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The University Research Corridor's Support for Advanced Manufacturing in Michigan

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Foreword

Manufacturing is embedded in our state's history, and in our national consciousness, as the engine of economic growth for much of the 20th century. Michigan was the "arsenal of democracy" in World War II, where Henry Ford's revolutionary wages brought immigrants from numerous countries, and where companies like General Motors, Chrysler, and Ford grew into global enterprises.

Michigan is also the place that, far too often, is saddled with a reputation for being very good at something that is no longer relevant, modern, or particularly useful in the 21st century. In particular, we suffer from the misguided notion that manufacturing is not a "high tech" or high-value-added enterprise. This report provides, in great detail, hard evidence that manufacturing is alive and vital in Michigan today, and that much of the manufacturing done in Michigan today is high-tech, high-productivity advanced manufacturing.

Indeed, there are numerous places in the world where low-tech manufacturing can take place, often where labor and other costs are much lower than in the United States. Manufacturers in Michigan, therefore, must produce high-quality products using high-productivity techniques, and advanced technologies. As we note in this report, advanced manufacturing in Michigan is:

- An *important* industry that employs over 10% of the state's workforce;
- A *productive* industry where over half of the employment is in firms whose productivity is growing faster than the average U.S. manufacturing firm;
- A *highly-skilled* industry where over one-third of the research and testing jobs in the Midwest are located.

The University Research Corridor in Michigan plays a vital role in supporting this cornerstone of the Michigan economy. As documented in this report, Michigan State University, the University of Michigan, and Wayne State University expend large amounts each year on R&D focused on advanced manufacturing. Furthermore, they train many of the engineers, logistics specialists, scientists, and others that become the key employees of manufacturers and their many suppliers and consultants. While the core mission of these universities remains the education of tomorrow's leaders, it is important to observe how much of these universities' efforts today translate directly into benefits for this important sector of our economy.

Any state in the country, and indeed any country in this world, would be proud to have the high-tech, high-productivity manufacturing sector that we enjoy in Michigan. As this report documents, the efforts of our research universities will help us preserve that advantage in the future.

Patrick L. Anderson

Patrick L. Anderson is the founder of Anderson Economic Group, LLC, an economic consulting firm headquartered in East Lansing, Michigan.that serves clients across the country. He is the author of more than 100 published works, and the executive editor of

The State Economic Handbook, *published annually by Palgrave MacMillan. He was the winner of the 2004 Edmund A. Mennis prize for the best writing in business economics by the National Association for Business Economics, and was recognized again in 2008 by the same organization for outstanding writing in business economics.*

I. Executive Summary

PURPOSE OF MICHIGAN'S UNIVERSITY RESEARCH CORRIDOR

The University Research Corridor (URC) is an alliance of Michigan's three largest academic institutions: Michigan State University, the University of Michigan, and Wayne State University. The purpose of this alliance is to accelerate economic development in Michigan by educating students, attracting talented workers, supporting innovation, and facilitating the transfer of technology to the private sector.

URC SPECIAL TOPIC REPORTS

This report is part of a series of special topic reports begun in 2007 and released by the URC in early summer of each year. The purpose of each report is to highlight the URC's contributions to a specific industry important to Michigan's economy. This year's report focuses on how the URC is shaping Michigan's advanced manufacturing industry through research, development, and partnerships with private business.

The United States is the largest manufacturer in the world. While manufacturing's share of total employment has declined steadily since the mid-1950's, the number of manufacturing jobs has remained steady at around 20 million nationwide. However, the type of manufacturing in the U.S. has changed over the years. Today, manufacturers are more *productive*, adding more value and generating more output per worker. This increase in productivity is the direct result of improved technology and manufacturing processes. The University Research Corridor universities are playing a vital role in developing the technology and processes that are transforming manufacturing, as this report shows.

OVERVIEW OF REPORT AND METHODOLOGY

We begin this report by developing a rigorous, comprehensive definition of advanced manufacturing. We were careful to include only the manufacturing sectors that met at least one of the following criteria.

- Sectors whose productivity is greater than the average U.S. manufacturing firm. We measure productivity as value added per production worker and value added per wages paid to production workers.[1]
- Sectors whose productivity growth was significantly faster than the average U.S. manufacturing firm.
- Sectors that manufacture high-tech products.
- Sectors that cultivate and/or invent the processes and solutions for future manufacturing.

We then divided the industry into three clusters:

- *Advanced Products & Processes (APP) Cluster*
  This cluster includes manufacturing sectors (i.e. NAICS industries) that manufacture high-tech products or use advanced processes when manufacturing their products. We identified these sectors by comparing the productivity of manufacturing

1. The Michigan Manufacturing Technology Center helped us identify which productivity measures to use in this report.

sectors. We included those sectors with higher productivity than the U.S. manufacturing sector as a whole in 2008 (the most recent year for which data is available). This is the biggest cluster because it includes any industry that met more than one of our criteria described above.

- *Emerging Manufacturing Cluster*
  This cluster includes only sectors whose productivity is increasing at a faster rate than the U.S. manufacturing industry as a whole. Firms included in this cluster are increasing their productivity through adopting new practices, implementing improved processes or operating more effectively.
- *Research Relevant Cluster*
  This cluster includes sectors that research and develop the processes and products for advanced manufacturers. We included several sectors that lack the word "manufacturing" in their sector titles, yet still play a vital role in advanced manufacturing.

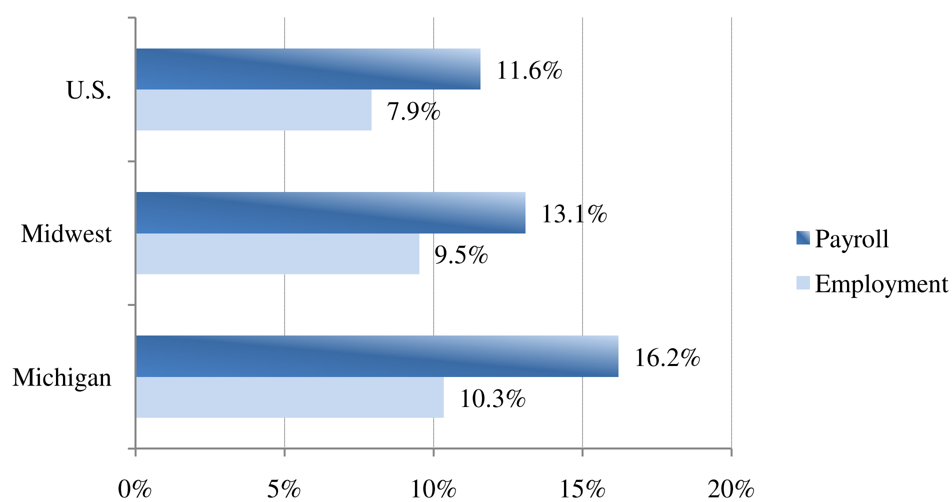
See Table 1, "Definition of the Advanced Manufacturing Industry by Cluster and Employment," on page 9 and "Methodology" on page A-1.

KEY FINDINGS

1. The Advanced Manufacturing Industry is Important in Michigan

The advanced manufacturing industry is an important part of Michigan's economy. As of 2007 (the most recent year for which data is available), the state's advanced manufacturing industry employed 381,351 workers, accounting for 10.3% of all employment in Michigan. Due to the industry's higher average wages, advanced manufacturing's share of total payroll in the state is even greater than its employment share. In 2007, advanced manufacturing's payroll in Michigan was over $24 billion, making up 16.2% of the state's total payroll. As shown in Figure 1 below, advanced manufacturing employment and payroll represent a larger share of Michigan's economy than in the Midwest and nationwide See "Advanced Manufacturing's Place in Michigan" on page 10.

FIGURE 1. Advanced Manufacturing's Share of Total Employment

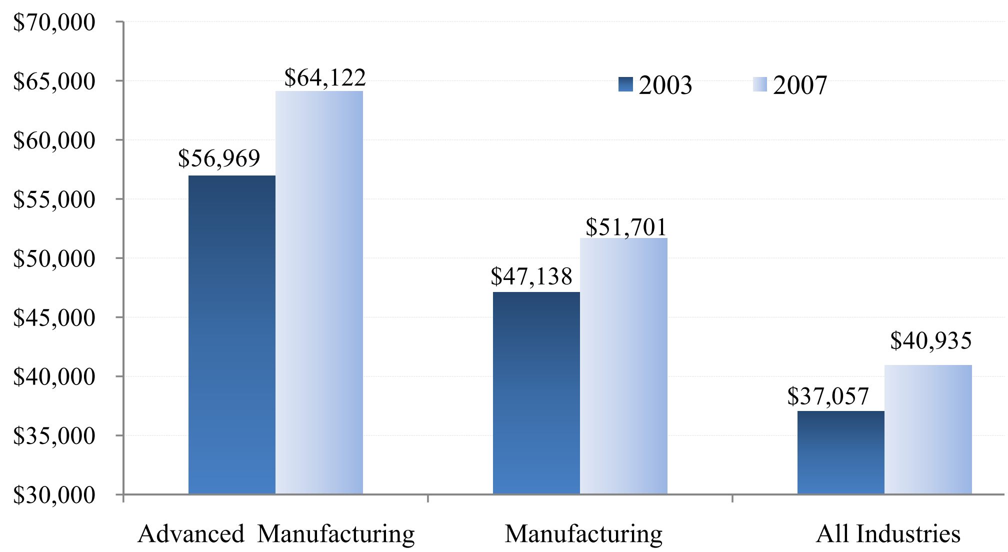


Base Data Source: U.S. Census Bureau, County Business Patterns, 2003 and 2007
Analysis: Anderson Economic Group, LLC
Note: Midwest includes Illinois, Indiana, Ohio, Wisconsin, and Michigan.

2. Advanced Manufacturing Wages Continue to Grow in Michigan

Michigan's average wage in the advanced manufacturing industry grew substantially between 2003 and 2007 while the overall Michigan economy was performing poorly. Average wages in advanced manufacturing grew 12.6% during the time period for an average annual increase of 3% per year, or slightly faster than inflation. In contrast, average wages for all industries increased from $37,057 to $40,935—a 10.5% increase, but less than inflation, meaning that real incomes for Michigan workers in most industries declined between 2003 and 2007. See "Employment and Payroll in Advanced Manufacturing" on page 11.

FIGURE 2. Average Annual Wage in Advanced Manufacturing, All Manufacturing, and All Industries

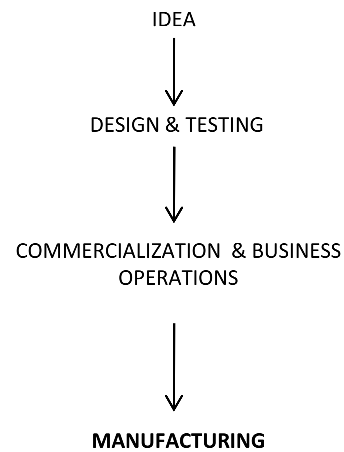


Base Data Source: U.S. Census Bureau, County Business Patterns 2003 and 2007
Analysis: Anderson Economic Group, LLC

3. Michigan's URC Universities are Supporting Advanced Manufacturing at Every Step of the Manufacturing Process

The research performed at the URC universities is improving advanced manufacturing in Michigan. The process of turning an idea into a final product is the "product development lifecycle." The stages of the product development lifecycle include basic research, design and testing, commercialization of the product, and business operations. The URC is assisting advanced manufacturers at every stage of the product development lifecycle. We illustrate this process in Figure 3 below and provide a few examples of the URC's work. See "URC Support for Michigan's Advanced Manufacturing" on page 25 for more examples.

FIGURE 3. Product Development Lifecycle



Source: Anderson Economic Group, LLC

- *Research that leads to new ideas*
  U-M’s S.M. Wu Manufacturing Research Center conducts basic and applied research in manufacturing science and engineering. Its broad scope of research consists of six different research laboratories for assembly and materials joining, dimensional measurement, drill research, in-process quality improvement, machine tools and machining, and sheet metal stamping and material forming. The WuMRC has ties with over 60 industrial partners including General Motors, Ford, Chrysler, and Boeing. A second example is WSU's Smart Sensors and Integrated Microsystems (SSIM) program located in the College of Engineering. SSIM occupies more than 35,000 square feet of centrally located laboratory facilities. This includes a jointly developed micro electro mechanical systems (MEMS) and microelectronics clean room facility that was jointly developed with Delphi Corp. Technological applications include micromachining, chemical and biological sensors, robotics and a wide range of biomedical applications from basic research to the design, development and manufacturing of high tech devices.
- *Design and Testing*
  The breakthrough design software Hierarchical Evolutionary Engineering Design Software (HEEDS) was developed by professors at MSU and spun-out to form Red Cedar Technology in 1999. The software product is recognized as the world's fastest and most comprehensive design optimization software. HEEDS interfaces with all popular computer-aided engineering software applications to automate and expedite the design process. HEEDS is utilized across many industries including aerospace, automotive, biomedical and manufacturing.
- *Commercialization/Partnerships*
  All three URC universities have partnerships with auto manufacturers in the state. One example of this type of partnership is the General Motors Collaborative Research Lab in Advanced Vehicle Manufacturing. The GM Collaborative Research Lab helps facilitate the exchange of technical personnel and knowl-

edge between GM Research and Development and U-M. A second example is WSU's TechTown, Detroit's research and technology park, that was established in 2000 to stimulate job growth and small business creation by developing companies in emerging high-technology industries including advanced engineering, life sciences, and alternative energy. The 12-block park includes TechOne, the 100,000-square-foot business incubator facility which now hosts 210 growing companies.

