MAKING PROSPERITY

CREATING A SOUND ECONOMY THROUGH ADVANCED MANUFACTURING WITH ADVANCED MATERIALS, ROBUST SUPPLY CHAINS, AND EXPORTS

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 | APRIL 2015

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“Tending the Beast”; charcoal and pastel on canvas, 72 x 50", © 2014 Donna Steger

The machinists in this department at Enoch Manufacturing in Clackamas, Oregon, work on older-style screw machines, which are fully automatic but not computerized. Once the machines are set up, they continue producing high-volume, quality, turned components with consistent accuracy and minimal human intervention. This piece depicts the intense efforts of the workers as heroic, using care and precision to produce parts that fulfill the needs of both local and global commerce.

GREATER PORTLAND REGIONAL
ADVANCED MANUFACTURING & MATERIALS
INDUSTRY PROFILES

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PREFACE

The federal government has awarded a grant in support of manufacturing advanced materials and metals 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 & Metals Manufacturing (JIAC IAM2) 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 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) completed 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 businesses.

This report is Part I of a four-part research portfolio addressing advanced manufacturing and advanced materials in major regional industries. Other reports include Aerospace & Defense, Computers & Electronics, and Metals & Machinery.

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 exports.

All product or company names mentioned in this publication are trade names, trademarks or registered trademarks of their respective owners.

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

Research is a rear-view mirror, especially where innovation is concerned. With that caveat, this report attempts to present a current portrait of the future of manufacturing and how it will affect the economic prosperity of the Greater Portland region.

The industries selected for this research overlap considerably. Computers & Electronics are embedded in Aerospace & Defense and Metals & Machinery. That convergence represents a distinct competitive advantage for this region, which is rich in companies serving those industries.

As a region's industrial ecosystem strengthens and grows, it adds resources to support robust supply chains that can penetrate new markets, resulting in economic growth. The Greater Portland region's manufacturing heritage is a significant asset, as its supply chain players provide parts, components, modular systems, and finished products to multiple industries.

An apt synonym for manufacturing is the Japanese word *monozukuri*, which means "making things." To "make" is to fabricate, construct, produce, mold, shape, forge, cast . . . to manufacture. Electronics and manufacturing come together in the making of things as "mechatronics," the marriage of hardware to the microprocessors embedded in semiconductor chips. Today, mechatronics powers and controls machinery manufacturing and enables technology capabilities in industries such as aerospace and defense, and oil and gas. New materials and software play key mediating roles.

Manufacturing supports the entire industrial value chain, from demand for raw materials and components to logistics, warehousing, distribution, wholesaling, and retailing.

When you make what you sell, you own your economic future and can create your own growth through productivity and innovation. Profitable manufacturing that pays livable wages relies on new technology. To compete today and be relevant tomorrow, companies need to create efficient processes and new products. They need to reinvent themselves.

Portland's Christensen Shipyards in Vancouver, Washington, began as a home builder in the 1950s and now makes luxury yachts. When that market slowed, the company diversified, using its core competencies to serve a new industry. Today they are developing an unmanned autonomous surface vessel that can track a quiet diesel-electric submarine for months over great distances. Their work is part of a $58 million contract from the Defense Advanced Research Projects Agency (DARPA).[2] DARPA awarded the contract to Science Applications International Corp. of McLean, Virginia, which is teaming with Christensen and Oregon Iron Works of Clackamas, Oregon. Oregon Iron Works began in 1944 as a simple fabricator. Today it makes streetcars, bridges, and military patrol craft in steel, aluminum, titanium, and other advanced materials.

2 http://www.bizjournals.com/profiles/company/us/va/arlington/defense_advanced_research_projectsagency

Forward-thinking companies such as Christensen and Oregon Iron Works retool their business models to secure a new future by combining manufacturing expertise with access to research and development (R&D) capabilities that form a solid foundation for innovation. Creation of new technologies and commercialization of new products rely on learning through the design and production processes inherent in manufacturing.

Growth for companies and regions comes from local, state, and national consumption of the goods and services they provide. In today's global economy, growth also comes from exporting. Twenty-five percent of U.S. Gross Domestic Product (GDP) is tied to trade; and ninety-five percent of today's consumers – both businesses and people – are outside the U.S. in developing economies where middle classes are growing.[3] They want access to better quality of life and to purchase goods made in the U.S., which they trust for safety, quality, and design.

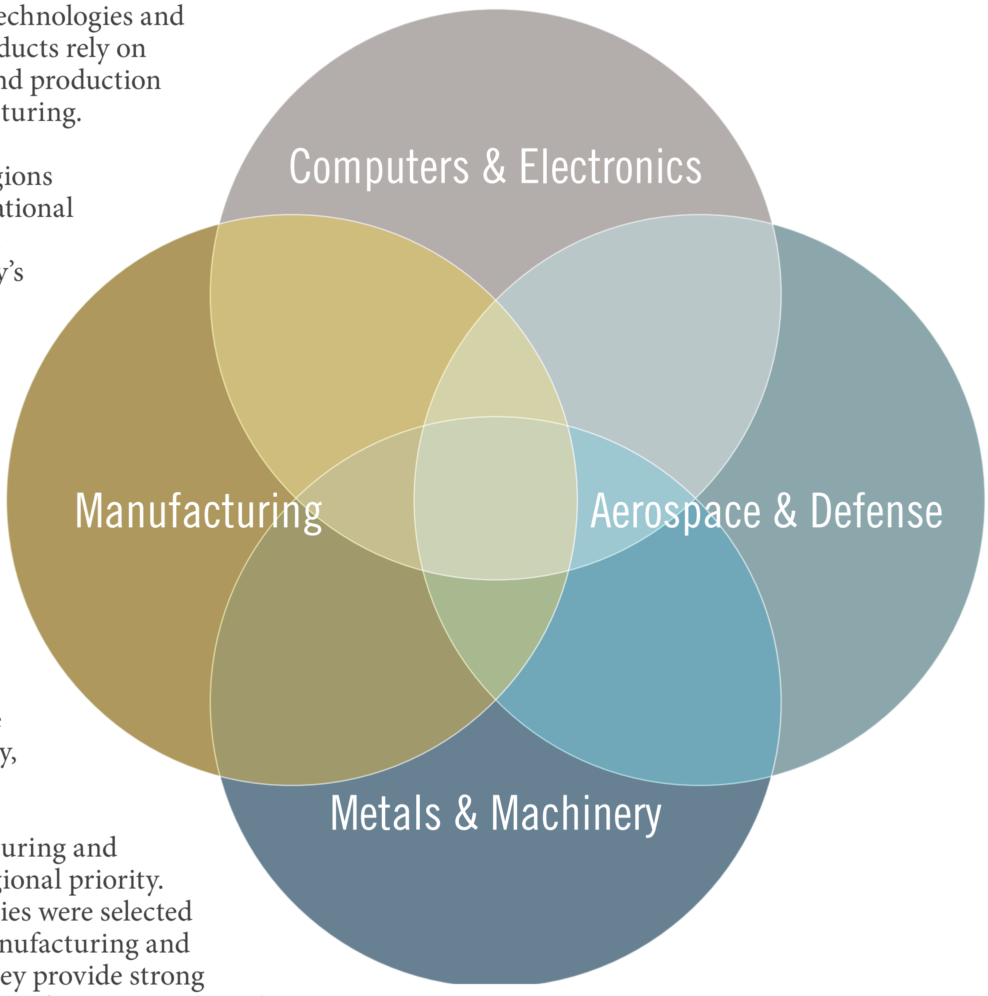

Figure 1

Growth of both U.S. manufacturing and exporting is a national and regional priority. The following regional industries were selected for research into advanced manufacturing and advanced materials because they provide strong opportunities for achieving manufacturing scale and scope, as well as significant export potential.

1. **Computers** (NAICS 334) & **Electronics** (NAICS 335)
2. **Aerospace & Defense** (NAICS 336)
3. **Metals & Machinery** and advanced materials including fabricated lightweight metals (NAICS 331); Plastics, Polymers & Composites[4] (NAICS 322, 325, 326, 327, 333, 336) for industrial uses such as Machinery Manufacturing (NAICS 332); and Oil & Gas pipelines (NAICS 237).

3 The U.S. and Global Trade, National Foreign Trade Council www.nftc.org/default/trade/US%20&%20Global%20Trade%20Report.pdf

4 No specific NAICs for Composites, but 326 and 336 overlap most composite materials including fibrous, laminar and particulate. OSHA, cited by Composites Manufacturing Online, June 4, 2010 http://www.compositesmanufacturingblog.com/2010/06/osha-lists-top-citations-for-composites-manufacturers/

To Thrive and Evolve, Economic Regions Need a Healthy Ecosystem Including:

- **Infrastructure** such as roads and bridges to carry freight to air, rail, and marine ports, and to bring in raw materials
- **Capital** to start new technology-based companies and grow existing small and medium businesses in new ways
- **Training** for generations of skilled, creative workers from technicians and metal workers to research scientists, engineers, and physicists
- **Education** for generations of skilled, creative people in a valuable STEM-based workforce, from technicians and TIG welders to research scientists, engineers and physicists. STEM is Science, Technology, Engineering & Math, from K-12 through graduate school and university research
- **Regionalism** created by thousands of workers who commute between Portland and Vancouver every day. The more income the region generates, the more money there will be to invest in schools, roads, public safety, and sustaining quality of life for families on both sides of the Columbia River

Putting Those Regional Assets to Work Supports Two Major Objectives of this Grant:

1. Addresses Manufacturing Business Development Opportunities by identifying challenges to overcome and options to pursue that enable company agility and sustainability through dynamic capabilities such as:

- Lean Manufacturing
- Advanced Manufacturing
- Advanced Materials
- New Product Development
- Market and Industry Diversification
- Exporting

2. Addresses Manufacturing Economic Development Opportunities by strengthening regional supply chains and growing high-potential suppliers, aided by regional manufacturing extension partnerships, workforce agencies, and R&D institutions:

- Enables companies to engage with new technologies and processes
- Assists companies seeking viable paths for growth through new products, markets and geographies
- Trains and supports certifications for incumbent and new workers
- Promotes and enables exporting
- Recruits missing supply chain links

Performance Measures

Performance of the agencies and companies participating in this grant will be measured by:

- Introduction or refinement of manufacturing enhancements such as lean processes, optics, modeling simulations, or additive manufacturing, and entry into new national and international export markets
- Workforce certifications (e.g. ISO 9001, ITAR)
- Training for incumbent and new workers
- Increased business mentoring and networking for marketing and sales

Regional economic success metrics include:

Short Term:

- Developing Geographic Information System (GIS) supply chain maps for the five-county region (Multnomah, Clackamas, Washington, Clark, and Cowlitz)
- Understanding regional supply chain weaknesses
- Identify missing supply chain players
- Addressing assets and gaps in the economic ecosystem
- Creating deliberate paths for expanding small and medium companies' participation in advanced manufacturing and advanced materials
- Addressing workforce skills needs with training and recruiting:
    - TIG[5] Welders and Electricians
    - Electrical, Mechanical and Process Systems Engineers
    - Software Programmers and Data Analysts
    - Computer Numerical Control (CNC), Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) Professionals
    - Coordinate Measuring Machine (CMM) Programmers and Operators
    - Automation and Robotics Technicians
    - Product and Packaging Designers
    - Supply Chain Management Experts

Long Term:

- Increasing regional competitiveness in crucial supply/demand industries
- Strengthening companies with more capacity and advanced capabilities
- Invigorating supply chains to support and attract new anchor firms
- Increasing employment
- Increasing economic output
- Establishing the region's reputation as a U.S. innovation leader, paving the way for increased investments in regional manufacturing

5 Tungsten Inert Gas Arc welding

WHAT IS ADVANCED MANUFACTURING?

Advanced manufacturing consists of multiple processes employing lean production techniques, automation, computation, software, sensing, modeling, simulation, and networking; for example, robotics and optic sensors.

Advanced manufacturing employs the use of cutting-edge materials and emerging capabilities enabled by physical and biological sciences, such as nanotechnology, chemistry, and biology; for example, growing crystals for semiconductor wafers.

It includes improvement in processes such as mass production efficiency, customization, and quality controls; for instance, ISO 9001 certification.

Advanced manufacturing includes both new ways to make existing products and new products emerging from advanced technologies.[6]

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6 Report to the President on Advanced Manufacturing, Council of Advisors on Science and Technology, July 2012

WHAT ARE ADVANCED MATERIALS?

Advanced materials are early in their technology or product lifecycle. The term refers to all new materials, plus modifications to existing materials, to obtain superior performance for critical characteristics.

There are four main categories of advanced materials:

1. **Structural:** metals and metallic alloys used in aerospace, defense, machinery, and transportation
2. **Functional:** carbon nanotubes, graphene, and conducting polymers, used in semiconductors, computers, electronic devices, and monitors for aerospace, defense, and medical devices
3. **Multifunctional:** damage-tolerant, self-diagnostic and self-healing materials; and integrated structural or power-generating materials for aerospace, transportation and defense, such as carbon fiber
4. **Biomaterials:** derived from a biologic source, or applied to a biological system for implants, tissue scaffolds and biological sensors and monitors

Advanced materials manufacturing is multidisciplinary, including chemistry, metallurgy, physics, and applied mathematics. It cuts across industries (electronics, machinery, transportation, healthcare), and crosses market sectors (photonics, biosciences).

Advanced materials can also be categorized by usage, such as those for aviation, which requires low weight and limited risk of failure that could be catastrophic.

Advanced lightweight materials for aerospace and commercial use include metals such as graphene, aluminum alloys, titanium, lithium, magnesium, and beryllium. Scientists at the University of California have developed a new material, micro-latticed metal, that is 1,000 times thinner than a human hair, 100 times lighter than polystyrene foam, yet as strong as steel. It is made of nickel phosphorous tubes and can be used to make lightweight batteries.[7]

Advanced non-metal materials include polymers, plastics, non-metallic composites, adhesives and sealants, coatings, glass and ceramics, and quartzware used in semiconductor and optical industry applications.

Light alloys, light metals, and new materials have low density and high strength-to-weight ratios. They are designed to outperform conventional materials with superior toughness, hardness, durability, and elasticity. They resist corrosion and are excellent for aircraft, marine and tool applications, pumps and prosthetics. They enable the design of innovative new products including medical implants.

Shape memory metal, 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.

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7 www.inhabitat.com/scientists

Manufacturing Technologies Reliant on Advanced Materials

Sources of Opportunity for Regional Suppliers

- Additive Layer Manufacturing (3-D Printing, Digital Fabrication) – powder-based manufacturing with metals, ceramics, and polymers
- Advanced forming and joining techniques
- Advanced manufacturing and testing equipment
- Advanced materials design, synthesis and processing
- Advanced sensing, measurement and process controls
- Bioinformatics and biotechnology using natural or bio-based materials: bio-active and bio-compatible materials and medical devices
- Electronic and optical functional materials
- Fiber and textile-based technologies
- Flexible electronics manufacturing
- Industrial robotics
- Lightweight materials and structures including composites and hybrids
- Materials designed for reuse/recycle/remanufacture
- Materials for portable power sources: batteries, fuel cells
- Materials designed to withstand aggressive environments (high temperature, corrosive, erosive)
- Materials with reduced environmental impact
- Nanomaterials
- Condition monitoring and structural engineering inspection, evaluation, and health monitoring with permanently attached sensors
- Particulate engineering; producing components close to the finished size and shape, requiring a minimal amount of finish processing such as machining, closed die forging, investment casting, metal injection molding
- Predictive modeling through product life cycle, including lifetime prediction
- "Smart" and multifunctional materials, devices and structures
- Surface engineering and coating technologies
- Sustainable manufacturing
- Visualization, informatics,[8] and digital manufacturing technologies

Flexible Electronics

The technology for assembling electronic circuits by mounting electronic devices on flexible plastic substrates, such as polyamide or transparent conductive polyester film creates flexible electronics. "Flexible circuits" may use identical components to those used for rigid printed circuit boards, but allow the board to conform to a desired shape or to flex during use. An electrical conductor made of gold nanomesh that is both very flexible and transparent was developed by the University of Houston. Researchers say it can be rolled and folded and will be used for flexible smart phones and flat screen TVs. Because it is made of gold, it is less likely than copper or silver conductors to lose conductivity due to oxidation.[9]

Additive Manufacturing

Also known as 3-D Printing and Digital Fabrication, additive manufacturing is the process of making a three-dimensional solid object of any shape from a digital model using an additive process. Successive layers of materials are laid down in different shapes, as opposed to removing material by cutting or drilling.

