacturing Technology (AMT) – AMT represents and promotes the interests of American providers of manufacturing machinery and equipment; the organization also actively supports and promotes American manufacturers of machine tools and manufacturing technology.

Association of Steel Distributors (ASD) – ASD is a non-profit organization, providing the steel distribution industry a forum for ideas exchange and market information.

Association of Women in the Metals Industry – International professional organization dedicated to promoting and supporting the advancement of women in the metals industries.

Canadian Welding Association (CWA) – CWA was formed as a national membership-driven association, mandated to promoting and supporting the welding and joining industry in Canada.

Fabricators & Manufacturers Association, International – This association keeps members current concerning metal forming and fabricating trends and technologies.

Forging Industry Association – Focuses on improving members' global competitiveness in the areas of industry benchmarking, global networking, public policy advocacy, developing technology, and training and education.

International Iron and Steel Institute (IISI) – The IISI is a non-profit research organization providing a world forum concerning aspects of the international steel industry.

International Training Institute – This association provides training opportunities to union members in the Sheet Metal and Air Conditioning industry.

Machine Tool Technologies Association – A national organization representing companies that are involved in the U.K. machine tool and manufacturing technology sector.

Manufacturing Institute – Authority on attraction, qualification and development of manufacturing talent.

Materials Research Society – Brings together scientists, engineers and research managers from industry, government, research labs, and various analysts and provides the online community in which to share findings and ideas.

Metal Treating Institute – Metal Treating Institute is the only international trade association representing the corporate heat-treating industry.

National Additive Manufacturing Innovation Institute – Works to accelerate additive manufacturing (3-D printing) technologies and increase the nation's global manufacturing competitiveness.

National Association of Manufacturers – Supports manufacturers' ability to grow the economy, create good paying jobs and improve standards of living.

National Association of Metal Finishers – Industry association representing hundreds of independent member surface finishing firms.

National Association for Surface Finishing – Works to promote an environmentally and economically sustainable future for the finishing industry and promotes the role of surface technology in the global manufacturing value chain.

National Center for Excellence in Metalworking Technology (NCEMT) – The NCEMT develops leading-edge capabilities in process analysis and optimization, materials analysis and selection, process development, product analysis and simulation, technology transition and deployment, and training and education for advanced metalworking technologies.

National Coil Coating Association – Dedicated to promoting the growth of coil coated products.

National Institute for Metalworking Skills (NIMS) – NIMS was formed in 1995 by the metalworking trade associations to develop and maintain a globally competitive American workforce.

National Institute of Standards and Technology (NIST) – NIST promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology to enhance economic security and improve quality of life.

National Tooling and Machining Association (NTMA) – NTMA helps members of the U.S. precision manufacturing industry achieve growth and business success through advocacy, advice, education, networking, programs and services.

Association for Packaging and Processing Technologies (PMMI)– Global resource for packaging and processing.

Portland Community College – Offers an academic program in Machine Manufacturing Technology, which trains students to become machine operators, manual machinists, CNC machinists, maintenance machinists, mechanical inspectors and computer-assisted machining programmers.

Portland State University – Offers academic programs in Civil Engineering and Mechanical Engineering.

Precision Machined Products Association – Represents the interests of the precision machined products industry which produces highly engineered components to customer specifications using a variety of materials including steel, aluminum, brass, plastics, and multiple aerospace and medical grade metallic alloys.

Precision Metalforming Association – Represents the metal forming industry and leads innovative member companies toward superior competitiveness and profitability.

Resistance Welding Manufacturing Alliance – Develops equipment standards for the protection and benefit of buyers and users of resistance welding equipment and accessories.

Robotics Industries Association – Provides information to help engineers and executives apply robotics and flexible automation.

Society of Manufacturing Engineers – Dedicated to advancing manufacturing by addressing deficits in knowledge and skills for the industry through events, media, membership, training and development.

Specialty Steel Industry of North America (SSINA) – SSINA is a trade association representing virtually all the producers of specialty steel in North America including bar, rod, wire, angles, plate, sheet and strip, in stainless steel and other specialty steels.

Steel Manufacturers Association – Develops public policy positions, provides a forum for the exchange of information on technical matters and operations among member companies, and serves as a source of information on the steel industry to suppliers, customers and government entities.