- *Business Operations*
  MSU's Supply Chain Management/Logistics Program is widely acknowledged by industry and academia as the leader in dissemination of procurement, manufacturing and logistics knowledge. The program integrates topics from manufacturing operations, purchasing, transportation and physical distribution into a unified course of study.

4. Michigan Companies Are Leaders in Advanced Manufacturing R&D and URC Universities Support This Leadership

The URC universities spend millions on advanced manufacturing research. This support has helped develop a concentration of advanced manufacturing research jobs in Michigan. Fully one-third of these jobs in the Midwest are in Michigan. In FY 2009, the total value of *active* research awards on advanced manufacturing topics at URC universities was almost $425 million. The URC universities actually *spent* $101.9 million on advanced manufacturing R&D in FY 2009. This figure represents 6% of total R&D expenditures by these universities. See "URC R&D Expenditures on Advanced Manufacturing" on page 25 and "Research Relevant Cluster" on page 21.

5. URC Research Has Led to New Advanced Manufacturing Companies

Between 2004 and 2008, the URC has helped cultivate an average of 20 start-up companies annually.[2] Below we provide a few examples of advanced manufacturing companies the URC has helped to start. See "URC R&D Has Led to New Companies in Advanced Manufacturing" on page 37.

Draths Corp. Draths Corp. was founded in 2005 to commercialize a suite of biobased materials technology developed in the laboratory of John Frost and Karen Draths at MSU and licensed by the university. The company's products enable nylons, plastics, paints, resins and other materials currently made using petroleum-based chemicals to be manufactured from renewable feedstocks. This breakthrough is accomplished through environmentally friendly and economical processes.

Sakti3. Sakti3 was founded in 2007 by Ann Marie Sastry, who is the director of the energy systems engineering program at U-M. Sakti3 is developing solid-state lithium ion battery systems for the hybrid and electric vehicle markets as well as the advanced manufacturing processes of batteries. Sakti3 has raised $7 million in ven-

2. See Caroline M. Sallee and Patrick L. Anderson, *Empowering Michigan: Third Annual Economic Impact Report of Michigan's University Research Corridor*, September 28, 2009.

ture capital investment, $3 million in grant money from Michigan's Centers of Energy Excellence program, and received a Michigan Economic Growth Authority tax credit valued at up to $2.3 million. In addition, Sastry has launched a battery system graduate program to support the continued workforce needs of the sector.

SenSound, LLC. SenSound is a privately held company based in Detroit, Michigan founded on patented technology initially developed in the College of Engineering at Wayne State University. SenSound diagnostic software creates three-dimensional digital images of sound as it travels through space and time. The software is unique in its ability to quickly, accurately and at low cost effectively map sound sources on arbitrary three-dimensional surfaces. SenSound quality control software distinguishes between environmental noise and source object noise without the need for sound enclosures. SenSound technology has broad applications in product design, development and manufacturing where noise needs to be identified, understood and eliminated, or where manufacturing and component defects need to be identified.

6. URC is Educating the Next Leaders in Advanced Manufacturing

The URC universities are collectively educating over 14,000 students in engineering. Of the seven peer university clusters with which the URC regularly compares itself, the URC ranks third in number of graduates with an engineering, math, and/or computer science degree. All three universities have a number of degree programs that prepare students for a wide variety of careers in advanced manufacturing. Some of these programs include U-M's Manufacturing Engineering Program, WSU's Industrial and Manufacturing Engineering Program and MSU's Supply Management and Logistics Program. These universities also have educational partnerships with businesses, such as the Electric Drive Vehicle Engineering Program that is a partnership between WSU, NextEnergy, and Macomb Community College. See "URC is Educating the Next Leaders in Advanced Manufacturing" on page 39.

URC professors are currently informing national manufacturing policy. U-M Mechanical Engineering professor Sridhar Kota is the assistant director of advanced manufacturing and ASME Fellow at the White House Office of Science and Technology Policy (OSTP) in Washington, DC. OSTP advises the President on the effects of science and technology on domestic and international affairs. As assistant director, Dr. Kota's responsibilities focus primarily on identifying promising technologies and effective strategies to strengthen the nation's manufacturing base.

URC ANNUAL ECONOMIC IMPACT REPORTS

Each fall, the URC releases an annual report that quantifies the economic impact of the URC's activities on the state of Michigan's economy. This report provides Michigan residents with an assessment of how the URC universities are spending their time and money and allows citizens to track the performance of the URC. Main findings from the 2009 *Annual Economic Impact Report* include:

- Michigan's residents were $14.5 billion richer due to the URC's operations in FY 2008.
- The URC universities spent $1.4 billion on research and development in 2007, which is 94% of all R&D expenditures by universities in Michigan.
- The URC brought $862 million in federal research dollars to Michigan in 2007. This is money that paid salaries and bought supplies and equipment, fueling other economic activity in the state.
- 572,123 URC alumni living in Michigan earned $26.6 billion in salary and wages in 2007, or 14.2% of all wage and salary income in Michigan.
- The URC helped cultivate an average of 20 start-up companies annually between 2004 and 2008.

ABOUT ANDERSON ECONOMIC GROUP

Anderson Economic Group is a research and consulting firm with expertise in public policy, economics, market research, and business valuation. AEG's past clients include the Michigan Manufacturers Association, Automation Alley, General Motor Company, Ford Motor Company, and Visteon. AEG has offices in East Lansing, Michigan and Chicago, Illinois. See "Appendix C: About the Authors" on page C-1.

II. Michigan's Advanced Manufacturing Industry

In order to successfully conduct an industry analysis, we must first properly define the industry. In this section, we define advanced manufacturing and then report the employment, payroll, and average wage for this industry in 2003 and 2007.[3] We then compare Michigan's advanced manufacturing industry with advanced manufacturing in the Midwest and nationwide.

ADVANCED MANUFACTURING DEFINITION

We developed a definition of advanced manufacturing using North American Industry Classification System (NAICS) codes—the classification system that the United States Census uses to report industry data. This definition provides a solid foundation for our analysis and makes possible year-to-year data comparisons that illustrate the evolution of an industry.

We defined the advanced manufacturing industry to include firms that create high-tech products, use innovative techniques in their manufacturing, and are inventing new processes and technologies for future manufacturing. Our definition is comprehensive and includes any sector that meets at least one of the following criteria:

- Sectors whose productivity is greater than the average U.S. manufacturing firm. We measure productivity as value added per production worker and value added per wages paid to production workers.[4]
- Sectors whose productivity growth was significantly faster than the average U.S. manufacturing firm.
- Sectors that manufacture high-tech products.
- Sectors that cultivate and/or invent the processes and solutions for future manufacturing.

After identifying the manufacturing sectors that meet at least one of the four criteria, we divided the industry into three clusters, which we discuss in detail in "Advanced Manufacturing Industry Clusters" on page 17.

Our unique definition takes into account more than traditional manufacturing industries by including research-focused businesses. For this reason it is more extensive than our definition of advanced manufacturing in our annual technology study for Automation Alley.[5] For a description of the methodology we used to define the

3. We selected 2003 and 2007 so that a comparison could be made on the same basis. 2007 is the most recent for which data is available.
4. We analyzed the productivity for the advanced manufacturing industry using two different measures: value added per worker and value added per production workers' wages. We used data from the Census Bureau Annual Survey of Manufacturers (ASM). The ASM defines value added as the value of shipments (products manufactured plus receipts for services rendered) less cost of materials, supplies, containers, fuel, purchased electricity, and contract work.
5. AEG's previous work in advanced manufacturing includes its annual *Automation Alley's Technology Industry* report. All NAICS industries included in our Automation Alley definition of advanced manufacturing are included in this definition.

advanced manufacturing industry, see "Methodology" on page A-1. See Table 1 below for a detailed list of the NAICS sectors we have included in our advanced manufacturing definition.

TABLE 1. Definition of the Advanced Manufacturing Industry by Cluster and Employment

NAICS Code	Description	2007 Employment
Advanced Products and Processes (APP) Cluster		
3361	Motor Vehicle Mfg.	39,870
3339	Other General Purpose Machinery Mfg.	18,426
3372	Office Furniture (including fixtures)	15,374
3329	Other Fabricated Metal Product Mfg.	12,840
3345	Navigational, Measuring, Medical & Control Instruments Mfg.	11,257
3391	Medical Equipment & Supplies Mfg.	8,434
3254	Pharmaceutical & Medicine Mfg.	6,973
3336	Engine, Turbine & Power Transmission Mfg.	6,385
3118	Bakeries & Tortilla Mfg.	6,205
3332	Industrial Machinery Mfg.	6,182
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg.	4,710
3221	Pulp, Paper & Paperboard Mills	4,516
3311	Iron & Steel Mills & Ferroalloy Mfg.	4,194
3121	Beverage Mfg.	4,171
3115	Dairy Product Mfg.	4,096
3251	Basic Chemical Mfg.	3,951
3255	Paint, Coating & Adhesive Mfg.	3,662
3259	Other Chemical Product & Prep Mfg.	3,521
3364	Aerospace Product & Parts Mfg.	3,510
3359	Other Electrical Equipment & Component Mfg.	3,323
3119	Other Food Mfg.	3,025
3331	Agriculture, Construction & Mining Machinery Mfg.	2,650
3369	Other Transportation Equipment Mfg.	2,438
3353	Electrical Equipment Mfg.	2,385
3333	Commercial & Service Industry Machinery Mfg.	2,050
3314	Nonferrous Metal (except aluminum) Production	1,933
3112	Grain & Oilseed Milling	1,886
3241	Petroleum & Coal Products Mfg.	1,642
3352	Household Appliance Mfg.	1,509
3113	Sugar & Confectionery Product Mfg.	1,369

Source: Anderson Economic Group, LLC

TABLE 1. Definition of the Advanced Manufacturing Industry by Cluster and Employment

NAICS Code	Description	2007 Employment
Emerging Manufacturing		
3328	Coating, Engraving, Heat Treating, & Allied Activities	13,602
3315	Foundries	12,027
3323	Architectural & Structural Metals Mfg.	8,977
3371	Household & Institutional Furniture & Kitchen Cabinet Mfg.	6,421
3272	Glass & Glass Product Mfg.	6,254
3321	Forging & Stamping	6,110
3256	Soap, Cleaning Compound, & Toilet Preparation Mfg.	3,160
3313	Alumina & Aluminum Production & Processing	2,707
3326	Spring & Wire Product Mfg.	2,551
3325	Hardware Mfg.	2,445
Research Relevant		
541330	Engineering Services	50,494
541710	R&D in Physical, Engineering & Life Sciences	33,129
5415	Computer Systems Design & Related Services	29,749
54138	Testing Laboratories	4,864
541614	Process, Physical Distribution & Logistics Consulting Services	3,949
541690	Scientific & Technical Consulting Services	1,373
541420	Industrial Design Services	1,052

Source: Anderson Economic Group, LLC

ADVANCED MANUFACTURING'S PLACE IN MICHIGAN

Manufacturing has been a significant part of Michigan's economy for the past one hundred years. Today's manufacturers are productive, high-value businesses that generate more output with fewer workers. This has meant a lost of jobs in manufacturing, but the jobs that have remained in Michigan are pay high salaries and require more skills. In this section we present data on Michigan's manufacturing employment, payroll, and wages for the most recent year data is available (2007) and four years earlier (2003).[6]

In 2007, employment in all Michigan manufacturing (advanced and non-advanced) made up 15.7% of total industry employment in Michigan. Put another way, one in seven Michigan jobs was in manufacturing. A significant share of manufacturing in Michigan is advanced manufacturing. Using our definition of advanced manufacturing, 65.8% of Michigan's manufacturing employment is in advanced manufac-

6. This allows for a comparison of the industry on the same basis as a definition change was made in 2002 to the County Business Patterns.

turing sectors, as shown in Table 2 below. There are over 11,000 advanced manufacturing firms in Michigan.

Advanced manufacturing jobs in Michigan pay well. As shown in Table 2 below, payroll for advanced manufacturing jobs made up 81.6% of total manufacturing payroll while employment was 65.8% in 2007.

Between 2003 and 2007, advanced manufacturing's share of all manufacturing employment grew 3.1 percentage points while payroll increased almost 6 percentage points. This occurred while manufacturing employment as a whole fell in Michigan and became a smaller share of total employment in the state. Fewer advanced manufacturing jobs were lost during this time period than other manufacturing jobs.