Sustainable Manufacturing

Sustainable manufacturing is the creation of manufactured products while minimizing negative environmental impacts, and conserving energy and natural resources. It is safe and economical for employees, communities, and consumers.

8 The science of processing data for storage and retrieval; information science

9 NY Times, Business Section, February 14, 2014

THE SECOND MACHINE AGE

The first Industrial Revolution in the mid-to-late 1700s was arguably the most momentous event in human economic history – enabling iron bridges, the steam engine, and transcontinental railroads. New technologies propelled discoveries in chemistry, mechanical engineering, metallurgy, and other sciences that led to rapid advances in machinery, power generation, and mass production.

Scholars and economists in the 21st century argue that we are, or are not, at the start of a second industrial revolution – a new "second machine age"[10] based on computational power, advanced manufacturing techniques, and new materials . . . all enabled by electronics and software. Digital technology is reinventing our lives and our economy, perhaps initiating a manufacturing renaissance. Manufacturing increased 2.5% from 2012 to 2013, and 7.4% from 2013 to 2014.[11]

10 Ibid

11 www.tradeeconomics.com/united.states/manufacturing-pmi 2012-2014

POINT: Factors in Favor of a U.S. Manufacturing Renaissance

- Realization that separating production from R&D has taken a toll on innovation; locating R&D near manufacturing results in high-value intellectual property that creates innovation and employment
- Concern about intellectual property (IP) protection
- Energy advantage as U.S. production rises and usage drops, while Europe and China face increased energy demand, rising imports and higher fuel costs for trans-oceanic shipping by air and sea
- The U.S. is politically stable and has manufacturing expertise and quality
- Domestic labor costs are stable, while Asia's are on the rise
- The U.S. entrepreneurial culture is #1 in gross R&D expenditures
- Reshoring by General Electric, Ford, NCR, Motorola, Apple, and Element Technology; plus U.S. onshoring by Lenovo (China); Honda and Yamaha (Japan); BMW (Germany); and Michelin (France)

COUNTERPOINT: Don't Buy The Hype About a Manufacturing Revival[12]

- To compete with China . . . new jobs offer less in health care, pension and benefits than industrial workers historically received . . . General Electric assembly line workers (2012) start at just over $13.50 per hour
- Volkswagen . . . Chattanooga, Tennessee . . . bringing 2,000 jobs for $14.50 per hour, half of what unionized GM and Ford workers and German workers earn
- Wages across manufacturing dropped 2.4% from 2009 to 2013
- Controversial government subsidies pay Volkswagen, Boeing, and Airbus to locate in the U.S.
- Manufacturing has gained only 568,000 jobs since January 2010, as productivity gains are replacing the hiring of workers
- U.S. leads in advanced manufacturing such as aerospace are challenged by Lear jets made in Mexico and Cessna business jets made in China
- Fiscal tightening by the federal government has restricted R&D investment
- More than half of those employed in manufacturing are service workers in management, sales, and technical support
- "A state-of-the-art chipmaker is not a major job creator."[13] (*Author's note: Tell that to this region where Intel employs more than 16,000 people.*)

In 1950, 27% of U.S. gross domestic product came from manufacturing,[14] and 31% of Americans were employed in manufacturing. In 1953 manufacturing accounted for 28% of the U.S. economy.[15] By 2012-13, only 12% of GDP was from manufacturing and only 10% (12 million) of Americans were manufacturing workers.[16] In the Portland region, manufacturing was 11.1% of employment in 2013, an increase of one percentage point over 2012.

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12 The Myth of Industrial Rebound, NY Times, Business Section, Feb. 2, 2014 and Factory Jobs Are Gone. Bloomberg Business Week, p.12, Feb. 2, 2014

13 Factory Jobs Are Gone, Get Over It. Business Week, p. 12. Jan 27-Feb 2, 2014

14 Producing Prosperity. Gary P. Pisano and Willy C. Shih. Harvard Business Review Press. Boston, 2012

15 U.S. Bureau of Economic Analysis. NY Times, February 2, 2014. Manufacturing's Mythical Revival

16 American Association of Manufacturers, Statistics & Data, 2013

The Internet boom of the 1990s turned focus from manufacturing to services and from electronic product making to software development. Outsourcing production to Asian suppliers flourished, taking advantage of cheap labor. The "post-industrial society"[18] saw manufacturing follow the same path as agriculture a century before – shrinking, so resources could be put toward uses perceived to have higher value in other sectors. Why make socks when you can design new technologies?

Today, manufacturing is becoming more and more complex, interweaving computers, electronics, software, firmware, hardware and artificial intelligence. That requires massive computing power that must also be very tiny and inexpensive.

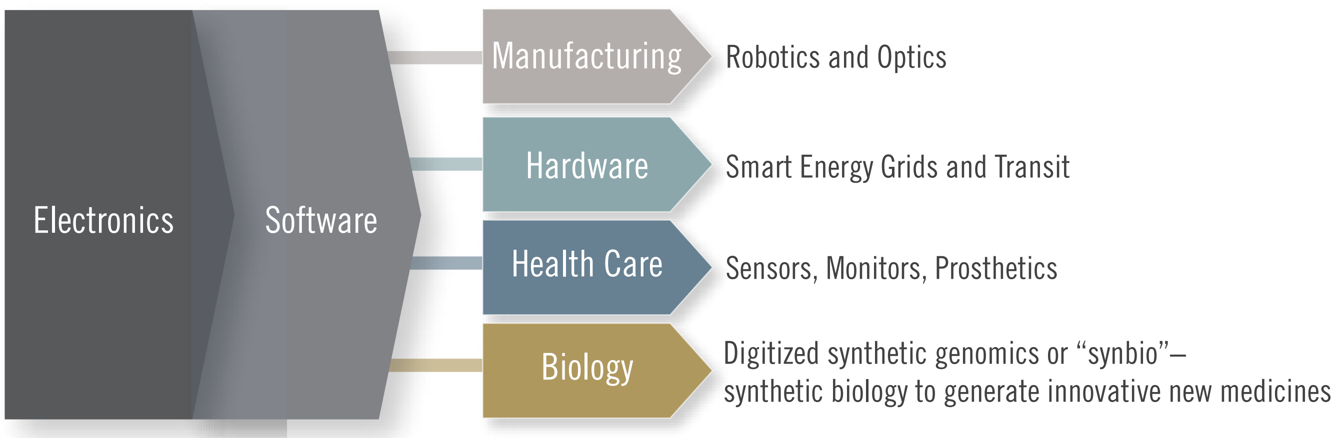

Figure 2

"Smart Cars" rely on those combinations. Nike's Fuel Band, a simple smooth bracelet, collects personal physical data – even tracking your sleep patterns – with a Bluetooth-enabled system that lets you monitor your own physical fitness.

Boeing's 787 Dreamliner contains seven to eight million lines of code. Lockheed Martin's F-35's capabilities are measured in bandwidth and teraflops as well as speed and thrust, as it securely connects soldiers, satellites, and weapons on warships, in planes, and on the battlefield. "Advanced industries hire more software engineers and integrators than 'traditional' software and computing companies."[19]

Manufacturing represents . . .[17]

- 9% of U.S. jobs
- 35% of engineering jobs
- 11% of U.S. GDP
- 68% of private R&D
- 90% of patents

Intel acquired McAfee to connect software to their hardware, making data more secure by embedding security right into their semiconductor chips and blocking the gaps between software and hardware. Soon there will be smart fabrics, and even smart money with embedded Radio Frequency Identification (RFID) chips.

Automation technology has changed manufacturing so much that now, higher value means industrial workers with highly skilled knowledge, and higher margins from highly engineered products with superior design and quality.

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17 Bruce Katz, the Brookings Institution. "Fostering Growth Through Innovation"

18 Daniel Bell, 1973

19 How can the US advanced-industries sector maintain its competitiveness? McKinsey Quarterly, February 2014

The results of outsourcing were not as positive as they first appeared. From 1990 through the mid-2000s, wages stagnated, trade deficits piled up, and productivity growth slowed. U.S. manufacturers also lost knowledge by separating R&D from production. The center of gravity for manufacturing moved to Asia and employment declined . . . all before the recession of 2008-2010.

Today, when fewer than one in ten workers is employed in manufacturing, and new tools and techniques such as robotics, optics, and "lean" processes are increasing productivity, it is unlikely that a U.S. manufacturing revival will create demand for the millions of unskilled workers who earned their way to the middle class on assembly lines. Manufacturing requires workers to operate complex precision equipment. In-demand skilled workers will have competencies in engineering, computer science, and math.

Gary, Indiana, once a world leader in steel production, today efficiently produces 20% more steel of higher quality with 80% fewer workers. General Electric (GE) has reopened its appliance factory in Louisville, Kentucky, to bring production back from China. However, they only hired 1,000 employees out of the 12,000 who applied[20] because lean processes, robotics, and other technologies have made manufacturing more efficient and productive with fewer people.

U.S. factories now produce more sophisticated products, such as biotechnology-based drugs, flat panel displays, aircraft engines, semiconductors, and medical devices. U.S. production in the automotive industry is expected to reach unprecedented levels in 2014. Alcoa is investing $300 million to expand its rolled product plant in Davenport, Iowa, to meet those needs and has increased production at its Texas refinery, which is now one of its most cost effective plants due to lower energy costs.

Businesses measure success by output and productivity, so even reshoring cannot create needed jobs without increasing supply chain capacity. That requires growing small and medium suppliers through advanced manufacturing, computer-aided design, new materials, product and market diversification, and exporting.

Since the U.S. has disinvested in R&D to a great extent over the past 30 years, other countries now lead in semiconductors, flat panel displays, advanced batteries, machine tools, metal forming, castings, stampings and forgings, precision bearings, optoelectronics, solar energy, and wind turbines. U.S. dominance in biotech, aerospace, high-end medical devices, and other advanced manufacturing sectors are under threat by overseas competitors.

Co-location of R&D and manufacturing is a must for an innovation-based economy. In the process from ideation to commercialization, research, product development and manufacturing have learned to collaborate, fail fast and cheap, and try again to anticipate and eliminate scale-up issues before they occur, shortening time to market. Manufacturing is integral to the innovation process.

Regional economic prosperity depends on a competitive industrial commons – a strong economic ecosystem with capabilities shared among manufacturing companies, suppliers, customers, partners, skilled workers and regional institutions such as universities – ecosystems often referred to as "clusters." Companies and governments must invest together in the regional industrial commons as their source of competitive advantage.

Exporting, defined as the production of traded sector goods created "here" and sold elsewhere, is also crucial to the economy. Manufacturing and exports are pillars of this region's employment.

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20 US Manufacturing: The Misunderstood Economic Powerhouse. Steve Minter, Industry Week.com. Jan. 15, 2013

Operating a Manufacturing Business is Different – and More Difficult

Complicating factors include product lifecycles, reliability, regulatory frameworks, capital costs, insurance, OSHA and certifications, multiple workforce skills and diverse management responsibilities, complex supply chains and inventory management, information technology and data analysis . . . everything is more complex and more challenging.

- Average capital equipment is 27 years old and needs replacing
- Within five years, 40% of skilled manufacturing workers will retire
- Manufacturers face a steeper innovation curve than ever before

Dynamic Manufacturing Trends[21]

1. Nano-engineering of Materials and Surfaces

- Large-area graphene production
- Roll-to-roll manufacturing
- 3-D integrated circuits for semiconductors
- Nano-engineered, fiber-composite materials
- Nano-etching of surfaces

2. Additive Precision Manufacturing Process Innovations

- Automation
- Precision manufacturing
- 3-D Printing: Additive and precision manufacturing
- Maskless lithography[22]
- 3-D printing at home (an extension of current inkjet printers to physical objects)
- Rapid prototyping directly integrated into computer-aided design (CAD)
- Next-generation injection molding
- Advanced Electrical Discharge Machining (EDM)
- MOSIS-like foundries (http://www.mosis.com) for prototyping of physical parts
- Laser-based manufacturing (fast control, short pulse)
- Aluminum, titanium, and nickel-based sintering and forming of custom parts
- Measurement and testing

3. Robotics, Automation & Adaptability

- Intelligent scheduling algorithms
- Robotics, adaptive automation, and intelligent automation
- Embedded sensors in products and processes
- Reconfigurable robotics
- Human-robot collaboration
- Wireless real-time sensing
- Networked control for telerobotics and remote operations

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21 MIT Trends in Advanced Manufacturing Technology Innovation. Web.mit.edu/deweck/Public/pie/Trends

22 MIT Trends in Advanced Manufacturing Technology Innovation. Web.mit.edu/deweck/Public/pie/Trends

4. Next Generation Electronics

- Flexible substrates for electronics
- Ultraviolet (UV) nanolithography
- Multifunctional devices with integrated sensing and control computer interfaces
  (touch, voice, brain waves)
- Wireless revolution in manufacturing (wireless factories)

5. Bio-Manufacturing/Pharmaceuticals

- Continuous manufacturing of pharmaceutical and bio-based manufacturing
- Stem cell-based manufacturing
- Human organ engineering and manufacturing
- Regenerative and personalized medicine
- Tissue manufacturing

6. Distributed Supply Chains/Design

- Supply chain and logistics
- Design and management of distributed supply chains
- Community-based design
- Open-source design of complex cyber-physical products and systems (e.g., AVM [24])
- Decentralized supply chain management
- Cloud computing for CAD/CAE/CAM

7. Green Sustainable Manufacturing

- New materials
- Multi-scale manufacturing – from nano and micro to large-scale
- Efficient energy
- Recycled materials
- New energy sources
  - Low-cost, high-efficiency photovoltaics (PV)
  - Concentrated solar power (CSP)
  - Impact of availability of U.S. natural gas on energy-intensive manufacturing
  - Waste-to-energy conversion
  - New energy storage batteries and super-capacitors technologies
  - Waste power/energy capture within plants
- Re-manufacturing and recycling at larger scale

GAME-CHANGING TECHNOLOGY TRENDS

Integrated digital technology has changed how the world works, from people to machines and wireless communications. It has also created conundrums for manufacturers.

A maker needs to be somewhat conservative to be reliable and efficient in order to provide consistent quality on time. Makers need to take risks to achieve rewards by learning to work with visualization, onboard diagnostics, remote connectivity, and digitization.

How and when to invest in new capabilities is not as simple as having enough capital to buy the right equipment. Industrial machinery is expected to last 20 years, but electronics and digital technology are changing every year. Legacy equipment is a huge investment, but new equipment with modular embedded electronics is necessary for upgrades and replacements. Companies also need to train employees, find employees with new capabilities, and reflow their work processes to accommodate lean methods. All that takes time and management bandwidth as well as money.

Advanced manufacturing also requires coping with new methods, materials, and even new vocabulary, like *integrated digital technology*,[23] which simply means the combination of mechanicals and electronics that are computer-enabled to work together seamlessly. It also requires fortune-telling, such as, “What will 3-D manufacturing mean for my business?”