Steel Recycling Institute – Promotes and sustains recycling of steel products; educates the solid waste industry, government, business and consumers about the benefits of steel's recycling cycle.

Washington State University Vancouver (WSUV) – WSUV offers bachelor degrees in Electrical Engineering and Mechanical Engineering.

World Steel Organization – Promotes steel and the steel industry to customers, the industry, media and the general public.

APPENDIX E: Regional Industry & Economic Development Support Organizations

Oregon Metals Initiative (OMI)

www.oregonmetal.org

OMI is a state-funded consortium of metals industry companies and research institutions pursuing research to advance the long-term competitiveness of the metals industry in Oregon. It invests in corporate research, which is matched dollar-for-dollar by the Oregon University System for new material discoveries, technology development, patenting and commercialization.

Business Oregon

www.oregon4biz.com

A state organization that works to retain, expand and attract businesses through public-private partnerships, leveraged funding, and support of Oregon companies and entrepreneurs. The Oregon Business Development Commission oversees policies in support of executive and legislative leadership for business. It provides company resources for exporting and is a partner in the Greater Portland Export Initiative.

Columbia River Economic Development Council

www.credc.org

CREDC is the business growth and expansion resource for Southwest Washington. They connect businesses and investors to economic resources to advance the economic vitality of Clark County, Washington, through innovation. CREDC partners with education, workforce and business communities, supports entrepreneurship, and provides leadership for improvements in physical infrastructure and amenities that help create, attract, grow and retain companies.

Greater Portland Inc

www.greaterportlandinc.com

A regional economic development partnership helping companies and site selectors find ideal spots to locate and expand. It helps position the Portland-Vancouver metro area as a competitive and vibrant economy. GPI provides business development, regional branding and marketing, and regional strategy coordination, including the region's Comprehensive Economic Development Strategy (CEDS), the Greater Portland Export Initiative in conjunction with the Brookings Institution, and the Jobs & Innovation Accelerator Challenge Clean Tech Advance initiative awarded by the Federal government.

Portland Development Commission

www.pdc.us

PDC is the City of Portland's economic development and urban renewal agency. It supports growth and competitiveness, healthy neighborhoods and social equity. It promotes innovation and economic opportunity, providing direct support for startups and growing businesses, including recruiting of new businesses and retention of existing businesses.

Metro

www.oregonmetro.gov

The elected regional government for the Portland Metropolitan Area works with businesses and communities to create a sustainable region. Metro's state-of-the-art economic mapping technology was used to create the Geographic Information System (GIS) maps of regional businesses in these reports.

APPENDIX F: Regional & National Exporting Related Resources

Organizations

Impact Washington ExporTech Training Program
www.impactwashington.org

Washington State Export Resource Program
www.exportwashington.com

Portland Export Assistance Center
www.export.gov/oregon

Business Oregon International Export Assistance
www.oregon4biz.com

Export Council of Oregon
www.exportcounciloforegon.org

U.S. Export Assistance Center
www.sba.gov

U.S. Commercizl Service, Oregon, International Trade Administration
www.trade.gov/cs/states/or.asp

Websites

Trade Leads, Finding Customers, Distributors, Company Directories and Databases

FITA: Federation of Int'l Trade Associations
www.fita.org

Global Industrial Products and Company Database
www.solusource.com

Global eMarketplace
www.alibaba.com

Business Oregon Export Assistance
www.oregon4biz.com

Trade Counseling, Mentoring

Find your local Small Business Development Center
www.sba/gov/tools/local-assistance/sbdc

Find U.S. Export Assistance Center (U.S. Commercial Service, U.S/ Dept. of Commerce)
www.export.gov

Find a local District Export Council that mentors exporters
http://districtexortcouncil.org/local-dec-locator

Foreign Market Data, Country Economic & Business Climate

U.S. Gov't/U.S. Commercial Service export portal
www.export.gov

U.S. Dept. of Agriculture, Foreign Agric. Service
www.fas.usda.gov

Global Business Web Portal
http://globaledge.msu.edu

Global Market Studies to Purchase
www.marketresearch.com

Global Market Studies to Purchase
www.researchandmarkets.com

Economist Economic Intelligence Unit, country market data and industry analysis
www.eiu.com