TABLE 2. The Share of Michigan Industry Captured by Advanced Manufacturing & Manufacturing Overall

Employment	**Manufacturing's Share of All Industries**	**Advanced Manufacturing's Share of All Manufacturing**	**Advanced Manufacturing's Share of All Industries**
2003	17.5%	62.7%	11.0%
2007	15.7%	65.8%	10.3%
Change 2003-2007	*(1.8%)*	*3.1%*	*(0.7%)*
Total Payroll ($1,000)	**Manufacturing's Share of All Industries**	**Advanced Manufacturing's Share of Manufacturing**	**Advanced Manufacturing's Share of All Industries**
2003	22.3%	75.8%	16.9%
2007	19.9%	81.6%	16.2%
Change 2003-2007	*(2.4%)*	*5.8%*	*(0.7%)*

Base Data: U.S. Census Bureau, County Business Patterns 2003, 2007
Analysis: Anderson Economic Group, LLC

EMPLOYMENT AND PAYROLL IN ADVANCED MANUFACTURING

Michigan has been in a recession since 2001. In every year since 2001, Michigan has lost private sector jobs. In this economic climate, it is not surprising that advanced manufacturing employment declined between 2003 and 2007. Nevertheless, advanced manufacturing payroll grew, and the sector still employed over 380,000 Michiganders in 2007. Advanced manufacturing jobs in Michigan in 2007 paid better on average than they did in 2003. Advanced manufacturing payroll totaled more than $24.4 billion in 2007, which accounts for 16% of Michigan's total industry payroll. See Table 3 below.

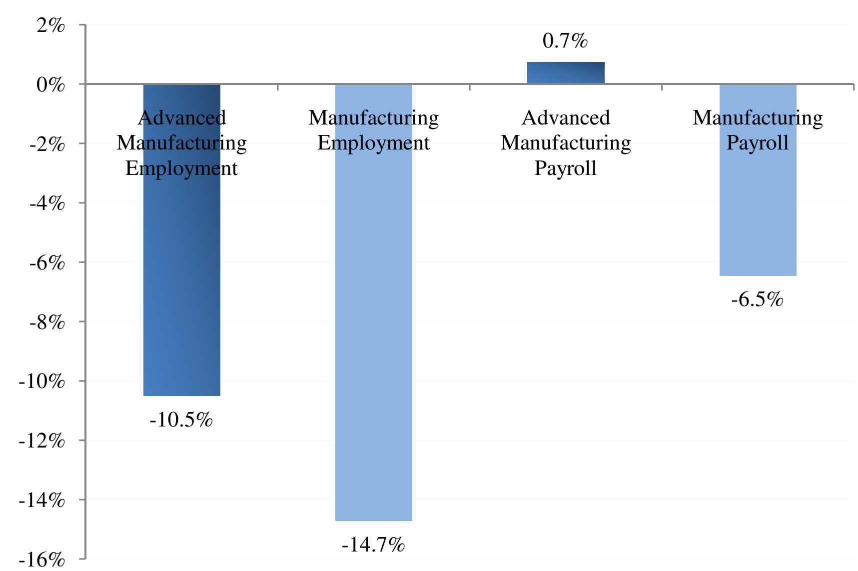
TABLE 3. Advanced Manufacturing Employment and Payroll

	Advanced Manufacturing Employment	Advanced Manufacturing Total Payroll ($1,000)
2003	426,106	$24,275,024
2007	381,351	$24,453,150
Change 2003-2007	**(10.5%)**	**0.7%**

Source Data: U.S. Census Bureau, County Business Patterns 2003, 2007
Analysis: Anderson Economic Group, LLC

While Michigan employment fell in all industries between 2003 and 2007, employment in advanced manufacturing fared better than manufacturing as a whole. Payroll in overall manufacturing fell during this period, highlighting the strength shown by advanced manufacturing as its payroll rose. See Figure 4 below.

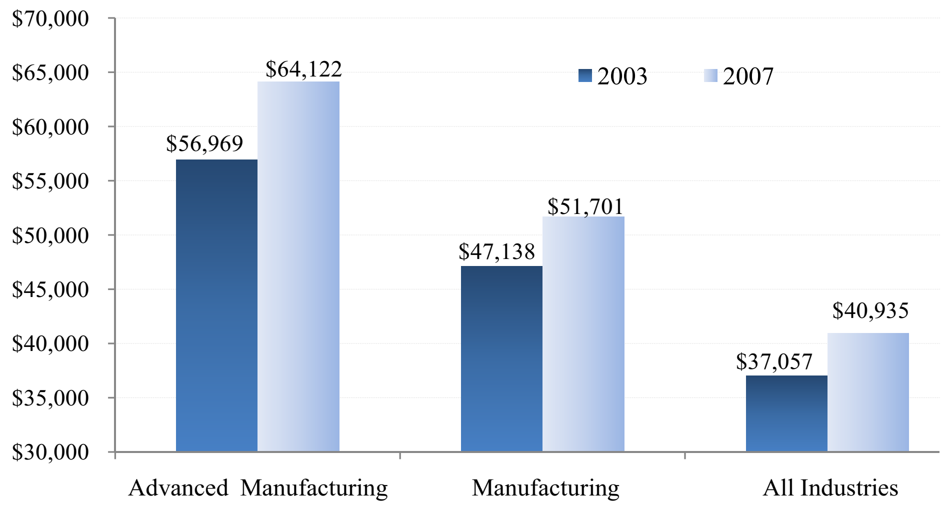
FIGURE 4. Change in Employment and Payroll in Advanced Manufacturing, Manufacturing, and All Industries, 2003-2007



Source: U.S. County Business Patterns
Analysis: Anderson Economic Group, LLC

Michigan's average wage in the advanced manufacturing industry grew substantially between 2003 and 2007, as shown in Figure 5 on page 13. Average wages in advanced manufacturing grew 12.6% during the time period (an average annual increase of 3%) while inflation was 11.6%. In contrast, average wages for all industries increased from $37,057 to $40,935—a 10.5% increase, but less than inflation.[7] See Figure 5 below.

FIGURE 5. Michigan's Average Annual Wage: Advanced Manufacturing, Manufacturing and All Industries 2003 & 2007



Base Data Source: U.S. County Business Patterns
Analysis: Anderson Economic Group, LLC

COMPARISON WITH MIDWEST AND U.S.

In this section we compare Michigan to the Midwest and U.S. on the following measures: advanced manufacturing's share of total industry employment and payroll, the change in employment and payroll in the industry between 2003 and 2007, advanced manufacturing's average annual wage, and productivity growth.

Comparison: Advanced Manufacturing's Industry Share. A greater share of workers are employed in advanced manufacturing in Michigan than in the Midwest or U.S. as a whole. As shown in Table 4 on page 14, in 2007 the payroll of advanced manufacturing made up 16.2% of Michigan's total payroll, higher than in the Midwest (13.2%) and U.S. (11.6%). The trend holds for employment as well,

7. We calculated inflation using the Consumer Price Index for All Urban Consumers from the U.S. Bureau of Labor Statistics. We calculated inflation between March 1, 2003 and March 1, 2007. We selected this time period because our employment and payroll data from the County Business Patterns is from March 12th of each year.

with 10.3% of all employment in Michigan coming from advanced manufacturing compared to 9.5% in the Midwest and 7.9% for the country as a whole.

TABLE 4. Advanced Manufacturing's Industry Share of Employment & Payroll

	State of Michigan		Rest of the Midwest (IL, IN, OH, WI)		United States	
	Employment	**Payroll**	**Employment**	**Payroll**	**Employment**	**Payroll**
2003	11.0%	16.9%	10.0%	13.5%	8.1%	11.7%
2007	10.3%	16.2%	9.5%	13.1%	7.9%	11.6%

Base Data Source: U.S. Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

Comparison: Change in Advanced Manufacturing Employment and Payroll. Between 2003 and 2007, Michigan's advanced manufacturing industry experienced a decline in employment but an increase in payroll, as shown in Table 5 below. The other midwestern states in our comparison group also experienced a drop in advanced manufacturing employment, but nationwide there was an employment increase. The employment increase nationwide was due to growth in research jobs in advanced manufacturing. Michigan's advanced manufacturing payroll growth lagged the Midwest and U.S. from 2003 to 2007.

TABLE 5. Changes in Industries in Michigan, Midwest & U.S. (2003-2007)

Industry Particular to Each Region	State of Michigan		Rest of the Midwest (IL, IN, OH, WI)		United States	
	Employment	**Payroll**	**Employment**	**Payroll**	**Employment**	**Payroll**
Advanced Manufacturing	(10.5%)	0.7%	(2.0%)	13.9%	3.6%	22.6%
All Manufacturing	(14.7%)	(6.5%)	(2.4%)	4.3%	(5.7%)	8.8%

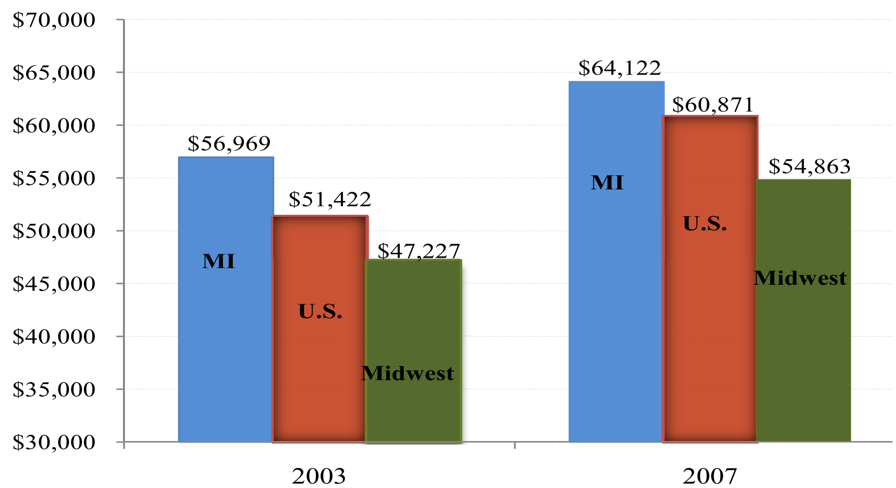
Base Data Source: U.S. Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

Comparison: Advanced Manufacturing Average Wages. Wages have remained high in advanced manufacturing and have been higher than wages in advanced manufacturing in the Midwest and nationwide. However, average wage growth between 2003 and 2007 was better in the Midwest and nationally. Given the productivity increases in advanced manufacturing by region, we would expect higher growth outside Michigan. Productivity grew faster nationwide than in Michigan between 2003 and 2008.[8] In Michigan, productivity increased 10.1% while the

8. Productivity is typically measured in terms of output per labor hour. We use annual value value added per worker as a rough approximation of the productivity of industries since this measure is comparable between states.

average wage increased 12.6%. Nationwide, productivity increased 30% while the average wage grew 18.4%.

FIGURE 6. Average Annual Advanced Manufacturing Wages: Michigan, the Midwest & U.S.



Base Data Source: US Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

Comparison: Manufacturing Sector Productivity and Growth. We compared the productivity of sectors in two of the three advanced manufacturing clusters in Michigan with these sectors' performance nationwide. As shown in Table 6 on page 16, about one-third of employment in these sectors have higher-than-average productivity *and* experienced faster productivity growth than the average U.S. manufacturing firm between 2003 and 2008. These highly-productive industries with good productivity gains include traditional Michigan industries such as office furniture manufacturing, medical equipment and supplies manufacturing, and transportation equipment manufacturing, as well as chemical manufacturing.

Almost of one-fifth of employment in advanced manufacturing sectors were in industries with high productivity, but lower productivity *growth* than the national average for manufacturing firms. Two of the largest industries are in this group—motor vehicle manufacturing and pharmaceutical and medicine manufacturing. However, both of these industries are much more productive than the average manufacturing firm. Motor vehicle manufacturing is 75% more productive than the average firm and experienced only an 11% in productivity between 2003 and 2008. Pharmaceutical and medicine manufacturing is over 2.5 times more productive than the average firm and experienced a decline of only 10%. These are sectors that are important to Michigan's economy. See Table 6 on page 16 and Appendix A-1 on page A-8.

TABLE 6. High Productivity Advanced Manufacturing Sectors in Michigan by Productivity Growth 2003-2008

Above U.S. Average Manufacturing Productivity; Accelerating Faster			Above U.S. Average Manufacturing Productivity; Losing Pace		
NAICS	**Description**	**Emp**	**NAICS**	**Description**	**Emp**
3372	Office Furniture (including fixtures)	15,374	3361	Motor Vehicle Mfg.	39,870
3345	Navigational, Measuring, Medical & Control Instruments Mfg.	11,257	3254	Pharmaceutical & Medicine Mfg.	6,973
3391	Medical Equipment & Supplies Mfg.	8,434	3241	Petroleum, Coal Products Mfg.	1,642
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg.	4,710	3113	Sugar, Confectionery Product Mfg.	1,369
3311	Iron & Steel Mills & Ferroalloy Mfg.	4,194			
3121	Beverage Mfg.	4,171			
3115	Dairy Product Mfg.	4,096			
3251	Basic Chemical Mfg.	3,951			
3255	Paint, Coating & Adhesive Mfg.	3,662			
3259	Other Chemical Product & Prep Mfg.	3,521			
3364	Aerospace Product & Parts Mfg.	3,510			
3369	Other Transportation Equipment Mfg.	2,438			
3314	Nonferrous Metal (except aluminum) Production	1,933			
3112	Grain & Oilseed Milling	1,886			
3352	Household Appliance Mfg.	1,509			
Total		**74,646**	**Total**		**49,854**

Analysis: Anderson Economic Group, LLC
Note: Data that allowed us to calculate productivity only exists for manufacturing sectors. We were unable to perform a similar analysis for the sectors in the Research Relevant cluster.