Trends to Monitor for Opportunity

- Biomimicry – chameleon-like robot arms for the Army; robotics or “steel collar workers”
- UAVs (Unmanned Aerial Vehicles) the size of dragonflies enabled by nanotechnology
- Manufacturing devices one billionth of a meter in size
- New materials: stainless steel, aluminum alloys, titanium fused in additive manufacturing for integrity, layer-by-layer, to provide tensile strength and flexibility and to fuse lubricity inside parts within a nonporous shell for self-lubricating machinery
- Artificial intelligence – machines that learn as they work and adapt to their operators for increased quality and efficiency
- Remote monitoring to optimize wind turbines’ curvature and speed
- Prognostic/diagnostic analytics for jet engines, oil and gas, and health care
- Lighter-weight, longer-life microbatteries and electronic sensors

Additive manufacturing, or 3-D printing, adds a new challenge. Apple, Boeing, GE, Caterpillar, Ford, and GM are figuring out what to do and how to do it by experimenting in-house, acquiring unique small players, and then training their suppliers. Small and medium suppliers need to ask how they can play in this new competitive arena where Stasys and 3D Systems are the big guys.

Clothes washers run on software, and jet engines have 20 sensors collecting data that airlines use to predict maintenance and monitor safety. The new industrial revolution combines software, hardware, and electronics. “Big data” helps identify and fix problems and makes delivery more efficient. Sensors and robotics enable nurses to give better care to more patients.

23 From Digitally Disrupted to Digital Disrupter: Every Business is a Digital Business. Accenture. January 2014

Poles strung with copper wire powered telephones ten years ago. Today, your smartphone is in your pocket. Technology is portable, programmable, accessible, and affordable. In the near future, technological advances will make life smarter, faster, and cheaper because of advanced manufacturing and materials. Combined with lower energy prices, these changes are creating new opportunities for U.S. manufacturers. While parts of many industries have moved overseas, innovative and radical solutions still come from the U.S., especially from regions like the Pacific Northwest, where businesses are connected with universities and public/private organizations to foster R&D and commercialize new technologies.

Mobile phones and cloud computing will provide infinite data storage, sharing, and communication options. Computers & Electronics (C&E) are enabling amazing advances:

- Digitized artificial intelligence
- Printed body parts
- Google glass for oil rigs and engine factories
- Hi-tech clipper ships that fly like the wind, powered by wind
- Unmanned vehicles for agriculture as well as defense
- Household appliances with broadcast capabilities
- Holographs on Google's videoconferencing system[24]

"A new breed of biologists . . . view life forms and DNA the way technology wizards . . . once looked at basic electronics, transistors and circuits . . . colliding, merging and transforming one another."[27]

3-D printing uses polymers, powdered metals, computer-generated designs, and control tools to produce tangible objects on demand. DARPA is experimenting with new metal alloys, ceramics, and lasers. From prototypes to mobile phone cases, teeth implants to life-like prosthetic devices, 3-D will enable do-it-yourself as well as industrial production. It works with plastics, gypsum, carbon, graphite and even food materials. Food scientists are researching how to layer amino acids and proteins for foods with longer shelf life and optimal nutritional mix. Basic 3-D printers now cost less than $1,000.

4-D printing takes the step beyond 3-D to self-replication and self-assembly.[25] MIT is experimenting with complex physical substances called "programmable materials" that build themselves. They will be used to "make life using life's own building blocks, DNA."[26]

Stanford University predicts that synthetic biology will lead in the near future to "an economic and technological boom like that of the Internet."[28]

"Digestible computing" means you will swallow a pill that emails your doctor from inside your body to monitor your health. Your body will be the battery source for sensors that relay information to your doctor's mobile phone.

RFID codes will be your password and your car key. Renewable materials will heal themselves. Google glass will tell you someone's name when you look at his or her face. Mind meld technology might "listen in" on your conversation, in person, by phone or VoIP, and send you informational conversation prompts based on what you're discussing.

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24 Fortune Jan 13, 2014

25 Biology's Brave New World, Foreign Affairs, pp. 28-46. November/December 2013

26 Ibid, p. 29

27 Ibid, p. 30

28 Ibid, p. 36. Quote from Prof. Drew Endy

Predictive search will give you information before you ask for it, sensing what you need before you do: traffic is making you late; search has scanned your email, found a reservation confirmation and synced with your GPS. Waze[29] tells your mobile phone, which calls the restaurant to say you will arrive ten minutes late.

GE has new capabilities to analyze turbines and other industrial objects to monitor how their technology is working with the power grid and when wind or solar is a better option than electricity depending on the weather . . . or when is the best time for maintenance.

Intel created the world's fastest computer, the X-86, to do big data analysis for long-range weather predictions and nuclear weapons monitoring.

Virtualization, cloud computing, and advanced analytics enable the "Internet of Things": sensing, monitoring, and transmitting devices from RFID tags to remote heart monitors. Every year brings faster processing speed, greater storage capacity, bigger data sets, and more advanced software. Automation of knowledge work through computation, storage, networks, and mobile technology will become ubiquitous, with integrated digital and physical experiences from retail stores to factory floors.

- New tools for better operating efficiency
- New ways to touch customers
- New methods for collaborating with partners and suppliers
- Automated knowledge tasks once thought to be beyond machines
- Wearable computers monitoring human health

The McKinsey Global Institute[30] has identified 12 disruptive technological changes that will bring enhanced economic opportunity; all of these engage advanced manufacturing and materials.

1. Mobile Internet
2. Automation of Knowledge Work
3. Internet of Things
4. Cloud Technology
5. Advanced Robotics
6. Autonomous (unmanned) Vehicles
7. Next Generation Genomics (for genetically engineered bio-fuels)
8. Energy Storage
9. 3-D Printing
10. Advanced Materials
11. Advanced Oil & Gas Exploration & Recovery
12. Renewable Energy

McKinsey also identified "Ten IT-Enabled Business Trends for the Decade Ahead."[31] Four have major implications for manufacturing.

29 GoogleMaps GPS-based navigation application for mobile devices

30 Disruptive Technologies Advances that will Transform Life, Business and the Global Economy. McKinsey Global Institute, May 2013

31 Ten IT-Enabled business trends for the decade ahead. McKinsey Global Institute, May 2013

1. Social Matrix

- Crowd sourcing solutions for difficult problems
- Improving collaboration and knowledge sharing by using internal and external networks to connect businesses, universities and R&D labs
- Using social networks to engage customers and co-create new products
- Reimagining business structures to be highly networked within and across organizations

2. Internet of Things

- Sensors, actuators, and other connectors in the physical world are proliferating: more than 12 billion devices around the world, such as computers and smart phones, are connected to the Internet; within the next ten years, that's expected to be 50 billion or more devices[32]
- Proliferation of devices and applications will transform manufacturing, supply chains, building infrastructure, transportation and health care
- 15% of companies have already implemented some Internet of Things solutions; 67% say they plan to within five years[33]
- The cost of sensors and actuators is declining rapidly; they are increasingly connectible, often wirelessly, enabling UPS to monitor a truck driver's performance and FedEx to track packages
    - o Monitor assets, systems, and people remotely
    - o Operate long, complex supply chains
    - o Improve preventive maintenance and performance management
- Enable closed-loop systems that make decisions considering a multitude of factors at speeds impossible for humans
- "Quantified self" applications monitor personal health and record physical activity such as blood pressure and sleep patterns
- Sensors now monitor the new I-35 Minneapolis bridge for stresses and deterioration that led to its predecessor's collapse in 2007
- GE has sensors in its gas turbines to monitor performance and identify anomalies that cause shut downs
- Disc drives sense imminent failure and inform the user and the manufacturer simultaneously to tailor maintenance services
- Smart grids for electricity, water and transportation networks use performance data to predict power outages, coordinate traffic signals, confirm repairs and improve system performance

3. Big Data and Advanced Analytics

Collect, analyze, experiment with and act on large and growing complex data sets to harness real-time information for insights that improve decision-making. For instance, know when to release inventory into the distribution system based on shelf-level retail data.

- Improve performance management
- Speed up the R&D process

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32 Trillions: Thriving in the Emerging Information Ecology. Lucas, Ballay and McManus. John Wiley & Sons Inc. NJ, 2012

33 Ibid

- Use behavioral data for micro-market segmentation
- Automate knowledge work to analyze thousands of business records
- Create new business models to monetize data from core operations

While 85% of companies collect and plan to use big data, only 17% say they have adequate capabilities for using it. Yet a study has shown that companies using big data have 4% more productivity than their peers and 6% more profitability.[34]

- Networked sensors capture data and computational power; cloud computing, visualization techniques, and advances in user interfaces allow rapid analysis and require new skill sets; accessing online records is faster than manual search, enhances transparency and saves money:
  - UK's National Health Service found ways to save £2 million
  - NYC's Performance Reporting tool collects data from 40 city agencies for public reporting and performance management
  - Data brokers offer profiles of 500 million customers worldwide to global businesses

4. Me+Free+Easy – Especially Important for Suppliers

Easier interactions, seamless transactions, and value-added services are crucial in a world where competitors are only a click away. Customers have more power and want free information as well as reliable service.

- Online searchable transaction histories mean fast access for repeat orders
- Electronic integration enables inventory management and automatic billing

Sensors and actuators track and manage machinery and other physical assets across a network via RFID tags and the mobile Internet. Physical and digital worlds are converging as physical things become web-enabled and physical spaces such as stores become interactive environments. A rack of pants can convey information about itself (prices, quantity, matching shirts) to a mobile Internet device.

Peer-to-peer networks began with online music and evolved to web-based "anything as a service." In a sharing economy, everything from gourmet food to vacant office space and componentry is sourced and secured online.

The economic impact of these trends is profound for businesses and regions. Cloud Computing, the Internet of Things and Automation of Knowledge Work could amount to $20 trillion per year by 2025.[35] Three billion new users will connect to the Internet, with half that growth coming from developing countries. Companies and regions that succeed will have integrated economic ecosystems, robust supply chains, clear pathways to capital along with exporting expertise, and economic policies that foster innovation and manufacturing.

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34 Brynjolfsson, Hitt and Kim, "Strength in numbers: How does data-driven decision making affect firm performance?" Social Science Research Network, April 2011

35 Ibid

REGIONAL VOICES & VIEWS

Confidential interviews were conducted with company managers, supply chain professionals, manufacturing experts, and researchers at regional R&D labs. Their insights are included to provide a living picture of the business realities faced by small and medium manufacturers.

"... lasers, microelectronics and computerized machinery ... manufacturing is not the old industry anymore."

TRENDS

"... integration of electronics with other industries: health care ... smart transit ... tech-enabled devices"

"... alignment of technologies ... mobile devices, cloud computing ..."

"Advanced materials ... all about small for microprocessing."

"New equipment ... to make smaller products ... accommodate new materials."

"The U.S. has a slight reputation advantage ... our difference is in service responsiveness and a fine sliver of quality."

SUPPLIERS

"Impeccable product performance ..."

"24-7 availability for technical support."

"You have to be able to dance with the big guys – and to their tune."

"Instant availability for back-up inventory"

"Suppliers need to be great partners."

"A day or two late is not acceptable. You cannot be late."

"Know what data you have and how to mine it."

CUSTOMERS

"Look to your competition ... collaborate. Microsoft and Oracle are an 'unholy match' but they are starting a cloud collaboration."

"Customer visits ... sit face-to-face ... discuss what their roadmap is."

"... learn them inside out. What solutions do they need?"

"Pay attention ... Internet, trade publications ... press releases ... conferences ... "

"Current customers ... ask who else they know."

SUPPLY CHAIN

"Aluminum was here but largely left ... that's a supply concern."

"Polyamide, polymer to make film ... not local."

"... missing here is the software to connect monitoring systems. California has it. Why not here?"

"Sourcing commodity and advanced materials is a disadvantage. Chemicals, specialty metals ..."

REGION

"Plastics and metals . . . hydropower, land to build on and a transportation backbone – infrastructure."

". . . need critical mass to succeed as a tech center...top notch researchers . . . tech companies. There's competitive advantage in that."

". . . no research capability here for advanced anything from a technology or manufacturing perspective. . . no research universities noted for science and technology."

"No acquisitions happen here. To keep people employed you need to keep business churning."

"Taiwan wants the 'Northwest': Seattle, Portland-Vancouver. We are a region, not one city or the other."

"Legislators don't realize we are all interconnected from Seattle to Vancouver to Portland . . . attached and co-dependent. We will be stronger if we act together."

"We get $65M in grants because Portland and Vancouver go in together. Neither one could get them alone. We have to be regional."

WORKFORCE

"It's hard to recruit talent. . ."

"Cheap labor means long-term costs."

". . . need highly educated workforce . . . engineers and physicists."

"No program where students learn big thinking, not just implementation."

"Big gap in soft skills and first line leadership."

". . . lack of high school grads interested in manufacturing. That's harmful to competitiveness."

"Oregon is a net exporter of bright young people. How do we find and grow local talent?"

R&D

"Research grants to Oregon universities are down in 2013."

"WSU and Clark College teach Mechatronics . . . Fluid and Electric Power and Programmable Controls. More schools need to understand what's needed in industry and how to train for it."

CAPITAL

"Investment funding sources are missing. The last VC firm left."

". . . little presence of early stage investment capital. Anything bigger than $1 million comes from outside the state."

"The real money comes from out of state. VCs put their own business people in who are not in Oregon and they move companies out."

"Angels pick up some slack. The future model here . . . local and networked investors."

"State financial support for innovation and manufacturing is missing."

EXPORTS

"Your best new customers may not be in Oregon."

"Small and medium companies need export support."

"Know your own boundaries for knowledge, volume, cost and security."

REGIONAL STRENGTHS

An Economically Sound Region Must Have Resources and Talent to Address Complex Ecosystem Issues:

- Availability of raw materials, the basic supplies for manufacturing, such as metal, chemicals and plastics
- Adequate, affordable, reliable energy sources
- Scientific, engineering, and management talent
- Trained and skilled technical workers
- Global trade access and support
- Sustainable energy efficiency reflecting low carbon, recycling, and reuse
- Ability to research, develop, and commercial-ize value-added products
- Logistics infrastructure to get to market faster than overseas competitors
- Robust supply chains with capabilities and capacity to serve technology-based global corporations

Twenty-eight percent of Oregon State's GDP came from manufacturing in 2012,[36] more than any other U.S. state.[37] Manufacturing made up thirty-two percent of the Greater Portland Metropolitan Statistical Area GDP that year, ranking it 22nd among the 380 U.S. MSAs.