FITA Market Research
www.fita.org or www.internationaltrade.org

World Bank Info re: foreign market regulatory environments
http://doingbusiness.org

Journal of Commerce
www.joc.com

Trade Information Portals, Tutorials, Export Guides, Links to Other Sources

Basic guide to exporting
www.unzco.com

U.S. Gov't. Export Portal
www.export.gov

FITA "Really Useful Links"
www.fita.org or
www.internationaltrade.org

International Trade Assocociation
www.ita.doc.gov

Free on-line Export Training
http://globaledge.msu.edu

Free on-line Export Training
www.export-u.com

Business Culture

Foreign Business Culture
www.executiveplanet.com

Foreign Business Culture
www.worldbiz.com

See Country Commercial Guides
www.export.gov

Trade Data; Tariffs, Duties; HS (International Harmonized System) Codes

International Trade Administration
www.ita.doc.gov and http://tse.export/gov

UN Trade Database
http://comtrade.un.org

USITC Interactive Trade Data Source
http://dataweb.usitc.gov

Census Bureau Trade Data
www.census.gov/foreign-trade

U.S. Gov't. Trade Data
www.usatradeonline.gov

U.S. Int'l Trade Commission
www.usitc.gov

Tariff Info, HS Codes
http://www.fedex.com/GTM?cntry_code=us

Trade Finance

Export-Import Bank Website
www.exim.gov

U.S. Gov't Trade Finance Guide
http://export.gov

Trade Shows, Events

Trade Show News Network Events Database
www.tsnn.com

See Trade Events section under "Opportunities" menu
www.export.gov

Legal and Compliance

Legal Export Assistance Network
www.exportlegal.org

EBook: Three Common Global Trade Compliance Deficiencies that Affect Your Bottom Line
http://info.amberroad.com/rl_wp_GTMDeficiencies.html

U.S. Customs & Border Protection Trade Resources
www.cbp.gov/xp/cgov/trade/

Stanford Univ. Export Control Info & Tools
http://doresearch.stanford.edu/research-scholarship/export-controls

Special 301 Report on Intellectual Property protection by country
https://ustr.gov/sites/default/files/USTR%202014%20Special%20301%20Report%20to%20Congress%20FINAL.pdf

U.S. Bureau of Industry & Security
(U.S. Export Controls)
www.bis.gov.doc

Export Council of Oregon
www.exportcounciloforegon.org

Acknowledgments

This report was prepared for the **Columbia River Economic Development Council** and **Business Oregon** by the **MarketLink**® Research Division of the **Oregon Microenterprise Network,** in support of the Federal Jobs and Innovation Accelerator Challenge Grant for the Innovations in Advanced Materials and Metals Manufacturing Project, and the Greater Portland Export Initiative.

The report was researched in partnership with Impact Washington, the Oregon Manufacturing Extension Partnership (OMEP), the Pacific Northwest Defense Coalition (PNDC), the Southwest Washington Workforce Development Council (SWWDC), Oregon Worksystems Inc., Greater Portland Inc, and the Portland Development Commission (PDC).

Special gratitude for inspiration and invaluable insights goes to the numerous (confidential) business and industry leaders who provided the in-depth interviews that enriched this research and grounded it in real-world challenges faced by regional businesses.

Appreciation goes to the many who shared their data and expertise, including: Elizabeth Scott of CREDC; Max Woodbury of Oregon Metro; Jim Wehrs of OMEP; Kristin Kautz of Impact Washington; Amy VanderVliet, Brenda Scott and Christian Kaylor of the Oregon Employment Department; Scott Bailey of the Washington Employment Security Department; Jo Oshiro of Oregon University Systems; Derrick Olsen of Greater Portland Inc; and Karen Goddin and Mike Meyers of Business Oregon.

Many thanks for research assistance and fact checking go to Emily Leuning and for proofreading to Susan Pagel. Researched and written by Dr. Beth Fitz Gibbon, founding principal of Fitz Gibbon Inc. Venture Development, and Senior Research & Policy Advisor, Oregon Microenterprise Network.

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Report design by Patrick Hildreth Brand & Design, Camas, Washington www.PatrickHildreth.com

Published May 2015

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