Almost half of the employment in the non-research relevant manufacturing sectors is in firms where the productivity is lower than the national average but productivity is increasing more rapidly for these firms compared to the average U.S. manufacturing firm. The sectors in this category are diverse and include industrial machinery manufacturing, glass product manufacturing, and bakeries and tortilla manufacturing, as shown in Table 7 on page 17. Only three sectors have lower-than-average productivity and slower than average productivity growth.

TABLE 7. Lower-Than-Average Advanced Manufacturing Sectors in Michigan by Productivity Growth 2003-2008

Below U.S. Average Manufacturing Productivity; Accelerating Faster			Below U.S. Average Manufacturing Productivity; Losing Pace		
NAICS	**Description**	**Emp**	**NAICS**	**Description**	**Emp**
3339	Other General Purpose Machinery Mfg.	18,426	3336	Engine, Turbine, Power Transmission Mfg.	6,385
3328	Coating, Engraving, Heat Treating, & Allied Activities	13,602	3119	Other Food Mfg.	3,025
3329	Other Fabricated Metal Product Mfg.	12,840	3331	Agriculture, Construction & Mining Machinery Mfg.	2,650
3315	Foundries	12,027			
3323	Architectural & Structural Metals Mfg.	8,977			
3371	Household & Institutional Furniture & Kitchen Cabinet Mfg.	6,421			
3272	Glass & Glass Product Mfg.	6,254			
3118	Bakeries & Tortilla Mfg.	6,205			
3332	Industrial Machinery Mfg.	6,182			
3321	Forging & Stamping	6,110			
3221	Pulp, Paper & Paperboard Mills	4,516			
3359	Other Electrical Equipment Mfg.	3,323			
3256	Soap, Cleaning Compound Mfg.	3,160			
3313	Alumina Processing	2,707			
3326	Spring & Wire Product Mfg.	2,551			
3325	Hardware Mfg.	2,445			
3353	Electrical Equipment Mfg.	2,385			
3333	Commercial, Service Industry Machinery Mfg.	2,050			
Total		**120,181**	**Total**		**12,060**

Analysis: Anderson Economic Group, LLC
Note: Data that allowed us to calculate productivity only exists for manufacturing sectors. We were unable to perform a similar analysis for sectors in the Research Relevant cluster.

ADVANCED MANUFACTURING INDUSTRY CLUSTERS

As noted earlier, we have defined the advanced manufacturing industry by NAICS codes, which classify businesses by their primary activity. In total, we identified 46 NAICS codes to be included in the definition of advanced manufacturing. We then organized them into three distinct clusters:

- *Advanced Products & Processes (APP) Cluster*
  The APP cluster contains manufacturing sectors with higher productivity than the U.S. manufacturing industry as a whole in 2007. We measured productivity as value added per number of production workers and value added per produc-

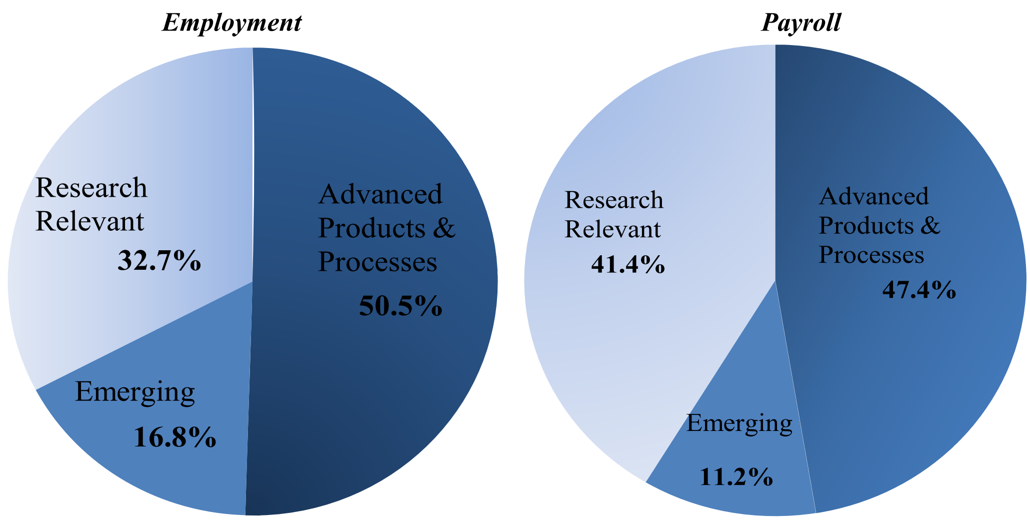
tion workers' wages. We included in this cluster any sector that manufactures advanced products or uses advanced processes. If a sector met one of these criteria in addition to being an emerging sector (defined below) it was included in the APP cluster.

- *Emerging Manufacturing Cluster*
  This cluster includes only sectors whose productivity is increasing at a faster rate than the U.S. manufacturing industry as a whole (whether or not its level of productivity was higher than the U.S. level). During the five years of our analysis (2003-2008), these sectors increased value added per worker or per production workers' wages at a rate faster than the average for U.S. manufacturers. These firms are increasing their productivity through adopting new practices, implementing improved processes, or operating more effectively overall.

- *Research Relevant Cluster*
  While firms with advanced products and manufacturing techniques are important sources of innovation in the U.S., there are other firms that do not directly manufacture goods, but which clearly contribute to the innovation in these industries. Any comprehensive definition of advanced manufacturing must include these firms. This cluster includes almost exclusively services, which cultivate or lead to the cultivation of advanced manufacturing processes or create the advanced products themselves. This is the area in which the URC contributes most directly to advanced manufacturing in the state.

Each cluster's contribution to advanced manufacturing employment and payroll in Michigan is shown in Figure 7 below. Emerging manufacturing firms account for 16.8% of employment in the industry. The research relevant cluster accounts for 32.7% of advanced manufacturing employment.

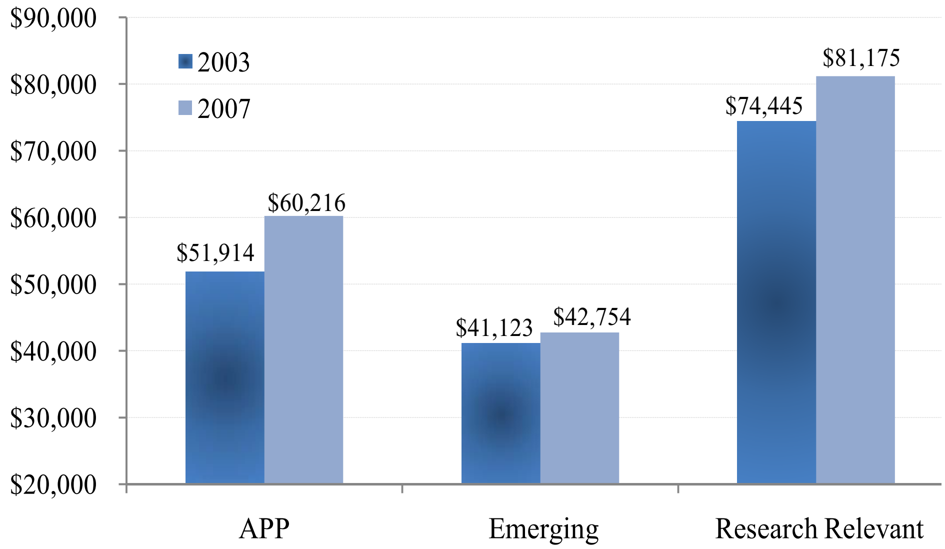
FIGURE 7. Michigan's Advanced Manufacturing Industry Employment and Payroll, by Cluster (2007)



Base Data Source: U.S. County Business Patterns, 2007
Analysis: Anderson Economic Group, LLC

The percentage of payroll attributable to each cluster closely tracks employment, with the advanced products and processes cluster representing the largest percentage of annual industry payroll. Although the research relevant cluster does not make up the highest proportion of employment, it has much higher average wages than the other two clusters. Figure 8 on page 20 shows average wage growth for Michigan's advanced manufacturing clusters.

FIGURE 8. Michigan's Advanced Manufacturing Industry Average Wage, by Cluster (2003 & 2007)



Base Data Source: U.S. Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

Advanced Products and Processes (APP) Cluster

This cluster includes 30 NAICS codes, as shown in Table 1 on page 9. As the largest cluster, its composition is varied, with sectors manufacturing everything from food products, chemicals, pharmaceuticals, electrical equipment, office furniture, aerospace products, and automobiles. There are over 3,400 firms in this cluster. Table 8 below shows the APP's contributions in employment, payroll and average wage in advanced manufacturing.

TABLE 8. Employment, Payroll, and Average Wage—APP Cluster

	Employment	Total Payroll ($1,000)	Average Wage
2003	215,951	$11,210,982	$51,914
2007	192,487	$11,590,839	$60,216
Growth 2003-2007	(10.9%)	3.4%	16.0%

Base Data Source: U.S. Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

This cluster employed 192,487 people in 2007, or 50% of the state's advanced manufacturing employment. Between 2003 and 2007, Michigan's average wage in the advanced cluster grew 16% from $51,914 to $60,216. Additionally, the total payroll increased by over $379 million.

Emerging Manufacturing Cluster

Businesses included in the emerging manufacturing cluster of the advanced manufacturing industry exhibit productivity rates in excess of average U.S. manufacturers from 2003-3007. These sectors have increased their productivity through adopting new manufacturing techniques and equipment. The over 1,800 firms in this cluster include manufacturers of cleaning products, glass products, hardware, and architectural and structural metals.

Michigan's emerging manufacturing cluster employed 64,254 people in 2007, or 16.8% of the state's advanced manufacturing industry. Its total payroll increased (from 2003-2007) by over $483 million and accounted for 11.2% of advanced manufacturing's payroll in the state. The cluster experienced a decline in employment between 2003 and 2007. However its average wage still grew by 4%, as shown in Table 9 below.

TABLE 9. Employment, Payroll, and Average Wage—Emerging Cluster

	Employment	Total Payroll (1,000s)	Average Wage
2003	77,457	$3,185,293	$41,123
2007	64,254	$2,747,136	$42,754
Change 2003-2007	(17.0%)	(13.8%)	4.0%

Base Data Source: U.S. Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

Research Relevant Cluster

This cluster is exclusively services, including design and process innovation, and advanced testing environments for new technologies, products, and processes. These sectors are the driving force of innovation in advanced manufacturing and thus an integral part of our comprehensive definition. The URC universities' activities are primarily in this cluster as they assist with the research, testing, and design of technologies that shape advanced manufacturing. We discuss the URC's role in this cluster more fully in the next section.

The research relevant cluster employed 124,610 people in Michigan in 2007, and generated more than $10.1 billion in total payroll. The cluster's average wage increased by 9% between 2003 and 2007. During that time period Michigan's research relevant cluster added over 230 firms, bringing the number of firms to over 5,800 in 2007. However, employment decreased by 6% and total payroll increased by just over 2%, as shown in Table 10 on page 22.

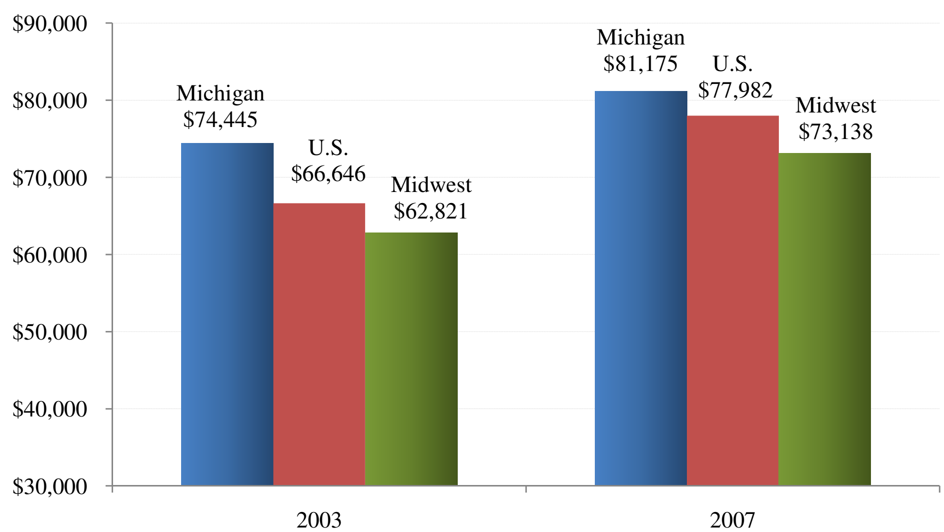
TABLE 10. Employment Payroll and Average Wage—Research Relevant Cluster

	Employment	Total Payroll (1,000s)	Average Wage
2003	132,698	$9,878,749	$74,445
2007	124,610	$10,115,175	$81,175
Change 2003-2007	(6.1%)	2.4%	9.0%

Base Data Source: U.S. Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

Jobs within the research relevant cluster pay well. Average annual wages were above $81,000 in 2007. The research relevant cluster boasts the highest average wage in the advanced manufacturing industry anywhere, as shown in Figure 9 below. Michigan's research relevant cluster has higher average annual wages than the rest of the Midwest and the United States as a whole.