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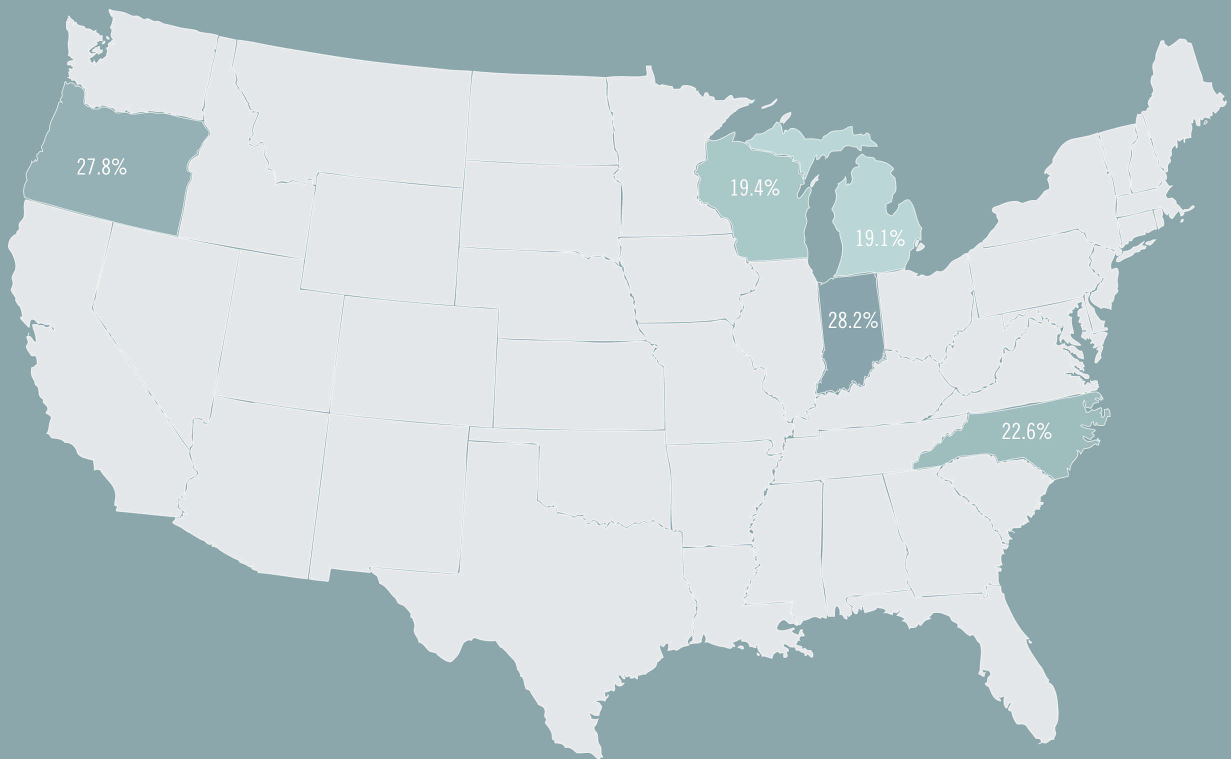
36 Business Oregon and http://www.bea.gov/regional/index.html

37 Greater Portland Inc. Workbook 2013-2014



Top Four States by Percent of GDP from Manufacturing

Indiana	28.2%
Oregon	27.8%
North Carolina	22.6%
Wisconsin	19.4%
Michigan	19.1%

Figure 3

Oregon was the third fastest-growing state economy in 2012, just after North Dakota and Texas, which are benefiting from the current oil boom. Two-thirds of Oregon's growth is attributed to durable goods manufacturing.[38] Manufacturing employment in the Greater Portland region was 113,850 compared to 63,325 in the Denver, Colorado, MSA and 51,092 in the Austin, Texas, MSA.[39] According to the Manufacturing News Industrial Directory, more than 177,000 Greater Portland MSA residents are employed in manufacturing – twice that of Denver and Austin[40] – and more than 100,000 of them work in the five-county region for this grant.

38 Manufacturing News Industrial Directory
39 U.S. Dept. of Commerce, Bureau of Economic Analysis, Regional Economic Accounts
40 Ibid

Greater Portland Vancouver Region Manufacturing Employment by AMJIAC IAM² Grant County, 2013[41]

Washington County	44,900
Multnomah County	32,800
Clackamas County	17,000
Clark County	12,983
Cowlitz County	6,167
	Total 113,850

Leading Oregon Industries by Employment:[42]

- **15% Electronics and Electric Equipment**
- 14% Food Products
- 13% Lumber & Wood Products
- **10% Industrial Machinery & Equipment**
- **8% Fabricated Metal Products**

Leading Washington Industries by Employment:[43]

- 19% Transportation Equipment
- 15% Food Products
- **11% Industrial Machinery & Equipment**
- 7% Lumber & Wood Products
- **7% Fabricated Metal Products**

Leading Regional Manufacturers by Employees:[44]

- **Intel Corp. (Hillsboro) - 16,800**
- Nike, Inc. (Beaverton) - 4,700
- **Daimler Trucks North America, LLC (Portland) - 2,750**
- **Tektronix, Inc. (Beaverton) - 2,000**
- **WaferTech (Camas) - 1,040**
- **SEH America Inc. (Vancouver) - 703**

Regional Cities with the Most Manufacturing Jobs[45]

- Portland – 55,664,
- Hillsboro – 25,389
- Beaverton – 15,928
- Vancouver – 6,377
- Camas – 2,297

41 Oregon Employment Department (Multnomah, Washington, Clackamas), Washington Employment Security Department (Clark, Cowlitz) and ECONorthwest, Economic Impact of Intel's Oregon Operations, 2012, by Batten, Tapogna, Wilkerson, Krebs, Jensen, and Tivnon, http://www.intel.com/content/dam/www/public/us/en/documents/reports/intel-oregon-economic-impact-report.pdf

42 2014 Oregon and Washington Manufacturers Directory and Industrial Data Base, Manufacturer's News

43 Ibid

44 Ibid

45 Ibid

For a relatively small state in population, Oregon ranks sixth in manufacturing output, surpassing Indiana, Michigan, and Pennsylvania. However, 38% of its $74 billion[46] manufacturing sector in 2012 came from computers and electronics, and much of that is from Intel.[47] The manufacturing boom in Oregon has not translated to jobs. Washington State manufacturing output was $88.3 billion.[48]

"*Data from the Bureau of Labor Statistics shows about 19,000 people dropped out of Oregon's labor force last year. Going back further reveals that Oregon's manufacturing jobs peaked in 1998 and have largely been on the decline since then.*"[49]

The region needs to diversify because "*job growth and personal income are flat and trailing other states.*"[50]

This area is heavily anchored with companies that make things bought here. Suppliers manufacture bridges, buildings, and boats. Old end-user markets, such as pulp and paper, are evolving to new uses, such as packaging. Industrial parks and old energy plants are being replaced by investments in clean energy.

When a company's "tribal knowledge" enables it to remake itself, instead of encasing it in "*the way we've always done things*," new opportunities abound.

Regional companies have a heritage of sustaining themselves through innovation and market diversity. An oil and gas equipment manufacturer started as a basic machine shop and redefined itself to build the largest biomass facility on the West Coast. It can go on to design, engineer, build, and ship nuclear plants around the world.

United Streetcar, a division of Oregon Iron Works in Clackamas County, Oregon, is the only streetcar manufacturer in the U.S. It has 350 suppliers, 140 of which are in Oregon. They are currently building new cars for Kansas City, Missouri's, light rail system. Oregon Iron Works was founded in 1944 and has evolved from a basic iron fabricator to serve industries as diverse as aerospace, defense, marine craft, and nuclear energy, using advanced materials such as titanium, aluminum, stainless steel, and important new materials such as carbon fiber and graphene.

Advanced manufacturing jobs are typically higher-paying, and the region has experienced a continuing decline in per capita income, which is below the national average.[51] Regional manufacturing assets can form the base for increasing per capita income:[52]

- Manufacturing provides higher wages and better benefits than non-manufacturing jobs
- The region has retained a larger manufacturing base than the average U.S. metropolitan region
- A strong manufacturing base helps a region's economy grow through research and innovation
- The Greater Portland region is a national leader in specialized manufacturing such as high tech electronics and specialty metals fabrication

46 CNN Money, June 10, 2013. Interview with Josh Lehner, OR Office of Economic Analysis
47 USA Today, August 10, 2013
48 WA State Department of Transportation, http://www.wsdot.wa.gov/planning/wtp/documents/freight.htm
49 CNN Money, June 10, 2013. Interview with Josh Lehner, OR Office of Economic Analysis
50 John Tapogna, President ECONorthwest, quoted in CNN Money, June 10, 2013
51 Higher Education and Regional Prosperity: the story behind Portland-metro's income decline, 2013
52 Portland Metro Manufacturing Sector report, Value of Jobs Coalition, 2012

As indicated by their location quotients, certain industries are sources of growth for the Portland regional economy. A location quotient, or LQ, is a way to quantify how concentrated a particular industry is, compared to the national average. It indicates what makes one region unique versus another. An LQ of 1 (one) is the national average. An LQ higher than 1 (one) is above the national average.

For example, using total U.S. employment as a base, the LQ for the Portland Metropolitan Area for C&E Product Manufacturing is 4.14 (NAICS 334) – four times the national average.

The LQs for subsets of the regional C&E industry are exceptional, as illustrated in the following chart. Semiconductors and optoelectronics are nearly 17 times the national average. Semiconductor and electronic component manufacturing are almost ten times the national average.[53] The chart also indicates the region is below the national average in electric equipment, with room to grow.[54]

2012 Computers & Electronics Industry Manufacturing Location Quotients[55]

Industry Title	NAICS Code	2012 Annual Average Employment	Location Quotient
Semiconductors & Related Devices Including Optoelectronics	334413	21,851	16.84
Semiconductors & Electronic Components	33441	25,214	9.63
Computer & Peripheral Equipment	33411	2,244	2.08
Wiring Devices & Lithium Batteries	33593	333	1.13
Electronic Computers	334111	555	0.91
Electrical Equipment	33531	372	0.38

Figure 4

While the region faces challenges, including limited developable sites for new industrial growth, high capital gains taxes, and a shortage of skilled and knowledgeable manufacturing workers, it also has huge potential.

However, while states like Ohio, Texas, and New York are making sustainable investments in their metros, Portland regional efforts are less supported at state levels. Despite the fact that the region has technology assets and potential for significant economic growth, neither Oregon nor Washington is reported to have enabled the region with meaningful investments in new ventures, infrastructure, and STEM education.

However, the cultural need to bootstrap, or "do it ourselves," has brought about a collaborative regional approach that is recognized by the Brookings Institution and federal entities, such as the Economic Development Authority, as unusual among other U.S. economic regions.[56]

> "A strong manufacturing industry (is) supported by a domestic and international trade network, a reasonable tax structure and regulatory environment, a supply of market-ready land for development, and a trained and educated workforce."
>
> Portland Regional Report on Higher Education & Regional Prosperity, 2013

53 Oregon Employment Department. November 20, 2013
54 Ibid
55 Greater Portland Export Plan Metro Export Initiative, 2012
56 Ibid

THE REGIONAL MANUFACTURING ECOSYSTEM

Highly engineered technology industries in advanced manufacturing and advanced materials with significant regional supply chain opportunities include:

Electronics – Electrical components, cables, batteries, motors and small electrical equipment, generators and conveyers (computers and consumer devices are not included in this research, as most are made overseas).

Aerospace & Defense – Manned and unmanned aircraft and parts, weapons, defense and intelligence systems, satellites, and launch vehicles.

Metals & Advanced Materials – Light metals, polymers (thermoplastics and thermosets), ceramics, glass, and composites.

Industrial Machinery & Equipment – Heavy industrial machinery, oil and gas equipment (does not include basic hand and power tools, small-scale machinery and components, or basic hardware).

Biotechnology for Advanced Medical Devices & Equipment – Sensing, monitoring, and scanning equipment: MRI, PET and CAT scan diagnostics, ultrasonic and electro-medical lasers and monitors, and other medical machinery. Treatment instruments and basic supplies: operating tables, surgical knives, dressings, syringes, stethoscopes, lab equipment, x-ray films, and dental drills.

Commercial Transportation:

- **Rail** – Designing, building, installing, maintaining, and repairing wheeled vehicles on permanent rail tracks for conveying goods and passengers. Includes railroads capable of traversing the continent and light rail
- **Marine** – Maritime vessels for cargo shipping as well as military water transport: deep-sea cargo, barges, inland water vessels, and freight transportation (excludes passenger vessels)
- **Aviation** – Design, development and production of military, commercial, and personal aircraft and related equipment
- **Freight Automotive** – Design and manufacture of heavy trucks and ship containers for transporting goods

The Greater Portland region has more than 1,200 technology companies ranging from large computer components manufacturer Intel, which employs more than 16,000 people, to WaferTech's semiconductor fabricator employing 1,000, plus smaller companies with hundreds or fewer employees. The density of high-tech businesses has led to the nickname "Silicon Forest." Well-established support industries and farsighted commercial planning continue to draw advanced materials fabricators and advanced manufacturers to the region.

THE ADVANCED MATERIALS & MANUFACTURING VALUE CHAIN

Across industries, supply chains include Primary Activities:

Figure 5

. . . and Supporting Activities:

Figure 6

Without a robust supply chain, businesses wither or leave.
Every supplier is part of a "chain" of providers serving large original equipment manufacturers (OEMs), known as "primes" in aerospace and defense, plus branded product companies. Many of the things suppliers make today can be adapted or used as-is to serve other industries.

To support a "cluster," the advanced manufacturing and materials supply chain must have players at every level, from raw materials through waste management and recycling.

Typical Supply Chain:

Figure 7

Tiered chains are prevalent in complex industries such as electronics and aerospace manufacturing, where the final products consist of many intricate components and sub-assemblies that must comply with strict quality standards. Typically, Tier Two companies supply businesses in Tier One, Tier Three supplies Tier Two, and so on. Tier One and Two companies generally represent significant spend, transaction volume and business impact.[57]

57 Sources: Council of Supply Chain Professionals, 2013; and CH2MHill

Larger companies want to strengthen their supply chains to ensure they have robust capacity, advanced technical knowledge, and capable workforces. A trend in the aerospace industry is for anchor companies to share information with their suppliers to build new technologies. Large corporations want to reduce cost and risk. Small and medium suppliers must have access to resources, internal competencies, and must run lean.

"Lean" is about efficiency in processes and economies of scale in production, which increase margin. Investing in a skilled workforce by providing training and apprenticeships, as well as competitive wages and benefits, is just as important. Businesses that survive to thrive will recognize employees as assets, not expenses. Regions that thrive will support workforce systems that train and provide readiness for certifications.

Companies that want to rise in their supply chains will also need product exploration, market diversification, and succession planning. They can be lean, but could have their largest customer walk away or have their workforce dry up, so they could not produce. They must maintain and nurture their own supply chain so their sources of supply are readily available.

Fourth tier supplier – Raw materials and basic parts/tools. Typically one-time procurement with no ongoing relationships or expenditures.

Third tier supplier – Subcomponents and other parts and services. Considered "value-added" relationships and used for lower volume agreements with infrequently used suppliers.

Second tier supplier – Subcomponents and components, some assembly;
"preferred" suppliers with longer term but lower volume agreements.

First tier supplier – The most important member of a supply chain, providing modular assemblies and parts directly to OEMs and branded companies. They have strategic, long-term, high-volume agreements, are generally the largest or most technically capable with skills, resources and capacity to supply critical parts. They also manage suppliers in the tier below them. Their manufacturing services allow OEMs to concentrate on final assembly and marketing. Collaborative relationships with OEMs improve quality, eliminate waste, cut costs and reduce lead times. Sophisticated suppliers use data networks to exchange supply and demand information and synchronize production, purchasing, and logistics with customers.

Anchor companies, or primes, such as Boeing, rely on complex supply chains. Intel is a supplier to and competitor of Samsung. Suppliers and anchors often have interconnected electronic systems for inventory control and payment transactions.

SUPPLIER ROAD MAP TO INNOVATE, DIVERSIFY & EXPAND

The following models depict options supply chain manufacturers have for strategizing and planning growth initiatives and targeting end-user markets through innovation, diversification, and expansion.

Traditional Metals

RAW MATERIALS	MANUFACTURING PROCESS	CURRENT MARKETS	NEW MARKETS
Steel Copper Aluminum Titanium Nickel Alloys	Forging Casting Rolling Bending/Cutting Grinding/Polishing Machining, Milling, Shearing Fabrication	Commercial Construction Infrastructure Industrial Machinery & Equipment Transportation Electronics Recycling Tooling & Fixtures	Transportation (Traditional & Light Rail, Trucking, Railcar, Material Handling) Agricultural Machinery & Equipment Pressure Vessels Pipes & Pumps Oil & Gas Industry

Figure 8

Traditional Plastics

RAW MATERIALS	MANUFACTURING PROCESS	CURRENT MARKETS	NEW MARKETS
PET (polyethylene terephthalate) PVC (polyvinyl chloride) ABS (acrylonitrile butadiene styrene) PES (polyester) PC (polycarbonate) PU (polyurethanes)	Injection Molding Roto-Molding Blow Molding Thermoforming Extrusion Rolling Surface Coating	Consumer Products Consumer Electronics Home Hardware Improvement HVAC Pipes Containers & Packaging Textiles	3-D Printing Medical Devices Plastic Screens Automotive Plastics, Textiles Security/Safety Products Aerospace & Defense (Planes, UAVs, Helicopters)

Figure 9

Lightweight Metals

RAW MATERIALS	MANUFACTURING PROCESS	CURRENT MARKETS	NEW MARKETS
Silicon Silicon Crystals Graphene Structural Alloys	Microfabrication Engineered Products Molded Assemblies Sensors, Meters and Monitors	Semiconductor Chips Computers & Electronics Biomedical Devices Tooling & Fixtures	3-D Printing Consumer Products Industrial Products Optoelectronics LED Dislays/Lighting Liquid Crystal Displays Flexible Metal Products

Figure 10

Advanced Materials

RAW MATERIALS	MANUFACTURING PROCESS	CURRENT MARKETS	NEW MARKETS
Advanced Polymers Fiberglass Composites Kevlar Synthetic Fibers Carbon Fiber Fiberboard Bio-ceramics Thermoplastics	Injection Molding Roto-Molding Blow Molding Thermoforming Extrusion Rolling Surface Coating	Consumer Products Consumer Electronics Home Hardware Improvement HVAC Pipes Containers & Packaging Textiles	3-D Printing Medical Devices Plastic Screens Automotive Plastics, Textiles Security/Safety Products Aerospace & Defense (Planes, UAVs, Helicopters)

Figure 11

Successful Suppliers Share Advice For Small & Medium Manufacturers

Relationships

"Buyers are low on the totem pole in companies where engineering rules. In others, purchasing is the gatekeeper. It's all about perceived value and who you need to build a relationship with first."

"Be a trusted partner for providing the finest products and service."

"Have capabilities, certifications and testimonials."

"You need to have design engineering for capability and manufacture-ability."

Knowledge

"Know the trends and industry tech terms: 'infrared astronomy,' 'polymorphic coding,' 'FPAs,'[58] *'open source.'"*

"Have detailed documentation and materials management systems."

"Manufacturing and tech today are like pharma . . . complicated, regulated, science-based."

"Look up 'open hardware' and 'quirky' – could be the future of local production and big cost reductions."

Strategy

"Intelligent automation – robotics and artificial intelligence – will change the factory floor. But cables and wire harnesses won't go away. Some work is exquisitely human."

"You have to worry about the next three years to be okay for the next twenty."

"Competitors come out of the woodwork, entry barriers are falling. Small Mom & Pops can boom here with excellent quality. They can compete with bigger guys by using better technology."

"Know what business you are in. IBM sold servers to Lenovo. Servers aren't their business anymore."

"Lean is key, and technology. We tripled in size without adding more people."

"Do modular, build stations. Don't have WIP [work in progress] inventory."

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58 Field Programmable Arrays: an integrated circuit designed to be configured by a customer or a designer after manufacturing

Technology

"3-D custom build-to-order and digital signal processing music, warfare – it all runs on the same stuff . . . electronics."

"Spacecraft will make their own spare parts on board."

"Making a circuit board is like making a pizza but the technology is awful – 40 plastic layers of interconnections with icky chemicals. In 2000 there were 1,200 CB fabricators, now there's less than 300 . . . unpredictable, unreliable production; management is poor."

"3-D tomography is like an MRI for a circuit board."

"To spur development you have to help small companies get money."

Requirements

"A day or two late is not acceptable."

"You have to be able to dance with the big guys – and to their tune."

"Understand the need for 24/7 operations. 9 to 5 in your own time zone fails."

"Instant availability for back-up inventory . . . companies need immediate replacement to keep producing."

"CRM, supply chain, order processing and market systems are all electronically driven now."

". . . market information. The best way to get that is stay connected."

Opportunities

"Learn customers inside out. What solutions do they need?"

"Real solutions are needed . . . a modular energy grid, energy storage, films and coatings for electronics and optics . . . flat panel displays, but they've gone to Asia and won't come back without a major tech disruption."

"Nuclear will grow along with solar."

"Suppliers thrive when they figure out what changes are needed to their own supply chain . . ."

"Work harder right here at supplying more to each other."

The Greater Portland Region is Primed for Manufacturing Growth

By the Numbers:[59]

- 19th largest U.S. MSA
- Population (2012): 3,289,800[60]
- Population percent change (2000-2012): 18.8%[61]
- Year-over-year new residents from out of state: 4.10%
- Unemployment rate (Dec. 2013): 6.2%
- Job growth rate 2012-2013: 1.6%[62]
- Projected job growth rate for 2014: Oregon 2.14% (8th in the nation), Washington 1.76% growth (16th in the nation)
- 2013 median MSA household income: $56,978[63]

Population

The region added an average of 28,817 residents per year between 2000-2012, and its annual growth rate exceeded the state of Oregon's rate of 1.1%.[64] Population growth is expected to continue at a rate of 0.9% through 2017. The population has grown at least as fast as the U.S. since 1930, sometimes growing at twice the rate of the nation.

Income, Education and Age[65]

The Portland MSA is more affluent than Oregon as a whole. U.S. median household income in February 2013 was $51,404 (a decline from 2007 when it was $55,438). Median household income for the Portland MSA is $56,978. That is 15.9% greater than the corresponding figure for Oregon, which is $47,656.

Greater Portland MSA residents have a higher level of educational attainment than those of Oregon. An estimated 34% of Portland MSA residents have four-year college degrees versus 29% of their Oregon counterparts. The City of Portland's rate is 45%; Clark County's is 26.8%, and Cowlitz County's is 16%.[66]

Gross Metropolitan Product

The Greater Portland MSA is the 20th largest economy in the nation based on Gross Metropolitan Product (GMP). The region's GMP rose by 6.14% in 2012, 3.81% in 2013, and is estimated to grow 5.44% in 2014.[67]

The Portland MSA has a per capita Gross Regional Product (GRP) of $53,587, is 23% higher than Oregon's state GSP of $43,430, and 41% higher than Washington's Gross State Product at $47,157. Portland MSA industries and employers are adding relatively more value to the state economy.[68] Much of that value comes from manufacturing.

59 http://en.wikipedia.org/wiki/List_of_United_States_metropolitan_areas
60 www.citydata.com
61 http://koin.com/2014/01/24/more-people-on-the-move-to-oregon/
62 U.S. Census Bureau
63 U.S. Census 2012, ACS, Table S1901
64 Claritas, 2012
65 U.S. Census Bureau 2012
66 US Census, ACS 2012, table S1501
67 http://www.usmayors.org/metroeconomies/2013/201311-report.pdf
68 Bureau of Economic Analysis and Economy, 2011

PUTTING THE REGION TO WORK

An industrial maintenance technician can make $80,000 to $100,000 a year; they are absolutely necessary to keep factories running. However, they are hard to find. There are 2.7 million manufacturing workers expected to retire between now and 2018.[69] It is estimated that 40% of those vacant jobs will now require a post-secondary education as industry becomes more technically sophisticated. Employers also expect employees to have the ability to work in teams, be capable of communicating clearly, and to have the potential to develop leadership skills.

This is crucial to U.S. competitive advantage and to regional economies, as collaborative environments foster new businesses and innovative technologies in places such as Silicon Valley, California; Austin, Texas; and Cambridge, Massachusetts.

Manufacturing workers in demand have mechanical ability, can be team players and self-starters, and have troubleshooting and problem solving skills.[70] Many manufacturers provide on-the-job training. Some have relationships with engineering programs at local universities, colleges, and technical schools to ensure high-quality talent is available. Some pay for certifications, re-training, and continuing education. Smart manufacturers recognize their labor force is an asset, not an expense.

In a 2013 survey of manufacturing workers by Industry Week magazine,[71] 85% of respondents reported being satisfied to very satisfied with manufacturing as a career. Seventy-four percent said they were satisfied to very satisfied with their current job. Those statistics have important implications for manufacturing companies.

- Manufacturing, while perhaps not considered "cool" by the young, and often considered "dirty and dangerous" by their parents, is a satisfying career for a majority of workers.
- Satisfied workers are not looking for new jobs.

Replacing retiring baby boomers and finding new, younger workers for increasingly sophisticated manufacturing jobs may not be easy. Manufacturing today is knowledge-based, requiring workers to design and operate complex precision equipment. Salaries in manufacturing have grown during 2012 and 2013, with raises being the norm, not the exception. The average manufacturing management base salary has passed the $100,000 mark.

69 Fostering Growth Through Innovation. the Brookings Institution, 2013

70 Industry Week Salary Survey, 2013

71 www.industryweek.com/globaleconomy, September 9, 2013

Average 2013 Manufacturing Salaries by Position[72]

Position	Average Salary
C-level	$141,500
VP/Dir. Manufacturing Operations	$137,440
VP/Dir. Sourcing, Supply Chain	$111,622
R&D/Product Development Mgr.	$107,055
Sales & Marketing Management	$100,642
Finance	$99,257
Engineering	$96,623
Lean, Continuous Improvement	$91,748
Mgrs.: Ops, Quality, Logistics, Supply Chain, HR, Health/Safety, Environment, Admin	$66,840 to $88,215

Figure 12

Many manufacturing managers reported receiving bonuses averaging $25,000.
The highest salaries in those positions are in technology-intensive industries particularly strong in the Pacific Northwest: Aerospace & Defense, Electronics, Transportation (rail, marine, aviation), Light Metals, and Industrial Machinery. The average salary by education level is also higher in manufacturing

Average 2013 Manufacturing Salaries by Education Level

Education Attained	Average Salary
High School	$75,907
Some college to two-year degree	$81,000
Four-year degree	$102,305
Masters degree	$129,037
Doctorate	$131,005

Figure 13

Company size does not have as much impact on salary as might be expected.

Average 2013 Manufacturing Salaries by Company Size

Company Revenue	Average Salary
< $25 million	$92,429
$25 million to $50 million	$108,899
$51 million to $100 million	$103,201
$500 million to $1 billion	$114,970
$1 billion to $20 billion	$108,355
> $20 billion	$110,471

Figure 14

72 Industry Week Manufacturing Salary Survey, 2013

In terms of average salary per geographic region, the Northwest reflects its advantage over other U.S. regions because of its strength in technology industries.

Average 2013 Manufacturing Salaries by Location

Company's U.S. Location	Average Salary
New England States	$115,731
Far West & Northwest States	$114,138
Mid-Atlantic States	$108,839
South Atlantic States	$104,764
Mountain States	$102,669
South Central States	$101,995
North Central States	$99,697

Figure 15

According to Forbes magazine, the U.S. "Left Coast" – California, Oregon, and Washington – has the highest percentage of STEM workers in the U.S. – more than 50% above the national average. It also has the largest share of engineers in its workforce. Despite high housing prices and regulations seen by some as business-unfriendly, it is expected to continue to be a leading technology hub thanks to aerospace, defense, aviation, and electronics. Health care is expected to be a significant part of that mix by 2023.[73]

> "Intel is making a huge investment in the Portland region.
> It's up to Oregon to live up to that commitment with the right workforce."[74]

As of July 2013, two occupation classes relevant to industry and technology have the highest number of vacancies and are reported to be the hardest to fill:[75]

- Welders, cutters, solderers, braziers
- Computer numerical controlled ("CNC") machine tool operators, metal and plastics workers

Other difficult-to-fill manufacturing occupations include mechanical engineers, cutters, trimmers and hand electricians, machinery maintenance workers, first-line production and operations supervisors, and production workers.

The most common reasons cited by employers for being unable to find employees are:

- Unfavorable working conditions – perhaps a perception based on low-tech manufacturing of years past; may reflect irregular schedules or physically demanding work
- Lack of qualified candidates
- Lack of applicants
- Lack of work experience

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73 Reinventing America, Kotkin and Schill. Forbes, September 4, 2013

74 Confidential interview, July 2013

75 Oregon Employment Department

Hard-to-fill jobs are more likely to require education beyond high school plus prior work experience. Some positions also require certifications (e.g., journey level electricians) or licenses (e.g., limited maintenance electricians). Lack of soft skills is also an issue. As reported by business leaders, missing skills include oral and written communications, ability to work in teams, creative problem solving, initiative, and leadership potential.

Even among those with post-secondary education, lack of technical skills and STEM-related degrees make it hard to fill advanced manufacturing jobs. At the graduate degree level, jobs also go unfilled. The primary reason given by employers is lack of applicants.

Mechanization, computerization, and robotics have changed the manufacturing workplace. Labor-saving technology displaces workers, but over the long term it generates new products and services that raise the overall demand for labor. Computers are good at fast, routine, repetitive tasks, but they require engineers to design and build them, programmers to write their rules, and skilled technicians to manage and repair them.

While computer manufacturing has moved mainly to Asia, quality-intensive, innovation-based industries such as electronics and aerospace remain a U.S. strength – and a huge asset for the Pacific Northwest in particular. Three of the world's largest semiconductor companies operate in one county in the Portland region. Major global corporations, such as Boeing, Intel, and TriQuint, depend on the region's labor market and supply chains.

As the labor force bifurcates into low-wage service jobs (driving trucks, cleaning hotel rooms, serving food) and high-wage technical, managerial and professional occupations (law, medicine, science, engineering), the middle of the labor market is caving and income inequality is rising.

Advanced manufacturing and the trend toward reshoring can fill that gap with help from investments in education, logistics-supportive infrastructure, R&D, and capital for new machinery and equipment. That combination will produce the healthy economic ecosystem that creates demand for jobs with livable wages and benefits, but the supply of skilled workers must keep up with that demand.

Only 40% of Americans enroll in four-year colleges after high school graduation and fewer than 70% finish within eight years. This region does not perform as well as the U.S. in general for high school graduation rates. Only 78.2% of all U.S. high school students graduated in four years in 2010.[76] The target rate is 67% for Oregon and 77.5% for Washington. Five counties did not meet those targets. In 2012, the City of Portland's graduation rate was 63% and Vancouver's was 72.8%.[77] However, the region significantly outperforms the nation with college entrants. On average, 42% of young Americans enroll in four-year colleges after graduating from high school. In Oregon, 59% of high school graduates enroll in college.[78] In Washington, the average is 64.2%.[79]

76 www.ed.gov, January 13, 2013
77 Greater Portland Pulse
78 www.Oregonlive.com.edu
79 www.wsac.wa.gov

The Labor Market from an Industrial Perspective

"Training is a long term investment . . . [it] supports wages that support families who can pay taxes to build infrastructure and the community . . . full circle growth for the economy."[80]

Industry Employment Forecast, 2010-2020[81]

As shown in the following chart, employment trends are positive for all the region's manufacturing sectors . . . a good thing if there are enough of the right employees.

NAICS	Industry	2010	2020	Change	% Change
3353	Electrical Equipment Manufacturing	300	380	80	26.7%
3332	Industrial Machinery Manufacturing	1,840	2,260	420	22.8%
3359	Other Electrical and Component Manufacturing	1,000	1,170	170	17.0%
3345	Navigational, Measuring, Electromedical and Control Instruments	4,190	4,880	690	16.5%
3341	Computer & Peripheral Equipment Manufacturing	2,450	2,810	360	14.7%
3344	Semiconductor & Other Electronic Component Manufacturing	23,110	26,100	2,990	12.9%
	Totals	32,890	37,600	4,710	14.3%
	All Industries	806,540	972,570	166,030	20.6%
	Durable Goods Manufacturing	67,660	79,460	11,800	17.4%

Figure 16

*Tri-County Area (Multnomah, Clackamas, Washington, OR). An updated Employment Forecast was published in March 2015 providing estimates for 2012-2022 and including estimates for Clark and Cowlitz Counties in Washington.

"Advanced manufacturing" and "high tech" have been identified by Worksystems, Inc. and the Workforce Investment Council of Clackamas County (WICCO) in their efforts to develop sector strategies, which are employer-driven partnerships aimed at addressing the workforce needs of key industries. Partners include business, economic development, education, and training providers. Those sector strategies are a key component of the Governor's Ten-Year Plan and the Oregon Workforce Investment Board Strategic Plan.