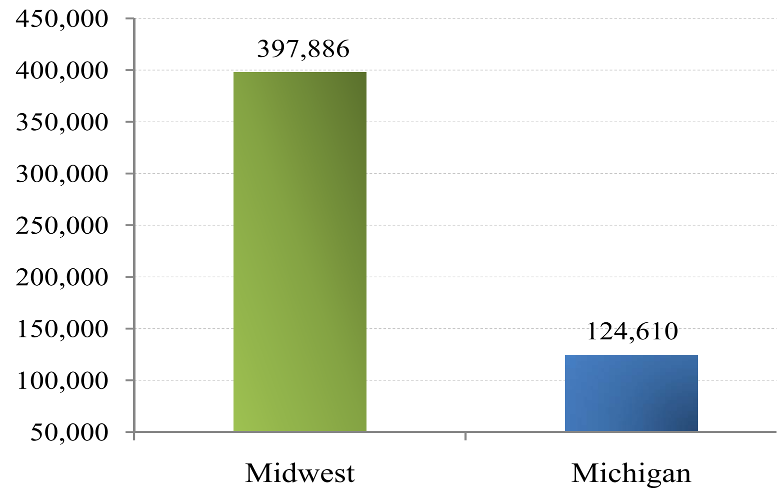
FIGURE 9. Research Relevant Cluster Average Annual Wage.



Base Data Source: U.S. Census Bureau, County Business Patterns 2003, 2007
Analysis: Anderson Economic Group, LLC

Michigan's research relevant cluster employs nearly one third of the cluster's workforce in the entire Midwest, as shown in Figure 10. In 2007, Michigan's research relevant employment contributed 3.9% of the nation's employment in this cluster. This is greater than Michigan's overall national employment share, which is 3.1%.

FIGURE 10. Research Relevant Employment in Michigan v. Midwest 2007



Base Data Source: U.S. County Business Patterns
Analysis: Anderson Economic Group, LL

INDUSTRY TRENDS SINCE 2007

The U.S. economy experienced two recessions in the past decade. Michigan's economy never fully recovered from the 2001 recession. In every year since 2001, Michigan's economy has lost private sector jobs. Between 2000 and 2009, 27% of private sector jobs lost nationwide were in Michigan.[9]

Manufacturing and advanced manufacturing have remained a large part of Michigan's economy, but manufacturing employment has declined 34% since 2001.[10] Manufacturing, especially of durable goods like cars, often suffers greater declines than the rest of the economy in recessions. This is because consumers are able to delay the purchase of such goods as they try to cut costs. Additionally, this is made worse as retailers and dealers reduce their inventories in anticipation of further hard times. As of 2009's second quarter, Michigan's overall manufacturing employment was down over 22% from 2007.[11]

Advanced manufacturing did not experience a decrease in employment quite as dramatic as total manufacturing between 2007 and 2009. Using data provided by the State of Michigan, employment in the advanced products and processes cluster fell

9. Data is from the U.S. Bureau of Labor Statistics. Data reported is annual private sector employment in 2000 and 2009.
10. Data is from the U.S. Bureau of Economic Analysis Regional Economic Accounts. The 34% decline is between 2000 and 2008, the most recent year for which data is available.
11. We decided not to use the more recent Michigan data to complete our full analysis because we did not have similar data for the Midwest and U.S. We used the older County Business Patterns data in order to make these comparisons.

10.4% between 2007 and the second quarter of 2009. Employment at firms in the emerging manufacturing cluster experienced a decline in employment of over 20%.[12] By contrast, research relevant industries in Michigan are growing and attracting investment from diversified industrial research companies like General Electric and IBM. We discuss some of these investments in the next section.

This evidence suggests that Michigan's advanced manufacturing industry experienced further drops in employment between 2007 and 2010. The research relevant industries have seen some investment in recent years, but it is likely that these firms too experienced a decline in employment since 2007. Wages for the advanced manufacturing industry have most likely remained high since 2007, but probably have not grown as fast as the national average for this industry. As we mentioned earlier, the growth in productivity in advanced manufacturing in Michigan has lagged the nation, part because Michigan's advanced manufacturing companies are already very productive. As a result, we would expect wages in other states to rise with their increasing productivity and to outpace wage growth in Michigan.

12. See http://www.michigan.gov for labor market information.

III. URC Support for Michigan's Advanced Manufacturing

The URC universities are leaders in research and development in advanced manufacturing, creating a locus of expertise and activity for this industry. In this section we begin with a brief summary of the scale of URC research and development in advanced manufacturing. We then describe the manufacturing industry's product development life cycle and cite specific examples of URC contributions to Michigan's industry at each stage, from developing and implementing new ideas to educating the next leaders in advanced manufacturing.

URC R&D EXPENDITURES ON ADVANCED MANUFACTURING

The URC universities are leaders in advanced manufacturing research and development. Currently, the URC universities have almost $425 million in active open awards for research that relates to advanced manufacturing. Of the $425 million in active awards, the URC spent $101.9 million in Fiscal Year 2009. This figure represents 6% of total R&D expenditures by the URC universities in FY 2009. In the next few years, we estimate that in an average year for the URC, almost 9% of R&D performed at their universities will be related to advanced manufacturing. See Table 11 below.

TABLE 11. Advanced Manufacturing R&D in the URC

	Amount ($, millions)
Total R&D Expenditures, FY 2009	$1,684.8
Advanced Manufacturing R&D Active Awards[a]	$424.8
Advanced Manufacturing R&D Expenditures in FY 2009[b]	$101.9
Advanced Manufacturing R&D Expenditures in a Representative Year, 2008-2013[c]	$147.1

Source: URC Universities, NSF FY 2009 Submissions
Analysis: Anderson Economic Group, LLC

a. We classified R&D projects at the URC universities by going through their detailed research award records and determining whether the project was consistent with our definition of advanced manufacturing.

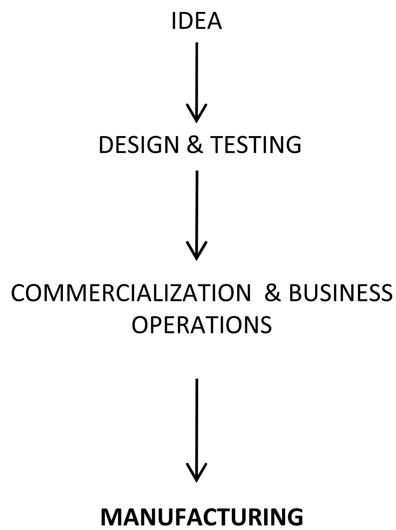
b. We estimated the amount of active awards spent in FY 2009 by looking at the award start and end dates and determining what portion of the project occurred in FY 2009. We then allocated proportionally the total amount of the research expenditures to the time period that falls within FY 2009, recognizing that the money may not be spent exactly that way.

c. We estimated a representative year by taking the total project awards for advanced manufacturing R&D, calculating the expenditures per day of the duration of the project and then multiplying it by 365 days.

PRODUCT DEVELOPMENT LIFECYCLE

The research performed at the URC universities is shaping the products and processes in manufacturing. In Figure 11 on page 26, we illustrate how research performed at a URC institution, or by a private company, is developed and commercialized. This process, which we have labeled the "product development lifecycle" is more complex than shown below. However, the figure illustrates in a simple way the key steps of the process. This process begins with an idea. Ideas are then tested and developed before they are eventually produced and sold to clients.

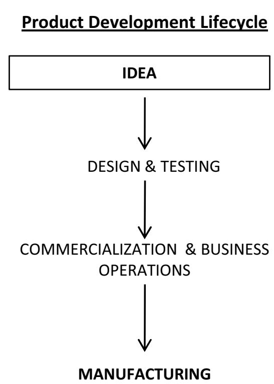
FIGURE 11. Product Development Lifecycle



Source: Anderson Economic Group, LLC

The remainder of this section discusses each stage of the product development lifecycle and provides specific examples of URC contributions to each.

URC CONTRIBUTIONS TO DEVELOPMENT OF NEW IDEAS



An important role the URC universities play is at the beginning of the product development lifecycle. URC universities provide the facilities, high-tech equipment, and researchers that allow for the development of new ideas, some of which are commercialized. For example, an average of 129 patent grants and 135 licenses were issued to URC universities annually between 2004-2008.

Below, we provide examples of how the URC universities are assisting with the development of ideas that affect advanced manufacturing.

MSU's National Superconducting Cyclotron Laboratory. The NSCL is a world-leading laboratory for rare isotope research and nuclear science education. Supported by the National Science Foundation, the laboratory operates as a national use facility that serves more than 700 researchers from 100 institutions in 35 countries.

The NSCL has been at the forefront of developing technology that makes nuclear science a reality. The laboratory's ability to conceptualize and fabricate equipment and machinery is one of its great strengths. Since most of the equipment used at NSCL is specialized and generally not available from manufacturers' catalogs, the lab must do its own mechanical engineering and design to carry out the work. Over the years, the lab has accumulated significant expertise in many technical areas including high field magnets (room temperature and superconducting), high power RF systems (room temperature and superconducting), high voltage electrodes, high vacuum techniques, charged particle beam tuning and diagnostic equipment, beam target and detection systems, and civil engineering for the infrastructure.

MSU's Facility for Rare Isotope Beams. The Facility for Rare Isotope Beans (FRIB) will be a new national user facility for nuclear science funded by the U.S. Department of Energy Office of Science, Office of Nuclear Physics and operated by MSU. The facility will cost approximately $600 million to establish and take about a decade for MSU to design and build. The FRIB will provide intense beams of rare isotopes—short-lived atomic nuclei not normally found on Earth—that will enable researchers to address important questions in nuclear structure and nuclear astrophysics. The heart of the new facility will be a high-intensity heavy-ion linear accelerator that will provide world-unique technical abilities. These will include the ability to conduct experiments with fast, stopped, and reaccelerated beams, which will help users extend the reach of nuclear science. The FRIB will establish global leadership in rare-isotope science conducted in the United States in the future.

MSU's Great Lakes Bioenergy Research Center. MSU and the University of Wisconsin-Madison are partnering in the Great Lakes Bioenergy Research Center with $125 million in funding from the U.S. Department of Energy. The GLBRC is one of three national centers funded by the U.S. Department of Energy to conduct transformational biofuels research. Led by the University of Wisconsin-Madison, in close partnership with MSU, the GLBRC is exploring scientifically diverse approaches to converting various plant feedstocks (agricultural residues, wood chips and nonfood grasses) into liquid transportation fuels. In addition to its broad range of research projects, the GLBRC also is collaborating with agricultural researchers and producers to develop the most economically viable and environmentally sustainable practices for bioenergy production.

U-M/MSU Engineering Research Center for Wireless Integrated MicroSystems (WIMS). The WIMS Engineering Research Center is focused on the intersection of three key areas: microelectronics, wireless communications, and microelectromechanical systems (MEMS). The center is developing the technology base needed to produce these microsystems, including precision sensors, micropower circuits, wireless interfaces, and wafer-level packaging. It is also developing the interdisciplinary educational programs that will produce engineering leaders for the emerging microsystems field. This center is funded by the National Science Foundation. It consists of three partnering universities (Michigan State University, the University of Michigan, and Michigan Technological University), the State of Michigan, and a consortium of automotive, chemical, and microelectronics companies including companies such as Stryker, Texas Instruments, ISSYS, Honeywell, and Agilent.

U-M's S.M. Wu Manufacturing Research Center. Based at U-M's Ann Arbor campus, the S. M. Wu Manufacturing Research Center (WuMRC) is a College of Engineering Center with participating faculty and researchers from the Departments of Mechanical Engineering and Industrial and Operations Engineering. The WuMRC also has ties with over 60 industrial partners, including General Motors, Chrysler, Ford, Boeing, and many of their suppliers. In addition, many of WuMRC's research projects have been supported by various government agencies including National Science Foundation, National Institute of Standards and Technology (ATP Programs), Department of Defense, and Department of Energy. The center conducts basic and applied research in manufacturing science and engineering. Its broad scope of research consists of six different research laboratories for assembly and materials joining, dimensional measurement, drill research, in-process quality improvement, machine tools and machining, and sheet metal stamping and material forming.

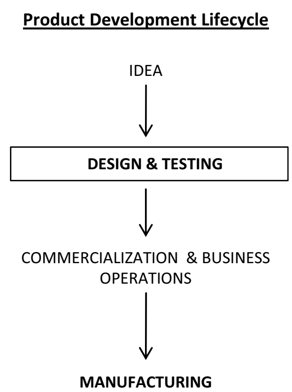
U-M's Center for Ultrafast Optical Science. The center develops optical equipment and techniques to generate, manipulate, and detect ultrashort and ultrahigh-peak-power light pulses. The center has produced commercial applications in sectors ranging from scientific lasers and micromachining, detectors and instrumentation, optics, precision surgery, and materials processing.

U-M's Ground Robotics Research Center. Established in 2007, U-M's Ground Robotics Reliability Center (GRRC) conducts research in autonomous ground vehicles and mobile robots. U-M's vision is to help establish Southeastern Michigan as a center of activity for these emerging new technologies through supporting programs in research and education. The GRRC research projects are primarily sponsored by the US Army's Tank-Automotive Research Development and Engineering Center (TARDEC). U-M leads the GRRC, which also includes partners from other academic institutions as well as industry.