The Portland Development Commission, the Columbia River Economic Development Council, and Greater Portland Inc. include advanced manufacturing on their lists of assets critical to the region's current and future economic health.

80 Confidential interview

81 Oregon Employment Department, September 2013

Workforce Assets and Challenges

"Technicians need to meet standards.
Who sets them?
Who trains to them?
Who certifies and enforces them?"[82]

The Portland Business Journal hosted a manufacturing roundtable in July 2013. Nine participants discussed the state's education system, workforce, and business climate.

Local business leaders are struggling to find skilled employees and would like the public school system to focus more on skill-based training for manufacturing occupations.

The president of Oregon Iron Works is collaborating with the founder of Benchmade Knife Company and others to support the Clackamas Academy of Industrial Sciences, where students learn industry-specific skills. Leatherman Tool Group has initiated an in-house apprenticeship program to address its workforce needs. The president of Silicon Forest Electronics is engaged in supporting STEM education, and its vice president teaches Leadership at Clackamas County Community College. Axiom Electronics is planning a hardware accelerator for new ventures. Clark College, which has the only Mechatronics degree program on the West Coast, works closely with regional businesses to provide graduates that meet workforce needs.

82 Confidential interview

In November 2012, the Southwest Washington Workforce Development Council commissioned a survey of manufacturers in the Portland region to better understand manufacturing employment trends and workforce needs.[83] Key findings revealed they face two major challenges:

- Keeping up with efficient manufacturing processes
- Hiring and retaining employees

The first challenge is related to the demands of constantly changing technology. Companies need to redesign their processes, employ lean manufacturing techniques, and invest in more automated production methods.

The second is indirectly related to changing technology. Finding skilled workers and retraining existing workers is a necessary investment. Successful candidates will not only need competency in math and science; many will need certifications. Employers are looking for workers with the following attributes:

- Experience through employment, internships or apprenticeships
- Soft skills:
    - Communications
    - Teamwork
    - Cultural competency
- Foundational skills:
    - Reading, vocabulary, basic arithmetic
    - Computer literacy
    - Problem solving
    - Supervisory and/or leadership potential

Lack of new workers and process re-engineering are the two major trends facing manufacturing firms over the next three years. For instance, primary metals manufacturers report facing a lack of new workers in four key areas:

- CNC machinists (49%)
- Mechanical machinists (39%)
- Welders, specifically TIG welders[84] (33%)
- Tool and die makers (29%)

Fifty-two percent of electrical manufacturers report having the hardest time filling engineering positions, and twenty-five percent have difficulty finding electrical technicians. Given the region's dependence on metals, machinery, and electronics, these are not healthy trends.

Just as internships are favored by schools, students, and businesses, apprenticeships provide valuable on-the-job training. Large companies with 500 or more employees are more likely to use formal apprenticeships (45%) than smaller companies (7%). Primary metals manufacturers are more likely to use apprenticeships than electrical manufacturers (4%). For smaller companies, apprenticeships are often too costly and time intensive.

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83 SW Washington Workforce Development Council and Worksystems, Inc. Manufacturing Workforce Survey Results, November 2012

84 Gas tungsten arc welding requiring skill and expertise

TOP PERFORMING ADVANCED MANUFACTURING METROS

Ask about the top U.S. technology centers and you will hear Silicon Valley, California; New York City, New York; and Boston, Massachusetts. But other regions are coming up fast and will compete with Portland in terms of manufacturing. They represent the most innovative cities in the U.S. and are centers of information technology, energy generation, and manufacturing. Each has a distinct *"geography that reflects different kinds of engineering talent."*[85] Examples include:

Austin, TX – R&D and technology leader in the design and manufacture of semiconductors and electronics.

Atlanta, GA – Strong in telecommunications and logistics, with major north/south and east/west interstates, the world's busiest airport (followed by Beijing's Capital and London's Heathrow) and five-hour trucking distance to the ports of Charleston and Savannah.

Orlando, FL – Power generation systems, wireless communications, medical imaging, instrumentation, controls, and automotive systems.

Houston, TX – The energy capital of the U.S. with 59,000 engineers, second only to Los Angeles.

Wichita, KS – An aerospace center with the presence of Boeing and Bombardier. Twenty-one engineers per 1,000 workers.

Other up-and-coming advanced manufacturing centers include Louisville, Kentucky; Seattle, Washington; Oklahoma City, Oklahoma; Nashville, Tennessee; Ft. Worth, Texas; and Salt Lake City, Utah.[86]

Shared Characteristics of Innovative Regions . . .

- Market their regions to attract new talent and new companies with jobs
- Invest in infrastructure that supports industry
- Employ workforce development programs to address skills gaps
- Top research universities with millions to $1 billion in sponsored research
- Strong network of trade and technical schools feeding their engineering talent pool
- Research recognition from the National Science Foundation and other funding sources
- Above-average patents per capita

Most importantly, they recognize their position as part of the global value chain,[87] where firms organize their activities to design, produce, market, and deliver their products. The chain relies on complex information, communication, and logistics systems. Transactions occur among multinational firms, divisions of multinationals, smaller companies, and suppliers.

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85 www.newgeography.com. America's Engineering Hubs: The Cities With The Greatest Capacity for Innovation. Joel Katkin. July 31, 2013

86 Forbes Magazine, America's New Manufacturing Boomtowns, May 15, 2013

87 Michael Porter, Harvard Business School

Greater Portland Regional Innovation Rankings[88]

Rich economic ecosystems have a variety of resources to build upon. How does the Greater Portland region measure up?

The Portland-Vancouver-Hillsboro metropolitan region ranked number 24 out of 381 U.S. metropolitan statistical areas in population in 2012 with 2,289,800, a 2.87% increase over the 2010 census of 2,226,009.[89] By 2013, the population in just the five grant counties had grown to 2,168,809.[90]

Regional rankings include:

- #230 in average unemployment; the unemployment rate was 6.2% vs. U.S. average of 6.7%[91] (2013)
- #22 of top 125 in tech sector share of employment (2012)
- #8 in GDP per worker of $129 (2012)
- #21 in SBIR awards (2011)
- #53 in SBIR award dollar amounts (2011)
- #89 in IPOs per capita (2011)
- 0 of top 10 science Ph.D. programs (2006)
- #80 in Ph.D. science programs (2011)
- #38 in STEM bachelor degrees awarded (2011)

Patents per year are an accepted proxy for a region's innovativeness but often reflect the efforts of a major corporation's R&D efforts. Portland regional averages for patents per year are:[92]

- 1976-1980 – 319
- 2006-2010 – 2,594
- 2007-2011 – 1,844

The number of patents issued tends to be highly correlated to the number of IPOs in a region and to the percent of job growth . . . if it draws highly educated workers to the metropolitan region. When patents are associated with creating new products and economic value, they may help create new companies.[93]

88 The Brookings Institution Metro Profile Data: Patenting & Innovation in Metropolitan America. Feb. 21, 2013
89 U.S. Census Bureau estimate
90 www.portlandonline.com
91 www.data.biz.gov
92 Ibid
93 Patenting Prosperity, the Brookings Institution. February 2013

Total Granted Patents by Metropolitan Area of Inventor 2007–2011

CITY	Avg. Patents Granted Per Year 2007-11	Largest Subcategory of Patents
San Jose	9237	Computer Hardware & Peripherals
San Francisco	7003	Biotechnology
New York City	6907	Communications
Los Angeles	5456	Communications
Seattle	3968	Computer Software (Microsoft)
Boston	3965	Biotechnology
Chicago	3886	Communications
San Diego	3165	Communications
Minneapolis-St. Paul	3068	Surgery & Medical Instruments (Medtronic)
Detroit	2720	Transportation
Austin	2497	Computer Hardware & Peripherals
Philadelphia	2370	Biotechnology
Houston	2202	Earthworking & Wells
Dallas-Ft. Worth	1945	Communications
Portland	1844	Computer Hardware & Peripherals (Intel)
Atlanta	1506	Communications
Washington, DC	1479	Communications
Phoenix	1437	Semiconductor Devices
Raleigh	1273	Computer Hardware & Peripherals
Poughkeepsie	1226	Semiconductor Devices

Figure 17

Regional Innovation Assessment

- Applied technologies for industrial manufacturing and materials as a rich source of tacit and explicit knowledge: **Yes**
  - o Computers & Electronics
  - o Aerospace & Defense
  - o Machinery & Equipment
  - o Light Metals & Advanced Materials
- Industry Associations: **Yes** (easy online and regional chapter access to national organizations)
- Regional Industry Support Organizations: **Yes** (see Appendix A)
- R&D Facilities: **Yes** (see Appendix A)
- Logistics infrastructure, including active ports: **Yes (**air, marine, railroad and interstate highways)
- R&D Funding: As of 2013, Oregon ranked #21 of 50 states in SSTI[94] awards, having received 1,890 awards

94 Small Business Innovation Research/Small Business Technology Transfer Award. www.sbir.gov

worth $538,831,131. Washington ranks #12 with 3,258 awards worth $850,416,628.[95] Greater Portland is not among the top 20 regions receiving SBIR awards[96]

- Educated, technically skilled workforce: **More are needed**
- Prominent Research Universities: **No**
- Sources of Capital: **No** Investment is scant, via angel investors and public sources. There are no regional venture capital firms. Washington State venture capitalists don't focus on Vancouver/Camas. The Oregon Investment Fund bridges the gap between Oregon entrepreneurs and venture capitalists

Another way to measure a region's innovation is by its entrepreneurship ranking on the Kauffman Index of Entrepreneurship. In 2012, Oregon rated 22% of a possible 100%, and Washington rated 27%. Neither was among the top 15 most entrepreneurial cities.[97]

Kauffman Index of Entrepreneurial Cities, 2013 Regional Rankings

State	2000 to 2002 Ranking	2005 to 2007 Ranking	2010 to 2012 Ranking
Oregon	.34	.35	.22
Washington	.27	.24	.27

Figure 18

A regional "cluster" in advanced materials manufacturing requires a diverse array of technology and business stakeholders. Following is a sampling of the many entities supporting technology in the Portland region. A complete list is provided in Appendix A.

- Industry giants plus medium and small enterprises in supply chains: Boeing, Intel, Precision Cast Parts, ElectroScientific Industries, Axiom, Thompson Metal Fab, and Enoch Manufacturing
- Portland State University, Washington State University Vancouver, Oregon Health & Science University, Clark College, Portland Community College, and Oregon Institute of Technology
- Public and private R&D organizations: Oregon Nanoscience and Microtechnologies Institute, Oregon Translational Research & Development Institute, Oregon Best, Drive Oregon, Oregon Metals Initiative
- Federal and state science and technology government groups: SSTI/SBIR,[98] Manufacturing Extension Partnerships,[99] Pacific Northwest Defense Coalition
- Regional economic development agencies: Business Oregon, Greater Portland, Inc, Choose Washington

95 http://www.sbir.gov/sbirsearch/technology?state=OR
96 Patenting Prosperity, the Brookings Institution. February 2013
97 Kauffman Index of Entrepreneurship 2012
98 State Science and Technology Institute, Small Business Innovation Research
99 Impact Washington and OMEP are Manufacturing Extension Partnerships under the National Institute of Standards and Technology

Regional Ports – Gateways To Economic Prosperity

The region's ports work together, have complementary services, and provide direct access to the Midwestern United States, Canada, and Asia. Portland's international airport is within 15 minutes of both ports, as are north/south and east/west Interstate highways. Both provide transloading services to Asia and the U.S. Midwest and East Coast. They are points of convergence for the BNSF Railway and the Union Pacific Railroad, as well as marine ports with access to Asia.

Both ports provide access to opportunity, as this region becomes more of a critical infrastructure supply chain player for mid-continental U.S. industries. They will be especially important as oil and gas production grows in the U.S. The Pacific Northwest can be a critical supply chain player for mid-continental infrastructure, as rail access is crucial.

Energy will be a key source of exports for the Northwest region: wind, solar, and forest products, and especially for metals and new materials manufacturing. The Bakken shale region provides a huge export opportunity. The Bakken covers 200,000 square miles of Montana, North Dakota, and Canada where hydraulic fracturing is being used to extract an estimated 2.1 billion barrels of oil. That region is behind Texas, but ahead of Alaska, as the third largest U.S. oil producer.[100]

Port of Vancouver

The Port of Vancouver has six terminals and thirteen marine berths in a 43-foot deep-draft shipping channel on the Columbia River, as well as 1.2 million square feet of waterfront warehousing, and 800 acres of industrial development with room to grow. It employs 100 people but has 50 tenants employing 2,300 people. There are an estimated 16,000 people with Port of Vancouver-related jobs. It is the West Coast expert in break bulk and heavy lift cargo such as steel and lumber, and big oddly shaped industrial equipment, with two mobile harbor cranes that can each lift 140 metric tons. The Port has 800 developed acres plus new development in progress. It is also a real estate development center for business accessing the Port and the companies that supply them. It plans to be a growing West Coast port for destinations in Asia and the Pacific Rim by water, and the U.S. Midwest and East Coast by rail.

Port of Portland

Port of Portland facilities include four marine terminals at the confluence of the Columbia and Willamette Rivers, connecting the Western U.S. to Asia, Central and South America. It ships containerized goods, liquid bulk, some break bulk, automobiles, grain and industrial goods, as well as electronics and consumer goods. The Columbia and Snake Rivers combine to form the second largest river system in the U.S., providing direct inland access as far east as Idaho. Cargo such as bulk grain and forest products comes by barge to Portland for export to international destinations. Regional companies relying on the Port, and many of the companies that supply them, are situated at the Port. The Port of Portland also hosts PDX, the state and region's largest international airport with three freight runways. Port of Portland is the third largest export tonnage port on the West Coast.

Regional small and medium companies usually cannot afford to truck and ship from afar. Local ports provide shipping line service connections to national and international locations. Ports support transportation, warehousing, and distribution logistics. Bridges are also a key port component; they need to be efficient, safe, and reliable. Highways need to be accessible and free moving. Ports also rely on technology, including the software and hardware used to track inventory and shipments. Real time data enables just-in-time delivery and reduces storage costs. Electronics and information technology are used to manage systems, maintenance, and energy efficiency.

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100 The New Oil Landscape, National Geographic Magazine. March 2013

EXPORTING – A CRUCIAL GROWTH FACTOR

"While the U.S. role in manufacturing electronics has declined, sites of electronics production such as Austin, Dallas, Portland, and Phoenix trade significant amounts with their Mexican metropolitan counterparts, relying on them for labor-intensive parts of the workforce."[101]

New Markets, New Customers

Trade routes globalized a much smaller world in ancient times, from the first oared boats to sail the Mediterranean and Marco Polo's visit to China, to Columbus sailing the ocean blue in 1492. Today's global trade routes crisscross the world over by land and sea.

The most export-oriented sectors in the U.S. are in advanced manufacturing industries that rely on R&D and significant technical knowledge. Advanced manufacturing industries represent 47% of goods trade in North America, and U.S. metropolitan regions account for 60% of trade in advanced industries.[102] They include Electronics ($115 billion), Industrial Machinery ($82 billion), Medical Devices ($26 billion), and commodities such as Oil & Gas ($108 billion).[103] While they represent only 3% of U.S. employment, they generate 30% of national exports.[104] This region has a wealth of manufacturing capabilities in those industries.

Countries no longer compete on price alone; quality and value are critical. The U.S. has those assets, but so do other developed countries. Developing economies are investing in their infrastructure and education so they can compete as well. To retain its leadership, the U.S. must regain its strength in innovative industrial manufacturing, led by strong investment in R&D and high-value engineering.

Technology makes it easy to connect with worldwide customers, and there are strong correlations between market diversification, exporting and growth.[105] Those are good reasons to identify fast-growing products in this region. If above-average growth in particular products continue for an extended time, they become an important source of export earnings.

Exports of U.S. goods increased in 2011, 2012, and 2013.[106] The U.S. is the world's second largest exporter. China is number one and Germany is number three.[107] As of June 2013, U.S. exports had reached an all-time high.[108]

Historically, the top U.S. export commodities were civilian aircraft, engines, and equipment. In 2012, refined petroleum products were at the top. Automobiles were second, and civilian aircraft moved to third place.

101 Export Nation 2013, the Brookings Institution Metropolitan Export Initiative
102 Metros as Hubs of Advanced Manufacturing. the Brookings Institution, November 7, 2013
103 Export Nation 2013, the Brookings Institution Metropolitan Export Initiative
104 Patenting and Innovation in Metropolitan Cities. the Brookings Institution, 2013
105 www.worldbank.org. Export Competitiveness
106 US International Trade: Trends and Forecasts. Congressional Research Service. Oct. 2012
107 World Fact Book of the CIA
108 www.tradingeconomics.com United States Exports, September 2013

U.S. Exports By Sector[109]

67% of exported goods are in sectors strong in the Portland-Vancouver region.

Export growth has been central to the U.S. economic recovery. Exports are growing at a rate of 16% annually and expected to reach $3.1 trillion by 2015.[110] New technology is contributing to those numbers. Unmanned aircraft, known as drones, are growing exports for defense, agricultural use, fire fighting, and surveillance. The United Arab Emirates will purchase $170 million worth of drones from General Atomics in 2014.[111] Aerospace and defense, including aviation, is a particular strength of the Pacific Northwest.

Industrial Supplies	34%
Capital Goods	33%
Food, Feeds, Beverages	9%
Automotive Vehicles, Parts and Engines	9%
Consumer Goods	12%
$1 billion to $20 billion	$108,355
> $20 billion	$110,471

Figure 19

Exporting is the region's entrée to new markets, new customers, and new product ideas. Intel accounts for 60% of Oregon's exports to China, and most of it travels by air.[112] Air cargo is a critical regional asset. Portland is the only metropolitan area with an easily accessible major international airport just 15 minutes from commercial centers in two states.

Computer systems and electronic controls have steadily increased the labor productivity of U.S. manufacturers over the last decade. Even so, U.S. labor costs are high compared with Asia's, resulting in much production moving overseas. C&E products today represent nearly 15% of U.S. product exports.[113] However, they are expected to decline over the next five years due to Asian competition.[114] Many U.S. goods have high-technology content, with semiconductors in everything from cars to computers and machinery. A large part of U.S. exports are components shipped to Canada and Mexico for assembly and imported back to the U.S. as finished goods. Imports of manufactured goods to the U.S. come mainly from China, Mexico, Canada, Japan, and Germany. While the U.S. imports more goods from China, our largest import-export partner is Canada.

As the U.S. shifted from manufacturing to services, theoretically to reduce costs and concentrate on information technology, biosciences and health care, its trade deficit (the total value of exports minus imports) grew and the U.S. went from being the largest creditor nation in the 1970s to the largest debtor nation by 2010. Service exports have not made up for manufacturing imports. Manufactured goods account for 75% of world trade.

While services such as brain surgeons and baristas remain local, and the U.S. can export other services such as investment banking and consulting, some services can be performed less expensively overseas: accounting, tax preparation, data processing, even medical diagnostics, and engineering analysis.

U.S. high technology exports have declined as a percent of the total.[115] In 1992, "high tech" accounted for 33% of U.S. exports – the highest proportion of any country. China's were just 6%. By 2009, U.S. tech exports had declined to 23%, and China's had risen to 31%. Today, China has expanded way beyond the low-skilled, low-value labor sector and become a major competitor.

109 www.tradingeconomics.com United States Exports, September 2013
110 US Commerce Dept. US International Trade in Goods and Services, Sept. 4, 2013
111 Los Angeles Times, February 22, 2013
112 The Brookings Institution Portland Metropolitan Export Initiative Report 2012
113 First Research Manufacturing Sector Industry Profile, May 6, 2013
114 IBISWorld, 2013
115 United Nations Commodity Trade Statistics Database; World Bank World Development Indicators. 2010

Example: Photovoltaic (PV) Cells. Invented at Bell Labs and incorporated into efficient products by RCA, Boeing, IBM and others, global sales have grown exponentially since 2007. Yet today, the U.S. is a small manufacturer of PV cells, providing only 6% of production; 27% comes from Europe, another 27% from China, 18% from Japan, and 12% from Taiwan.[116]

Since PV production draws on the same process technologies as microelectronics, Asian companies such as Sharp, Kyocera, and Sanyo leveraged their expertise in materials and semiconductors (also invented here before the transistor). They are close to the electronics manufacturing industry and key components suppliers in Asia.

When production of semiconductors, flat panel displays, light emitting diodes (LEDs), and solid-state lighting moved offshore, so did much of their technology and most of their suppliers. All those technologies had their roots in the U.S. but have mostly vanished from our shores. Yet, they are critical components of industrial and military production for aerospace, computers, electronics, and transportation industries with significant growth potential both nationally and internationally.

In response to lagging exports, the federal government has identified small and medium manufacturers as a prime source for increasing U.S. exports.[117]

Exporting is a Boon for the Regional Economy

According to analysis from the International Trade Administration, in 2012 every $1 billion of U.S. exports supported 4,926 jobs.[118]

- Exports are the core of Greater Portland's economic resilience and potential. Between 2005 and 2012, the region increased its export volume by 82%, which supported an additional 45,000 new jobs.
- In 2012, the Portland MSA was the 15th largest exporter among all 370 U.S. MSAs, with $20.3 billion in exports.[119]

On a national basis, the Portland metro area is a relatively small but very mighty exporter, having doubled its export value in the past ten years. Exports accounted for 18% of Oregon's manufacturing sales in 2011, which supported 23,400 direct jobs in manufacturing throughout the state. An additional 5,100 indirect jobs in manufacturing and 38,200 jobs supported by exports in non-manufacturing businesses brought total employment supported by manufacturing exports to 66,700.[120]

> "Understand foreign customers and be ready to fly there to help them."

116 Pisano & Shih Producing Prosperity, 2012

117 2012 National Export Strategy, www.trade.gov

118 U.S. Department of Commerce, International Trade Administration, Jobs Supported by Exports 2012: An Update, by Johnson and Rasmussen, http://www.trade.gov/mas/ian/build/groups/public/@tg_ian/documents/webcontent/tg_ian_004021.pdf

119 U.S. Department of Commerce, International Trade Administration, Metropolitan Export Series

120 U.S. Census Bureau 2011 Annual Survey of Manufacturers

Of the Portland MSA's $20.3 billion in exports in 2012, nearly one-third of exports came from computers and electronics (C&E) manufacturing.[121] In 2011, 46% of employment in C&E manufacturing in Oregon was supported by exports. Only one other manufacturing subsector in Oregon, Primary Metals, is more dependent on exports than C&E.[122]

To sustain that momentum, the region needs to engage more companies, in more diversified industries, in exporting. Computers and electronics and a small number of big companies drive Portland's exports; Intel, Tektronix, and TriQuint represent 57% of total exports and 63.4% of total export growth.[123]

The region has many small and mid-sized companies with opportunities to enter the global export market through existing supply chains. But many of those companies are hesitant to do so, and mostly unaware of the many services available to help them get started with limited risk. As part of the Greater Portland Export Initiative, regional companies were surveyed to assess their interest.

Companies expressed concern about many aspects of exporting:

- Limited knowledge of where to go and how to get there
- Fear of the unknown
- Hassles with global marketing, logistics, regulatory requirements, and unfair trade practices
- Concerns about financing and about getting paid
- Connecting to international partners and foreign distributors
- Impact of currency fluctuations

"Know foreign business conditions and how they affect you."

Smaller businesses also face challenges, with little time or financial resources to dedicate to exporting. However, many companies are under the misconception that the U.S. *". . . was, and still is, the biggest market and there is no need to export."*[124] That is fundamentally wrong for two key reasons:

- 95% of consumers are outside U.S. borders[125]
- Foreign governments and companies are major buyers of U.S. products

Other companies want to expand their business in the U.S. first, which is a good growth strategy if the market is lucrative enough and competition isn't too strong. Still more say they have enough business locally – a satisfying short-term plan; but it leaves money on the table today and can be risky if it makes a business uncompetitive in the future.

Eighty-nine percent of survey respondents had not received export assistance; yet of those who had, eighty-one percent rated the services "*good to excellent.*"

121 U.S. Department of Commerce, International Trade Administration, Metropolitan Export Series
122 U.S. Census Bureau, 2011 Annual Survey of Manufacturers.
123 Greater Portland Export Plan, Brookings Metropolitan Export Initiative, 2012
124 Confidential research interview
125 www.ustr.gov/trade. . ./economy-trade

Regional Voices and Views

If your business is hesitant about exporting, consider these comments from regional companies doing well by selling into other countries.

"We have been exporting for years and have an active sales effort to expand international markets."

"We don't think about markets by country; we think about them by customers."

"Our export markets are wherever our large customers are located."

"The (real) obstacles are payment, contracts and foreign regulations. Internally, obstacles relate to company capacity building."

Lack of awareness of technical and financial assistance hampers companies who want to export. Local resources, many of them free, include:

- Business Oregon
- City/County Economic Development Agencies
- Greater Portland Inc.
- Metro
- Oregon Export Council
- Pacific Northwest International Trade Association
- Port of Portland
- Port of Vancouver
- Portland Business Alliance
- Portland Development Commission
- Portland State University
- Small Business Administration
- Small Business Development Centers
- Travel Portland
- U.S. Commercial Service

A complete list of over 50 exporting resource providers is included in Appendix C of this report.

To help companies overcome perceived barriers, the Greater Portland region, in cooperation with the Brookings Institution and the Rockefeller Foundation, have created the Metropolitan Export Initiative and the Greater Portland Export Plan.[126] The goal of this important work is to focus attention on trade through innovation:

1. Create and retain export-related jobs to maintain the region's standing as a leading exporter
2. Diversify export industries, increasing the number of companies exporting and the markets they access
3. Create a strong local export culture and a global reputation as a competitive trading region

The objective is to double the Portland region's exports by 2017. The best way to accomplish that ambitious goal is to focus on small and medium companies and by leveraging regional strengths in industries such as Computers & Electronics, Aerospace & Defense, and Metals & Machinery.

126 The Brookings Institution Metropolitan Policy Program, 2012

REGIONAL ECOSYSTEM GAPS

Only two large regional corporations are manufacturing firms, and much of Nike's manufacturing is done overseas.

Major Employers in the Portland MSA[127]

Intel and Nike are the largest regional multinational companies and the only two engaged in manufacturing.

Company	Number of Employees
Intel Corp.	16,700
Providence Health System	14,132
Oregon Health Sciences University	14,106
U.S. Federal Government	13,900
Fred Meyer Stores	10,176
Kaiser Permanente Northwest	9,896
Legacy Health Systems	9,835
City of Portland	9,318
State of Oregon	7,559
Nike, Inc.	7,000

Figure 20

University Research Funding[128]

Oregon State University research funding declined from $380 million to $260 million. University of Oregon funding went from $200 million down to $130 million.

Portland State University funding dropped from $155 million to $50 million. Oregon university research totals about $800 million. "*We should do better.*"[129]

In 2010, Oregon Health & Science University received $392 million; it received $192 million from the National Science Foundation alone in 2012,[130] but expected an 8% reduction from the NSF in 2013.

Educated Workforce

"For the next ten years, technology is all about physics and math."[131]

"Many engineers in Oregon are mediocre, without quality education. They can crank on tools and equations, but there's no critical thinking."[132]

127 2014 Portland Business Journal Book of Lists
128 The Lund Report, July 1, 2013
129 Confidential interview
130 Faseby.org, The National Institutes of Health, by the numbers Oregon in 2012
131 Confidential interview
132 Ibid

Oregon's state treasurer identified regional challenges in an address to the World Affairs Council of Oregon.[133]

The State's workforce has a large and growing disparity in education and income. Technical knowledge and training are needed. Mexico has as many degreed engineers as the U.S. (80,000) plus free trade with 44 countries. We invest one-third less than China on infrastructure and 50% less on education. Tuition costs have risen 50% in the last ten years with no similar increase in incomes, resulting in growing student debt.

- Student aid is anemic. The Oregon Opportunity Initiative Grant is insufficient. Young people cannot afford cars, appliances, or houses and have little savings. Only two of any ten who qualify receive aid money, and that is only $2,000 per year.
- Employers struggle to fill jobs. Twenty-five Oregon companies are reported to have 100 high-wage jobs to fill.
- A small population with big geography does not mean you cannot succeed. Israel's technology, entrepreneurship, and big business investment are world-renowned.

> "There's no give-to-get, no communication skills, no holistic approach – no empathy and understanding. All that is missing in the culture."[134]

Access to Capital

Investment capital is needed at every stage of a company's growth:[135]

- Seed stage or pre-startup – friends, family, and "fools" money
- Early stage
    - o Startup: grants, loans, convertible debt notes
    - o First stage commercialization: angel investors
- Expansion: Venture Capital, Series A investors
- Venture Capital Series B, C, D
- Merger, Acquisition, Buyout or IPO

Capital is not easy to come by. New, young companies may have no collateral to obtain a loan; and if they do not have intellectual property or compelling product/service differentiation, they may not attract money beyond friends and family. Angel investors want startups that are strong enough to get follow-on funding so they can recoup their investment. Venture capitalists (VCs) usually look for a short-term return within three to five years. Long term investments, such as biotechnology and pharmaceuticals requiring ten years or more to achieve FDA approval and commercial viability, face even bigger financing challenges.

133 World Affairs Presentation, Multnomah Athletic Club, May 17, 2013
134 Confidential Interview
135 Investopedia

In the ten years leading up to 2012, over 400 U.S. venture funds went out of business or stopped making new investments. That left only 86 funds to lead a Series A round – a particular disadvantage for Oregon and the Greater Portland region, as they have no established traditional early stage VCs headquartered here.[136] Outside VCs will invest but tend to move companies to their own state.

"Seed-stage capital is sparse across sectors with the exception of software . . ."[137] That is particularly problematic for manufacturing, as a sample of prominent Oregon venture deals as recently as 2011 were all in software or clean technology.

While medium-size companies may have access to capital investment loans if they are generating cash from proven products, smaller companies looking to grow face challenges:

1. Little awareness of financing options
2. Neither the capital nor the expertise to employ formal business systems and processes needed to pursue financing options (financial reporting, human resources)
3. Trouble attracting private equity because of their small size, high risk, or long-term returns
4. *". . . little formal capital in the hardware-based technology space"*[138]

"*Small manufacturers are particularly limited by a lack of working capital ($150k+ lines of credit).*" Yet they need capital to finance inventory, equipment, facility expansions and capability improvements. "*There is a* [regional and state] *gap between . . . small successful growing businesses and the working capital they* [need]."[139]

Economic development agencies can play a key mediating role in helping smaller businesses understand the array of financing options available and how to connect with them: convertible notes, venture debt, non-bank capital loans, revolving loan funds, working capital loans, lines of credit – even microfinancing.

Regional Voices & Views

"There's little presence of early stage investment capital.
Anything bigger than $1 million comes from outside the state."

"The real money comes from out of state.
VCs put their own business people in who are not in Oregon and they move companies out."

"We need a whole lot more to invest in next-stage companies.
To capture jobs and investment benefits we need to keep them."

"Angels pick up the slack. The future model here is the Oregon Angel Fund,
Willamette Angel Conference, Bend Venture Conference – local and networked investors."