WSU's Smart Sensors and Integrated Microsystems Program. The Smart Sensors and Integrated Microsystems (SSIM) program at WSU has recently expanded to 35,000 square feet of laboratory facilities, tripling its size with the addition of several new state-of-the-art centrally located laboratories. The SSIM Program now includes an advanced design and simulation laboratory, an advanced materials laboratory, a biomicrosystems translational lab with a bio-level 2 clean room, a robotics lab, a 3-lab characterization suite, a class 100 advanced packaging clean room, a class 100 biointegration clean room, a class 100 multi-laser rapid prototyping clean room, a class 100/class 10 advanced microfabrication clean room, as well as a number of cluster rooms for project teaming. These facilities provide capability for basic design and simulation of the physics, chemistry, mechanics, and engineering. This includes device development, manufacturing, software and system integration, all the way through human factors and virtual reality. This, combined with the rest of the SSIM facilities, allows for the development of advanced devices and instruments with particular emphasis on biomedical systems.

WSU's Biomedical Engineering and Bioengineering Research Center. The Bioengineering Center of Wayne State University is a leading laboratory pioneering research in human impact tolerances. This research has contributed to the development of major safety equipment in automobiles and aircraft, including seat belts, air bags, highway guardrails and other safety barriers. Current projects in impact trauma include research on vehicular side impact, rear end collisions, head injury, and lower extremity injuries. Foremost among the goals of the center is the reduction of fatalities and major injuries that occur in all fields.

URC CONTRIBUTIONS TO DESIGN AND TESTING OF PRODUCTS & PROCESSES



After initial research has been conducted, the next steps in turning an idea into a product include design and testing. The URC universities have many laboratories and centers that assist with this step of the development process. Below we describe how the URC is assisting companies and shaping new products.

MSU's Fraunhofer Center for Coatings and Laser Applications. Founded in 2003, MSU and Fraunhofer Gesellschaft formed a mutually beneficial research partnership to establish the Fraunhofer Center for Coatings and Laser Applications. The center is focused on coating and laser processing technologies. The partnership was based on complementary expertise in the areas of conventional coatings, carbon-based coatings, microwave plasma processing, and laser processing. The center works on diamond-like carbon material projects across industries on applications from biomedical implants to fuel-efficient engine components to clean water. Of particular interest to the automotive industry are coatings that reduce the wear, as well as the friction, on engine parts such as piston pins and valve tappets.

Red Cedar Technology. Red Cedar Technology was co-founded in 1999 by Ron Averill and Erik Goodman with spinoff technology from MSU. Based in East Lansing, the company initially provided finite element analysis and optimization engineering services based on design optimization technology. These activities eventually led to the 2004 launch of the software product Hierarchical Evolutionary Engineering Design System (HEEDS). This flagship product was the culmination of more than 20 years of effort to improve upon the incremental advances enabled by traditional engineering software, such as CAD/CAM and CAE, in the areas of productivity, quality, cost reduction, and compressed development cycles.

The technology interfaces with all of the popular CAE applications to automate the design optimization process. Employing revolutionary search strategies, HEEDS removes the restrictions of conventional numerical search methods, yielding new design concepts that drive product improvement and competitive advantage. It intelligently conducts a broad, efficient search for optimized designs, often in a fraction of the time it would take to perform a handful of manual iterations. Using HEEDS, engineers can overcome the limits of human intuition and even professional experience. HEEDS is utilized across many industries, including aerospace, automotive, biomedical and manufacturing. Product examples include stents, crash rails in automobiles, MEMS devices and fiber composite parts.

MSU's Composite Vehicle Research Center. This center focuses on the research, design and testing of composite structures for lightweight, environmentally friendly, durable, and safe vehicles for air, ground, and marine transportation. The center's focus includes both military and civilian applications.

MSU's Center for Energy, Nano and Multifunctional Materials. Energy storage and conversion materials, as well as multifunctional composite materials, are a new class of materials combining two or more separate components into a form suitable for structural applications. The forerunner to this center, the Composite Materials and Structures Center, was founded in 1985 and had been led by Lawrence Drzal (professor of chemical engineering and materials science). The Center for Energy, Nano, and Multifunctional Materials is one of the foremost facilities for the study of polymer composites and is internationally recognized for its contributions to composite science and engineering. Composite materials offer a new manufacturing frontier for the state of Michigan with substantial new opportunities in energy-related systems such as wind turbine components. The center includes eight laboratories, totaling nearly 20,000 square feet, which are fully equipped with the latest instrumentation for the study of composite manufacturing, performance, and durability.

MSU's Energy and Automotive Research Laboratories. This $10 million, 29,000-square-foot research facility focuses on improving automobile engine efficiency, reducing vehicle emissions, and seeking alternative energy sources. The laboratories house a dynamic new center for synergistic research and development, bringing together leading engineers and scientists in one facility. These researchers are working together to solve problems important to the energy and automotive fields. The research complex features a powertrain lab and two engine test cells, one of which can accommodate a large SUV or small military vehicle. The complex also has a cold room to test engine turnover in temperatures as low as -40 degrees Fahrenheit.

MSU's Civil Infrastructure Laboratory. The Civil Infrastructure Laboratory is a dedicated facility for structural, pavement and materials engineering research and provides diverse space and equipment for micro-, meso- and macro-scale testing, including a structural fire testing facility. The large-scale structures and pavements testing area features a 30-foot high-bay area enclosing a reconfigurable 60-by-40-foot "strong testing floor" with a 3.5-foot-thick reinforced concrete slab, serviced by a 10-ton overhead crane. A furnace equipped with a load frame and serviced by a 20-ton overhead crane facilitates structural fire testing. The laboratory is outfitted with materials and structural testing equipment for simulated mechanical and environmental loading. Material testing capabilities include universal testing machines with thermal loading chambers.

WSU's NextEnergy. Located in the Wayne State University cluster, NextEnergy is one of the nation's leading research catalysts and business accelerators for alternative and renewable energy. NextEnergy is a nonprofit organization founded in 2002 and capitalized with a $30 million seed grant from the Michigan Economic Development Corporation. NextEnergy has a state-of-the art facility that provides training rooms, an auditorium, space for exhibits and demonstrations, and an 18,400 square foot accelerator laboratory for energy technology companies and projects. NextEnergy also offers a microgrid power pavilion and includes flexible test bays for application of on-site electrical power systems. There is also an alternative fuel testing platform for advancing the development of hydrogen, natural gas, biological, and synthetic fuels.

WSU's National Science Foundation Industry/University Engineering Research Center for e-Design. Wayne State University is in the process of joining the Center for e-Design. The purpose of this center is to create new design paradigms and electronic design tools that will assist in generating high quality products and systems at a reduced cost. The primary university consortium consists of University of Massachusetts Amherst, Virginia Polytechnic Institute and State University, University of Central Florida, and Carnegie Mellon University. The mission of the Center is to serve as a nationally recognized center of excellence in design where innovation and creativity are integrated with fundamental principles of science, mathematics, and engineering. The Center will focus on the development, testing, and implementation of new methods and technologies for the design of products and systems while reducing time to market, maintaining high quality, and reducing costs.

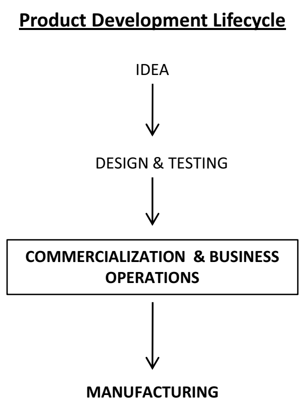
U-M's Environmental and Sustainable Technology Laboratory (EAST). The EAST laboratory is focused on technology, knowledge, and policy innovations that reduce the impact of engineering design and manufacturing decisions on the environment. Primary activities include the life cycle evaluation of technology systems and fundamental research leading to novel technologies that minimize environmental and health risks in manufacturing. One specific research project involves analyzing metalworking fluids for improved environmental and health impacts while simultaneously improving manufacturing performance.

U-M's Advanced Computer Architecture Laboratory. The Advanced Computer Architecture Laboratory (ACAL), established in 1985, serves as the focal point for interdisciplinary research into the theory, design, programming, and applications of advanced computer systems. Over the past two decades, ACAL researchers have made pioneering contributions to the design of high-performance computer systems. Examples include Intel's Pentium chip and Compaq's Alpha chip. ACAL research is supported from a variety of government and industry sources, including the Army Research Office (ARO), the Defense Advanced Research Projects Agency (DARPA), the Microelectronics Advanced Research Corporation (MARCO), the National Science Foundation (NSF), the Semiconductor Research Corporation (SRC), Compaq, IBM, and Intel.

U-M's Automotive Research Center. The Automotive Research Center (ARC) is a University-based U.S. Army Center of Excellence for advancing technology of high fidelity simulation of military and civilian ground vehicles. The ARC was established in 1994 as the key research partner of the National Automotive Center at the U.S. Army Tank-automotive and Armaments Command (TACOM) in Warren, Michigan. The overall goal of the center's research is the development of a distributed simulation and design environment for ground vehicles. In recent years, the center has increased its emphasis on research involving high mileage, low polluting vehicles, particularly those employing hybrid powertrains. In addition to automobiles, the center addresses the new, high technology needs for large trucks and off-road vehicles as well as robots. The center partners with researchers at Howard University, the University of Iowa, Wayne State University, the University of Wisconsin, Clemson University, Oakland University, the University of Tennessee, and the University of Alaska Fairbanks.

U-M's Integrated Manufacturing Systems Laboratory. The Integrated Manufacturing Systems Laboratory is the largest manufacturing laboratory in the United States, with numerous machine tools, measurement and inspection systems, and other research equipment. This facility houses the activities of the Engineering Research Center for Reconfigurable Machining Systems (ERC-RMS) and the S. M. Wu Manufacturing Research Laboratory.

URC CONTRIBUTIONS TO IMPROVING BUSINESS OPERATIONS



URC universities run research facilities specifically dedicated to assisting companies in Michigan with their business operations. This can take the form of developing processes that allow manufacturers to run their businesses more efficiently or helping companies get their products to market. We provide some examples below.

U-M's Center for Intelligent Maintenance Systems. The goal of the Center for Intelligent Maintenance Systems is to create products and systems that achieve and sustain near-zero breakdown performance. The Center is working to transform the traditional maintenance practices from "fail and fix" to "predict and prevent" methodology. Industry partners consist of over 35 companies including Boeing, GE Aviation, Siemens, Eaton, and GM.

U-M's Center for Ergonomics. The Center for Ergonomics is dedicated to furthering knowledge about human abilities as they relate to how humans interact with equipment in all settings including work, transportation, defense, daily living, education, and leisure. For nearly fifty years, the center's research has led to a better understanding of work-related musculoskeletal disorders, principles of human-centered technologies, and man-machine interaction.

U-M's Dynamic Systems Optimization Laboratory (DSOL). The DSOL is a multidisciplinary research laboratory that includes faculty members from the College of Engineering. It conducts research on dynamic systems, optimization theory and other applications involving sequential decision making over time. A recent project example includes collaborating with General Motors to optimize manufacturing decision-making including issues such as the sizing and timing of capacity expansions, the planning for production scheduling and maintenance tasking, and the replacement and acquisition of new equipment. This research will be grounded in a real application arena at General Motors with the intent of increasing the productivity and reliability of national manufacturing systems.

U-M's Tauber Institute for Global Operations. Founded in 1991 and originally called the Tauber Manufacturing Institute, the institute developed curriculum and collaborations to support the manufacturing industry. Initially guided by industry executives from 27 corporations, the institute supported student and faculty research projects and unique academic programs such as "Integrated Product Development" and "Agile Manufacturing". The institute was renamed the Tauber Institute for Global Operations in 2007. Activities in the past several years include joint symposiums with groups such as the Leaders for Manufacturing program at MIT, the Alliance for Integrated Manufacturing program, and the Global Operations Conference in 2008.

U-M's Center for Dimensional Measurement and Control in Manufacturing. The Center for Dimensional Measurement and Control in Manufacturing is a National Science Foundation - Industry/University Cooperative Research Center. The Center maintains a strong industry/university cooperative research program with three focused thrust areas: (1) Dimensional measurement principles and systems, (2) Dimensional control for machined parts, and (3) Dimensional control of stamped parts. The Center brings together expertise from mechanical engineering, industrial and operations engineering, electrical engineering and computer science, and materials science and engineering to address research needs and challenges in dimensional measurement and control.

WSU's TechTown. TechTown, Detroit's research and technology park, was established in 2000 to stimulate job growth and small business creation by developing companies in emerging high-technology industries including advanced engineering, life sciences, and alternative energy. The 12-block park includes TechOne, the 100,000-square-foot business incubator facility which now hosts 210 growing companies. With the TechOne facility already at capacity, TechTown is moving forward on the TechTwo facility which will add additional space. Plans eventually call for TechTown to host more than 300,000 square feet of office and laboratory space, with an emphasis on being a small business catalyst.

MSU Bioeconomy Institute. The MSU Bioeconomy Institute opened a R&D facility and pilot plant in March 2009 in Holland, Michigan in a building donated by Pfizer Inc. Lakeshore Advantage, a west Michigan regional development group, provides training, seed funding, and access to networking and collaborative opportunities for tenants of the BioBusiness Accelerator housed at the site. MSU's Bioeconomy Institute complements and extends campus research that supports the state's emerging bioeconomy. Projects of interest include biomaterials, biobased chemicals, and biofuels. The institute also hosts research for private and public sector collaborators. As a major Michigan infrastructure resource, the MSU Bioeconomy Institute offers businesses world class "wet lab" space along with industrial scale pilot production capacity, all specifically targeting technology commercialization. The pilot plant includes approximately 38,000 liters of diverse glass-lined, stainless steel, or Hastelloy reactors, plus associated condensers, dryers, centrifuges, and filters. The first successful scale-up manufacturing project was completed in the pilot plant in November 2009 for an MSU spin-off specialty chemical firm.