136 Oregon Capital Scan: A Developing Ecosystem. Neils Zellers. March 2012
137 Ibid
138 Ibid
139 Ibid

CONCLUSIONS & IMPLICATIONS

"Because its average weekly earnings are higher than national private sector earnings, manufacturing should be an important part of state job recovery strategies."[140]

Manufacturing is critical for the economic prosperity of the U.S. and metropolitan regions. State efforts are needed to create and support advanced manufacturing centers, providing research to develop new technologies and materials. Efforts are needed to educate businesses throughout supply chains about how to apply technologies and materials in their work.

Economic development agencies can work with the businesses they serve to connect them to resources.

Federal Support Opportunities

- National, State, and Regional Philanthropic Foundations
- National Science Foundation
- National Institutes of Health
- SBIR and STTR Grants
- Department of Defense DARPA and ARPA Grants
- DOT, DOE, and DOL Grants

State & Regional Support Opportunities

"There's no strategic business culture at the state level."[141]

- Venture capital
- Tax credits
- Government, civic, city, and non-profit matches for federal grants
- Venture development organizations

State-supported investments in innovation and new venture acceleration have had big economic impacts. A few examples include:[142]

- Ohio Third Frontier
- Pennsylvania Ben Franklin System
- Oklahoma i2E

140 Brookings-Rockefeller Project on State and Metropolitan Innovation, Accelerating Advanced Manufacturing with New Research Centers. Susan Helper and Howard Wial. February 2011

141 Confidential interview

142 Regional Innovation Acceleration Network, SSTI www.regionalinnovation.org

If you had a magic wand to accelerate advanced manufacturing, what would you wish for?[143]

"Electrical and mechanical engineers, Ph.D.s, and technicians."

"Emotionally intelligent workforce . . . good written communications, first-level leadership potential, initiative . . . teamwork."

"Premier university like MIT and Stanford generating world-class research."

"Single point of contact for exporting . . . who is prepared to discuss and connect business with resources?"

"More CNC machinists."

"Low-volume, high-mix companies need technicians on the floor."

If you could talk to the powers that be, what would you want them to hear?[144]

"Legislators don't realize we are all interconnected from Seattle to Portland and Portland to Vancouver. We're attached and co-dependent. We will be stronger if we act together."

"As the resource pie declines, it tears a hole in regionalism. We get $65M in grants because Portland and Vancouver go in together. Neither one could get them alone. We have to be regional."

"Budget cuts and government gridlock mean regions have to fix it themselves and not wait for state and federal help."

143 Unprompted responses from confidential interviews
144 Ibid

Regions must act on their own when they cannot rely on states; and states cannot rely on federal support. For instance, Manufacturing Extension Partnerships (OMEP and Impact WA) are under-funded, yet research findings need to be applied on the shop floor for small and medium companies to grow and thrive as part of a flourishing economic ecosystem, rooted in a robust supply chain and reaching out to compete around the world.

Making it easier for people to access resources can increase exports when all economic development entities are prepared to refer common points of entry. Currently, there's no map to navigate the system or to understand which agency does what in relation to exporting. Smaller companies have no bandwidth to map and navigate the many organizations involved. Who will pull an exporting roadmap together for them?

Individual attention and investment is also needed to address the following broader issues affecting small and medium regional manufacturing businesses and their supply chains:

- State-supported entrepreneurial investment
- Missing supply chain players: chemicals, circuit boards, and a metals forge
- Software to drive machinery and mediate electronics and hardware
- A skilled workforce – the critical factor in a healthy economy. Nearly three million manufacturing workers will retire between now and 2018. Forty percent of manufacturing jobs will require a post-secondary education[145]

Introduction to Portfolio of Manufacturing Industries

The purpose of this research was to define supply chain assets, gaps, and export opportunities for high-potential regional industries in advanced manufacturing and advanced materials with significant regional potential.

- **Computers & Electronics** – 7% of U.S. manufacturing revenue[146]
- **Aerospace & Defense** – U.S. revenues increased 5.5% in 2012 driven by record-setting commercial aircraft production that offset negative growth in the defense subsector[147]
- **Metals & Machinery** – Provide functional solutions as a source of growth and innovation[148] using system-level engineering to capture value. The industry is intrinsic to this region's economy but will have to adapt to the rapid progress of additive manufacturing

Supply chains for the selected industries are interwoven, providing a strong base to support a flourishing economic ecosystem of small and medium manufacturers providing products for major anchor firms.

This introductory report is part of a research portfolio addressing each of those regional high-potential industries. Each report includes a GIS map of that industry's supplier network.

The Computers & Electronics industry is presented first, as it is intrinsic to all industries and employs the greatest number of people in the region.

145 Industry Week: US Manufacturing: The Misunderstood Economic Powerhouse. Jan 15, 2013

146 Deloitte.com, September 2013

147 Ibid

148 Deloitte University Press, March 2013 (dupress.com)

RESEARCH METHODOLOGY

Qualitative research enables meaning, context, and causal explanations. Unlike most methods that emphasize a detached research stance to avoid bias, qualitative inquiry allows for connections and relationships among research resources. Insights for this research were derived from coded interview data, information from practitioner and scholarly journals, industry publications, books and white papers, as well as economic data from business and government sources.

Qualitative research is an appropriate method for this study because listening to the perceptions and goals of practitioners is crucial to understanding their challenges when trying to make sense about business development and resource allocations for growing firms. Triangulation of extensive secondary data, semi-structured interviews with probing, and industrial knowledge allowed for flexibility in soliciting ideas, observations, motivations and concerns about the region's advanced manufacturing sectors. Data was collected and interpreted with the aim of generating information about the five-county Portland region. Notes were transcribed and analyzed by the researcher to uncover insights about innovation in advanced materials, product development, the workforce, and serving diverse new industrial markets, including exporting.

Interviewees participating in this research included:

- Seasoned for-profit executives from all included industries and their supply chains
- Research institution scientists, engineers and physicists
- University scholars, researchers and administrators
- Economic development professionals

They are:

- Employed as senior managers in manufacturing, marketing and logistics, corporate officers, board members or technologists;
- Engaged in computers, electronics, aerospace, defense, semiconductors, nanotechnology, metals, and machinery manufacturing; plastics; polymers and composites; nanotechnology; marine, rail, or aviation transportation; exporting, port management, and economic development;
- Dependent on R&D and/or manufacturing of products involving specialists such as scientists, engineers and physicists; or,
- Business practitioners involved in strategy, R&D, and supply chain management

Participants were identified by individuals and organizations supporting the Jobs and Innovation Accelerator Challenge Grant "Innovations in Advanced Materials and Metals Manufacturing Project," the Greater Portland Export Initiative, and contacts within the researcher's professional network. Their organizations included small ($30-$490 million revenue), medium ($500 million to $1 billion), and large (>$1 billion) firms in for-profit industries with extensive supply chains. Their years of operation ranged from 10 to 121 years.

Data Collection

Participants were recruited by contacting individuals who satisfied the selection criteria. Confidential in-depth interviews were conducted over six months between March 2013 and January 2014. Each interview was based on questions aimed at exploring issues highlighted in the objectives for the research: industry trends, supply chain, market diversification, labor force, and exporting. Questions were prepared in advance but adjusted based on interviewee responses. The researcher's knowledge of manufacturing and materials development practices was used to gain a well-rounded perspective of the issues and to situate interviewees from different industries within a common environmental framework.

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APPENDICES

Appendix A: Northwest Oregon, Southwest Washington Technology Schools, Organizations & Associations

Oregon State University offers an innovative, hands-on undergraduate degree in electronics and computer engineering: Electrical & Computer Engineering. Its core curriculum includes:

- Electrical Fundamentals
- Digital Logic
- Electronics
- Systems & Signals
- Computer Networks
- Transmission Lines
- Computer Organization
- Supporting Disciplines: math, physical sciences, computer science

Washington State University School of Electrical Engineering and Computer Science has a research mission to develop technologies. Computer Science and Electrical Engineering degrees are available at the Vancouver, Washington campus. Faculty members engage in research for the C&E industry.

- Computer and Systems Engineering
- Bioinformatics and Computational Biology
- Control and Signal Processing
- Distributed and Networked Computing Systems
- Electrophysics
- Microelectronics
- Software engineering
- Smart Environments

The University of Oregon has research centers relevant for computers and electronics sciences: Oregon Center for Optics (OCO) in physics and physical chemistry, and the Materials Science Institute (MSI) for the study of the structure and properties of materials.

Portland State University has the Research Center for Electron Microscopy and Nanofabrication (CEMN).

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

Oregon Institute of Technology offers bachelor and master degree programs in Manufacturing Engineering Technology and Technology and Management.

Oregon Nanotechnology and Microtechnology Institute, an Oregon Signature Research Center focused on materials science and related device and system technologies including:

- Nanoelectronics, nanometrology and nanobiotechnology
- Microtechnology-based energy and chemical systems
- Safer nanomaterials and nanotechnology
- Sustainable materials chemistry

ONAMI works with companies to provide access to rapid prototyping, materials characterization, and fabrication equipment as well as university laboratories and highly skilled workers. It also provides companies with access to matching grant programs. Located in Corvallis, Oregon, its members include:

- Technology leaders such as Intel and IBM and small and medium companies
- Universities
- Established technology executives and professionals
- Entrepreneurs, startup business owners and independent contractors
- Service companies supporting the technology community

Oregon Metals Initiative (*www.oregonmetal.org*): Consortium of metals industry companies and research institutions supporting the long-term competitiveness of the metals industry and research infrastructure in Oregon. OMI partners invest $1 million in 20 research projects annually for new materials discoveries, technology advancements and patents.

Pacific Northwest Defense Coalition, Portland, Oregon (*www.nwaero-defense.com*, *www.pndc.us*): Association of companies in the defense and security industries. PNDC provides its members with connections to lucrative partnerships with government agencies, educational programs, business-to-business networking, and advocacy with government agencies and decision makers. Their "Connectory" is an on-line database that makes it possible for companies and potential partners to find Northwest suppliers with the technical capabilities they need.

Pacific Northwest National Lab (*www.pnl.gov*): Located in Richmond, WA, and Portland, OR. PNNL is a Department of Energy Office of Science National Laboratory operated by Battelle, the world's largest independent scientific research and technology development organization. PNNL provides unique laboratories and specialized equipment as well as the Environmental Sciences Laboratory. Work related to computers and electronics includes:

- Computational Sciences
- Instrument Development
- National Security
- Visual Analytics

Drive Oregon (*www.driveoregon.org*): Connects leaders in electric mobility to advance the industry. Members include entrepreneurs and innovators throughout the entire supply chain. It provides resources, industry information and development opportunities for building and strengthening member businesses.

Technology Association of Oregon (*www.techoregon.org*): The largest professional technology association in Oregon and Southwest Washington. TAO promotes, connects and advocates for companies involved or affiliated with software and technology industries. Forums include Software Development, Quality Assurance, IT Leadership, Enterprise Architecture, Marketing, Finance, HR, Legal, IP, and Health & Life Sciences IT. The TAO Foundation works toward an inclusive ecosystem that prepares all Oregonians to excel in the innovation economy.

Oregon Best (*www.oregonbest.org*): The nexus for clean technology innovation, convening collaborators and building capabilities to accelerate solutions to environmental challenges throughout Oregon. Oregon Best helps students, entrepreneurs, companies and universities with shared-user lab facilities, a research consortium, commercialization program and proposal matching program, strategically investing in projects and facilities that attract research revenue to create economic impact.

Oregon Translational Research & Development Institute (*www.otradi.org*): A bioscience incubator to discover, develop and commercialize pharmaceutical drugs, diagnostics, medical devices and products. It partners with universities and economic development agencies to provide access to scientific equipment and expertise to eliminate barriers between innovation and market capitalization.

Engineering & Technology Industry Council (*http://www.ous.edu/etic*): Supports post-secondary engineering and technology education and established criteria measurements for investments from the Oregon Engineering Education Investment Fund. A public-private partnership, ETIC members include business professionals from a variety of industries as well as leaders from Oregon public universities. Technology sectors receiving support include agriculture, healthcare, forestry, electronics, and utilities.

Axiom Electronic Systems Incubator is sponsored by Axiom Electronics in collaboration with the Oregon Technology Business Center. The Incubator's goal is to support hardware startups with technical assistance and funding. It will sponsor two companies and provide design assistance, materials, a line of credit, and short-term free rent and legal assistance. The Incubator will also sponsor workshops, networking events and pitch contests.

Appendix B: Local Economic Development Organizations

Business Oregon (*www.oregon4biz.org*): 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 economic development resource for Southwest Washington. It connects businesses and investors to economic resources to advance the economic vitality of Clark County 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 Project awarded by the federal government to a regional coalition led by the Portland Development Commission.

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. PDC 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 working with businesses and communities to create a sustainable region. Metro's state-of-the-art regional economic mapping technology was used to create the Geographic Information System (GIS) maps of regional businesses in these reports.

Appendix C: Regional & National Exporting Related Resources

Organizations

Impact Washington ExporTech Training Program:
www.impactwa.org

Washington State Export Resource Program:
www.waexports.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:
http://export.gov/oregon/

U.S. Commercial Service, Oregon, International Trade Administration:
www.trade.gob/cs/states/or.asp

Websites

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

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

Global Industrial Products and Company Database
www.solusource.com

Global eMarketplace
www.alibaba.com

Business Oregon Export Assistance
www.oregon4biz.org

Trade Counseling, Mentoring

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

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

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

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

Websites, continued

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" Trade Info
www.fita.org or *www.internationaltrade.org*

International Trade Assoc.
www.ita.doc.gov

Links to 100 Trade Websites
www.quazell.com/top100.html

MSU Global Business Portal
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://export.customsinfo.com/Defaultaspx

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

Trade Finance

Export-Import Bank Website
www.exim.gov/tradefinanceguide/

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

Websites, continued

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
http://www.ustr.gov/trade-topics/intellectual-property

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

Export Council of Oregon
www.exportcounciloforegon.org

Export Financial Assistance Sources

- Office of International Trade Export Assistance Program (*www.sba.gov*)
- Export-Import Bank Export Financial Assistance (*www.exim.gov*)
- SBA Export Working Capital Program (*www.sba.gov*)
- Oregon Capital Access Program (*www.oregon4biz.com*)
- Oregon STEP Program (*www.oregon4biz.com*)
- Oregon Entrepreneurial Development Loan Fund (*www.oregon4biz.com*)
- Oregon Trade Promotion Program (*www.oregon4biz.com*)
- Portland Development Commission Trade Programs (*www.pdc.us*)
- *www.Export.gov/OR*
- *www.Export.gov/WA*
- Export Finance Assistance Center of WA (*www.efacw.org*)
- Washington Export Resource Center (*www.waexports.com*)

Appendix D: Access to Capital

The Oregon Investment Fund (*www.oregoninvestmentfund.com*)[149] is a portfolio of funds to invest in mature, established businesses and early/seed stage fast-growth companies. Members include:

- **Burrill & Company** – Life sciences
- **Chrysalix** – Energy
- **DFJ Frontier** – Diversified West Coast companies
- **Evergreen Pacific Partners** – Midmarket buyouts and growth equity in manufacturing, packaging, media and consumer products
- **Montlake Capital** – Business-to-business, consumer products, retail and financial services
- **Nth Power** – Energy technology
- **Riverlake Partners** – Lower middle-market traditional manufacturing, distribution and service companies
- **Sherbrooke Capital** – Health and wellness
- **Voyager Capital** – Enterprise software and services, Internet infrastructure and wireless companies
- **Walden Venture Capital** – Digital media and technology-enabled services and e-commerce companies
- **Wedbush Capital Partners** – Invests in profitable, growing companies with revenues ranging from $10 million to $50 million

Portland Seed Fund
Privately managed with a non-resident accelerator, it provides capital, mentoring and connections through a 90-day mentor led program. In two years, 36 companies have collectively raised $23 million in outside capital and created more than 200 jobs. Startups include enterprise software, mobile technology, consumer Internet, and consumer products companies.

149 www.oregoninvestmentfund.com/venture_capitalists

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