MBI International. MBI is a non-profit service provider affiliated with Michigan State University and MSU's new BioEconomy Network. MBI works in collaboration with MSU to commercialize new biobased technologies. MBI also works as a fee-for-service organization that partners with companies to scale up their biobased technologies. MBI utilizes a disciplined approach to bridge the gap between research and commercial viability. With more than 25 years of experience in fermentation technologies, separation and purification innovation, biomass pretreatment, and biobased polymer development, MBI bundles a full spectrum of science, engineering, operational, and business expertise with an integrated 120,000-square-foot infrastructure of development laboratories and pilot-plant.

MSU's Supply Chain Management/Logistics Program. Part of MSU's Eli Broad College of Business, the Department of Supply Chain Management is widely acknowledged by industry and academia as the leader in dissemination of procurement, manufacturing, and logistics knowledge. The program integrates topics from manufacturing operations, purchasing, transportation, and physical distribution into a unified course of study. Its graduate program was recently ranked No. 2 in the nation by *U.S. News & World Report*.

MSU's School of Packaging. The MSU School of Packaging, considered one of the top programs in the world, supports the industry of packaging by educating students, conducting research to solve packaging problems, and developing new technology which can be used by the industry. Established in 1952, the program has more than 7,000 alumni located throughout the world and offers the only doctoral program in packaging. The program offers a wide variety of services, from design and sample making to processing and testing. Projects range from standardized testing to custom studies that may take several months.

MSU's Industrial and Organizational Psychology Program. MSU's graduate program in industrial and organizational psychology in the College of Social Science ranks first in the nation, according to U.S. News & World Report. Industrial and organizational psychology is the scientific study of the work place. Rigor and methods of psychology are applied to issues of critical relevance to business, including talent management, coaching, assessment, selection, training, organizational development, performance, and work-life balance. Examples of recent applied research projects include selection system design, training program development, employee surveys, and evaluations of interventions to enhance productivity and satisfaction. Company examples include Ford Motor Co. and Denso Manufacturing.

MSU Product Development Center. The MSU Product Center for Agriculture and Natural Resources (ANR) was established in Spring, 2003 with funds from the Michigan Agricultural Experiment Station and Michigan State University Extension to improve economic opportunities in the Michigan agriculture, food, and natural resource sectors. The Product Center helps entrepreneurs as well as established companies develop and commercialize high value, consumer-responsive products and businesses in the agriculture and natural resource sectors. The Center is a front door to MSU's vast and varied technical expertise, research, outreach, and educational services.

THE URC PARTNERS WITH INDUSTRY

In addition to the industry-supporting research institutes and programs described above, the URC has pursued several more extensive partnerships with individual manufacturers, particularly the automotive manufacturers in the state. These partnerships range from collaborative research projects to academic programs to develop talent for their industry partners. Below we provide several examples of collaboration between the URC universities and manufacturers.

Ford Motor Company - Wayne State Engineering Management Master's Program. This program has been very successful at Ford Motor Company and has graduated over 300 technical leaders since 1995. Ford engineers in the program are nominated by company management and earn a master's degree after three years. During their third year in the program, students complete a strategic project on a topic identified as a major concern by Ford leadership. Examples of past projects include:

- Prototype Optimization: This project helped determine requirements for prototypes as well as serving as a tool for prototype scheduling and tracking. The system carries an estimated cost savings of $250 million per year.
- E-Risk: Produced a model and process for engineering change decisions and associated risks. The software tool is fully integrated on Ford's product development website as a tool for all product development teams.
- Vehicle Shipping Facilities Optimize: Used in company facilities today, this project developed an optimization method and tool for analyzing outbound shipments at assembly plants to quickly identify facility constraints and bottlenecks, increase on-time shipments, and improve decision-making about related processes.
- Powertrain Package Envelope Implementation and Management: This project developed a plan to optimize the number of powertrain platforms in order to support corporate vehicle commonization efforts. Using a single vehicle program as a test case, the project identified a total engineering and investment savings of $99.2 million, and significant improvements in time-to-market, through the application of their commonization method.

WSU's Technology and Engineering Applications in Medicine and Surgery (TEAMS) . The SSIM program and the WSU Medical School, Department of Surgery, has formed the TEAMS consortium which consists of collaborators including the Detroit Medical Center and Children's Hospital of Michigan, Henry Ford Health Systems, Karmanos Cancer Institute, Beaumont Hospital System, Oakwood Hospital, Madrid Hospital (Spain), and the Department of Defense - TATRC, to develop advanced medical technology and provide resources for surgical assessment and training. Recently, Dr. Gregory W. Auner, the director of the SSIM program, received a $2.5 million endowment for the Paul Strauss, M.D. TEAM Chair. Current TEAMS projects include:

- Raman spectroscopy diagnostics (pathology and handheld)
- Live cell imaging (3-D tissue culture, tumor science and therapy investigation, and microbioreactor)
- Virtual biopsy & HIFU (High Intensity Focused Ultrasound)
- Smart helmets for brain trauma prognostics and diagnostics in collaboration with Visca, LLC and Beaumont Hospital
- Robotic surgery and augmented reality (microrobots)
- Point of care genetic and pathogen analysis
- Bio implants (central nervous system and drug delivery
- Atomic analysis of cancer/tissue via XPS
- ISO and FDA standard device fabrication clean room facility.

IBM's Partnership with MSU. In January of 2009, IBM announced they would be locating their Global Delivery Center for Application Services on the campus of Michigan State University. The first of its kind for the company in the United States, the IBM facility is the product of an agreement to expand MSU's recruiting, research, and educational partnerships with the information technology giant. The partnership leverages multiple assets across the university system including engineering and computer science, business, and also social science. These activities include customized training and work force programs, direct faculty interaction, as well as research and development collaborations. The project expects to create up to 1,500 direct and indirect jobs by 2014.

Engineering Research Center for Reconfigurable Manufacturing Systems (ERC/RMS). The ERC/RMS was founded in 1996 to bring science to the factory floor with new methodologies and equipment to increase production speed and reliability. The ERC/RMS was supported by the National Science Foundation (NSF) and approximately thirty industrial companies including Ford, General Motors, Cummins, and Chrysler. Though the formal NSF funding cycle was completed in 2007, center infrastructure and project thrust areas continue to exist.

The ERC/RMS's core partners, particularly the major automobile manufacturers, were active participants in advising the center, moving research results from the test beds to pilot demonstrations in their facilities, and recruiting graduates from the center to both transfer the technology and provide technical leadership in the future. The ERC/RMS has worked with its partners to move research and innovation from the test beds to adoption by industry. This includes both hardware and software tools. Evidence of this focus includes 12 patents, ranging from reconfigurable machine tools and inspection machines to software for designing and planning reconfigurable manufacturing systems.

General Motors/U-M Collaborative Research Laboratory in Advanced Vehicle Manufacturing. The General Motors Collaborative Research Lab in Advanced Vehicle Manufacturing (GM/UM AVM CRL) was established to carry out research and development activities in areas that are of critical importance to GM's vehicle manufacturing operations, with particular emphasis on automotive body manufacturing processes and systems. It also helps facilitate the exchange of technical personnel and knowledge between GM Research and Development and U-M. Current research thrust areas include assembly, welding and joining, metal forming, and manufacturing systems.

URC R&D HAS LED TO NEW COMPANIES IN ADVANCED MANUFACTURING

In addition to supporting existing advanced manufacturing firms in the state, the URC assists with the development of new companies to commercialize the research of their universities. Between 2004 and 2008, the URC helped start an average of 20 start-up companies annually for the commercialization of research.[13] Advanced manufacturing R&D in the URC has generated many new technologies with commercial value. Below we provide examples from each of the URC universities.

Draths Corp. Draths Corp. was founded in 2005 to commercialize a suite of biobased materials technology developed in the laboratory of John Frost and Karen Draths at MSU and licensed by the university. The company's products enable nylons, plastics, paints, resins and other materials, currently made using petroleum-based chemicals, to be manufactured from renewable feedstocks. This breakthrough is accomplished through environmentally friendly and economical processes, allowing reduced carbon footprints without absorbing the higher costs generally associated with renewable initiatives.

Draths has raised $21 million in venture funding to commercialize chemical intermediates used to make nylon and other products with renewable resources instead of petrochemicals. Draths has been selected to receive Corp! Magazine's 2010 Science & Technology Award and has been highlighted in the March/April print issue as well as the April 29th digital edition. Expecting to add 200 new jobs, Draths also received a 10-year, $5.2 million Michigan Economic Growth Authority state tax credit to secure expansion operations near MSU in Delhi Township.

Niowave Inc. Niowave, Inc. is a high-tech research and manufacturing company that specializes in superconducting particle accelerators and their components. Located in Lansing, it was founded by Dr. Terry Grimm, who used his 13 years of experience at MSU's National Superconducting Cycoltron Laboratory to create his product. Advances in this technology during the past 10 years have opened up new opportunities such as the International Linear Collider, Rare Isotope Accelerator, spallation neutron sources, free electron lasers, and advanced light sources.

Niowave Inc. won two new contracts with the Department of Defense for a total potential value of more than $7 million. Both contracts are in support of the United States Navy's Free Electron Laser program. In 2009, Niowave successfully tested the first superconducting electron injector produced by private industry. The power coupler used in the 2009 test can handle up to a kilowatt, meaning the next generation power coupler will deliver 1,000 times more power to the accelerator. Niowave's contract will continue to push the technology to the megawatt power level required to effectively operate the Navy's Free Electron Laser.

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13. See Caroline M. Sallee and Patrick L. Anderson, *Empowering Michigan: Third Annual Economic Impact Report of Michigan's University Research Corridor*, September 28, 2009.

Sakti3. Sakti3 was founded in 2007 by Ann Marie Sastry who is the Director of the Energy Systems Engineering Program at U-M. Sakti3 is developing solid-state lithium ion battery systems for the hybrid and electric vehicle markets as well as the advanced manufacturing processes of batteries overall. Sakti3 has raised $7 million in venture capital investment, $3 million in grant money from Michigan's Centers of Energy Excellence program, and received a Michigan Economic Growth Authority tax credit valued at up to $2.3 million. In addition, Sastry has launched a battery system graduate program to support the continued workforce needs of the sector.

Flexsys Inc. Flexsys was founded in 2001 by U-M professor Sridhar Kota and is today an established global leader in shape-adaptive structures and developing compliant systems. Kota developed proprietary systems and software for creation and optimization of compliant systems. These technologies, licensed by U-M to Flexsys, have successfully demonstrated the application of compliant design methods for aerospace, automotive, and other applications over the years.

Product examples include advanced airfoils for air planes and helicopters, windshield wipers, advanced actuators, and, most recently, very promising wind turbine blades. In detailed analysis and simulations conducted by Sandia National Labs, the FlexSys blades reduced structural loads and fatigue levels by 80 percent and increased energy capture rates by 20 percent. In addition to its products and proprietary software tools, FlexSys has a suite of commercial CAD/CAE tools for advanced modeling and analysis and extensive experience with materials, manufacturing techniques, and control systems for fabrication and testing of functional prototypes.

Visca, LLC. Visca, LLC was co-founded in 2004 by Dr. Gregory Auner, a professor in the Electrical and Computer Engineering Department and the director of the SSIM program. Visca is as a WSU-SSIM spin-off company and is located in TechTown in Detroit, Michigan. Visca develops microsensors and microsystems for applications ranging from spectroscopic analysis, lab on a chip, vehicle diagnostics and prognostics. Visca has received two Phase II SBIR's and a Phase III SBIR from the Department of Defense for developing platform devices in robotic and unmanned systems as well as industrial contracts for water monitoring microsystems. Recently, Visca was awarded the first option of a $36.3 million dollar Department of Health and Human Services contract for the development of a point of care or high-throughput biological assays for determining absorbed ionizing radiation dose (biodosimetry) after radiologic and nuclear events.

SenSound, LLC. SenSound is a privately held company based in Detroit, Michigan founded on patented technology initially developed in the College of Engineering at Wayne State University. SenSound diagnostic software creates three-dimensional digital images of sound as it travels through space and time. The software is unique in its ability to quickly, accurately, and cost effectively map sound sources on arbitrary three-dimensional surfaces. SenSound quality control software distinguishes between environmental noise and source object noise without the need for sound enclosures. SenSound technology has broad applications in product design, development, and manufacturing where noise needs to be identified, understood, and eliminated, or where manufacturing and component defects need to be identified.

URC IS EDUCATING THE NEXT LEADERS IN ADVANCED MANUFACTURING

Beyond supporting existing advanced manufacturing firms and creating new ones, the URC plays an important role in creating and sustaining the state's human capital in the industry. In short, URC universities are educating the next leaders in manufacturing. Engineering programs play an important role in this. All three URC universities have engineering programs. At U-M, approximately 8,000 graduate and undergraduate students are enrolled in engineering programs, most of which are ranked in the top 5 nationally. Michigan State has more than 3,000 undergraduate students and 772 graduate students in its nine programs. Wayne State's College of Engineering has more than 2,600 undergraduate and graduate students; most of these students (75%) will work in Michigan upon graduation.

Programs at URC Universities

The URC universities have programs that prepare students for careers in advanced manufacturing. Below we highlight some of these programs at the URC universities.

U-M has many degree programs including:

- Manufacturing Engineering Program
  U-M offers multiple academic degrees directly involving manufacturing. Students can choose to take program courses on-campus, online, or both. Specific programs include:
- Doctor of Engineering in Manufacturing
  The Doctor of Engineering includes a mix of engineering and business classes that prepare the student for a successful career in national or global manufacturing enterprises, higher education, or government.
- Joint Master of Engineering in Manufacturing/MBA
  With its first-class College of Engineering and the highly ranked Stephen M. Ross School of Business, U-M is uniquely positioned to prepare engineers to lead manufacturing enterprises.
- Master of Engineering in Manufacturing
  Today's increasingly competitive business climate has presented unprecedented challenges to manufacturers. Intense pressure and globalization have created urgent needs to restructure and redefine manufacturing processes. To be successful and effective, the manufacturing engineer of the 21st century must be well-educated technically and have a solid understanding of business and management fundamentals and tools.
- Sequential Graduate/Undergraduate program
  U-M College of Engineering undergraduates can obtain both a Bachelor of Science in Engineering and a Master of Engineering in Manufacturing in five years through this program.
- Master of Engineering in Global Automotive and Manufacturing Engineering
  The Master of Engineering in Global Automotive and Manufacturing Engineering program is strategically designed to build and develop a global organiza-

tional capability and profound knowledge in areas core to industry. This is the only engineering master's program that brings together people from both the product development and manufacturing areas within a global context. The aim of the program is to develop technical leaders who understand the total process of product creation, and who possess both the breadth and depth in engineering disciplines as well as management skills. The program provides students with the opportunity to work on a team project in a globally structured environment. Students who graduate from this program will have the skills necessary to guide product and process development and manufacturing in this exciting global industry.

- Executive Professional and Continuing Education

  Taught by internationally respected industrial engineering professors and research scientists, these programs are available online with streaming video enabling professionals to take classes whenever and wherever they chose. The program structure provides professional online user support and direct email communication with faculty for a seamless learning experience. More than 8,500 students have been certified through the programs. Course examples include Lean Manufacturing Certification, Six Sigma, Lean Product Development, and Supply Chain and Warehouse Management Certification

MSU has several programs that prepare students for careers in manufacturing. These include:

- Supply Chain Management/Logistics Program
  The Department of Supply Chain Management is widely acknowledged by industry and academia as the leader in dissemination of procurement, manufacturing and logistics knowledge. The program integrates topics from manufacturing operations, purchasing, transportation, and physical distribution into a unified course of study. Its graduate program was recently ranked No. 2 in the nation by U.S. News and World Report.
- School of Packaging
  The MSU School of Packaging supports the industry of packaging by educating students, conducting research to solve packaging problems, and developing new technology which can be used by the industry. The program offers a variety of services, from design and sample making to processing and testing. Projects range from standardized testing to custom studies that may take several months.
- Industrial and Organizational Psychology Program
  U.S. News and World Report ranks MSU's graduate program in industrial and organizational psychology No. 1 in the nation. Industrial and organizational psychology is the scientific study of the workplace. Rigor and methods of psychology are applied to issues of critical relevance to business, including talent management, coaching, assessment, selection, training, organizational development, performance, and work-life balance.

Wayne State University has a number of specific programs that prepare students for advanced manufacturing careers. These programs include:

- Department of Industrial and Manufacturing Engineering

  The Department of Industrial and Manufacturing Engineering develops engineers in production, quality, management, human factors productivity, and process across manufacturing, health care, and transportation industries. The department focuses on efficiency, productivity, quality standards, Six-Sigma principles, facility layout, work flow and productivity, transportation, and production scheduling. Company partnerships include Ford Motor Company, General Motors, General Dynamics, and Arvin Meritor.

- Professional Engineering Management Master's Program

  The Engineering Management Master's Program (EMMP) is a unique program that capitalizes on the synergy between the College of Engineering and the School of Business Administration at Wayne State University. The engineering management core covers subjects that are important to managing an engineering, manufacturing, or technical function. The business core presents an overview of business topics critical to the engineering manager. Courses cover analysis and system design tools supporting strategies for success.

  The program faculty and advisors are industry experts with many years of experience in the automotive industry. The program combines the latest developments from the academic disciplines of business and engineering with leadership experience in complex product development and manufacturing organizations. Admission to EMMP is by company management nomination only. Candidates must have an undergraduate degree in engineering (preferred) or another discipline with a significant course load in mathematics, and at least three years of full-time engineering work experience. Engineers participate in a three year, two evenings per week curriculum. They earn a Master's of Science in Engineering Management degree upon completion. During the third year of the program, teams of three to five students work on strategic issues of major concern to the company in the context of a Leadership Project.

- Alternative Energy Technology Graduate Program

  Established in 2004 as a graduate program, Wayne State University became one of the first universities in the nation to offer a degree in alternative energy. The curriculum concentrates on systems, control, and infrastructure across a wide range of alternative energy technologies.

- Advanced Battery Systems for Hybrid Electric Vehicles Courses

  This partnership with the Michigan Department of Energy, Labor, and Economic Growth was established to train hybrid electric vehicle (HEV) engineers for the automotive industry's transition to manufacturing more advanced, fuel-efficient vehicles. Graduate-level courses in advanced battery systems for HEV's will familiarize students with battery system design, applications, and interconnectivity with other operating systems in HEVs. The courses target employed automotive engineers as well as displaced workers who meet prerequisites. The program will be team-taught by engineering faculty, HEV engineers from Delphi and General Motors, and battery scientists from Ovonic Battery.

- Nanotechnology Program

  Wayne State has a strong nanotechnology program, particularly in the area of creating adaptive nanomaterials for sensing and drug delivery. A large multidisciplinary team from across WSU's campus, as well as the Detroit Medical Center and Henry Ford Health System, are leading initiatives in nanotechnology. This team of researchers is working to develop nanomaterials that respond and adapt to environmental and biological conditions and have features applicable to sensing and translational medicine. Wayne State aims to catalyze these efforts into educational components for science engineering, pharmaceutical, and medical students.

Education Partnerships

The URC universities have created several educational partnerships with private industry. The purpose of these partnerships is to match education with industry need. Below we provide a few examples of these partnerships in advanced manufacturing.

Partners for the Advancement of Collaborative Engineering Education (PACE). The PACE Program enables college students to learn and train on the same cutting-edge, math-based systems GM engineers use in the workplace to take a vehicle concept through its entire lifecycle. Product Lifecycle Management, is a core concept within PACE. It relates to all aspects of a product's life from its design inception, through its manufacture, marketing, distribution, maintenance, and finally into recycling, disposal, and sustainability. The experience of working with these cutting edge tools not only carries over to GM global operations, but is used by the world's leading manufacturing companies in the aero, medical, and consumer industries.

DTE Energy - Wayne State University Master Black Belt Certification Program. This new partnership and program offers an advanced certificate program that involves 18 credits and leads to the status of Master Black Belt. A Master Black Belt is a significant certification in the six sigma methodology, which is a set of practices designed to improve business processes and eliminate defects and inefficiencies.

Wayne State Electric-Drive Vehicle Engineering Program with Next Energy and Macomb Community College. Electrifying the Economy, Educating the Workforce (E3) is an electric drive vehicle engineering program and partnership between Wayne State University, NextEnergy, and Macomb Community College. Supported by a $5 million U.S. Department of Energy grant funded by the American Recovery and Reinvestment Act, the program will develop and implement a comprehensive set of advanced educational programs in electric drive vehicles. Programs will include a master's degree in electric drive vehicle engineering, a bachelor's degree in electric transportation technology, an associate's degree in automotive technology and electronic engineering technology, and an undergraduate concentration and graduate certificate program in electric drive vehicle engineering. In addition, the program will host national workshops, provide education for the general public, K-12 teachers, and first responders, and create a website to serve as a main portal of the most comprehensive and up-to-date information in electric drive vehicle technology and educational programs in the nation.

Advanced Manufacturing Policy Positions

URC professors are also advising the President on advanced manufacturing policy. U-M Mechanical Engineering professor Sridhar Kota is currently serving as the assistant director of advanced manufacturing and ASME Fellow at the White House Office of Science and Technology Policy (OSTP) in Washington, DC. OSTP advises the President on the effects of science and technology on domestic and international affairs. As assistant director, Dr. Kota's responsibilities focus primarily on identifying promising technologies and effective strategies to strengthen the nation's manufacturing base. He looks for gaps in current federal research and development in advanced manufacturing and works to develop strategies to address these gaps. He develops policy recommendations to foster commercialization and manufacturing of advanced technologies. This position holds special significance in light of the country's current economic condition, as the need to create domestic manufacturing jobs is crucial.

Appendix A: Methodology

We comprehensively defined the advanced manufacturing industry using the North American Industry Classification System (NAICS) codes, which is how the U.S. Census Bureau reports industry data. Because there is no universally accepted definition of advanced manufacturing, we employed the methodology described in this section to arrive at a comprehensive industry definition.

After establishing the industry definition, we used U.S. Census County Business Patterns data on employment and payroll in past years (2003 and 2007) to describe the advanced manufacturing industry nationally, regionally and in Michigan. For those NAICS codes for which employment and payroll information were unavailable, we employed the estimating techniques described in this section to make accurate payroll and employment estimates.

DEFINING THE ADVANCED MANUFACTURING INDUSTRY

We followed the process below to define the advanced manufacturing industry.

Surveyed existing definitions. We reviewed definitions of advanced manufacturing used in previous Anderson Economic Group reports, by industry leaders, the U.S. Employment and Training Administration (ETA), as well as the U.S. Bureau of Labor and Statistics. These definitions vary with some focusing solely on new technology, design, and high-tech processes and others on the products themselves.

Using those definitions and identifying what activity we wished to capture in Michigan, we developed a definition for the advanced manufacturing industry. This definition includes firms that create advanced products, use innovative techniques in their manufacturing, and are inventing new processes and technologies for future manufacturing.

Selection Process. We began with all manufacturing NAICS codes (31-33) present in Michigan, the advanced manufacturing cluster in AEG's annual *Automation Alley Technology Industry* report, and other research relevant sectors that support advanced or advancing manufacturing. Our definition includes each NAICS industry that met at least one of the following criteria:

1. *Sectors that manufacture high-tech products*
   We included industries in our definition that were part of our advanced manufacturing cluster in the annual technology study for Automation Alley. These industries were included because they had already been subject to a series of test to determine if they were producing high-tech products or using high-tech processes. Industries were also included if they appeared in the U.S. Department of Commerce high-tech definition, and if the industry had more than double the national average of workers in technology-oriented occupations. To see those industries selected by this criteria see Appendix Table A-1, "Industries Included in URC Definition of Advanced Manufacturing," on page A-5.

2. *Sectors whose productivity is greater than the average U.S. manufacturing firm.*

Building upon an advanced manufacturing study in Indiana, we analyzed the productivity of manufacturing industries based on the following assumption: Firms engaged in advanced manufacturing would be more productive.[14] We used productivity ratios to determine which NAICS codes to include under this criterion. We analyzed the productivity for the advanced manufacturing industry using two different measures: value added per worker and value added per production workers' wages. We used data from the Census Bureau Annual Survey of Manufacturers (ASM). The ASM defines value added as the value of shipments (products manufactured plus receipts for services rendered) less cost of materials, supplies, containers, fuel, purchased electricity, and contract work. Value added is considered to be the best measure available for comparing relative economic performance of manufacturing among industries.[15] We calculated "Productivity Ratio M" by dividing each industry's value added by its production workers' annual wages.[16] We calculated "Productivity Ratio P" by dividing each sector's value added by its number of production workers.[17]

Table A-2 on page A-6 shows the industries whose productivity on one of these measures was greater than the average productivity of the U.S. manufacturing sector as a whole. An industry with productivity lower than that particular industry's productivity nationwide was still included if the industry in Michigan exceeded the U.S. average for the entire manufacturing sector. To see those industries selected through by this criteria see Table A-1 on page A-5.

3. *Sectors whose productivity growth was significantly faster than the average U.S. manufacturing firm between 2003-2008.*

We included in our definition manufacturing industries whose productivity increased at a faster rate than the U.S. manufacturing sector as a whole. To measure increases in productivity, we analyzed the overall change on our two productivity ratios between 2003 and 2008. The manufacturing sectors that accelerated faster than the average productivity ratio for manufacturing in the U.S. were included in our definition. See Table A-3 on page A-7.

4. *Sectors that cultivate and/or invent the processes and solutions for future manufacturing.*

We included firms that are cultivating the processes and products through research and testing for future manufacturing. By examining definitions and occupations within sectors, we included several sectors that lack "manufactur-

14. The study, "A Link Between Advanced Manufacturing and Productivity", was conducted by the Research Office of the Indiana Chamber of Commerce by their senior economist Ted Jockel.

15. U.S. Census Bureau, detailed statistics, definition of value added.

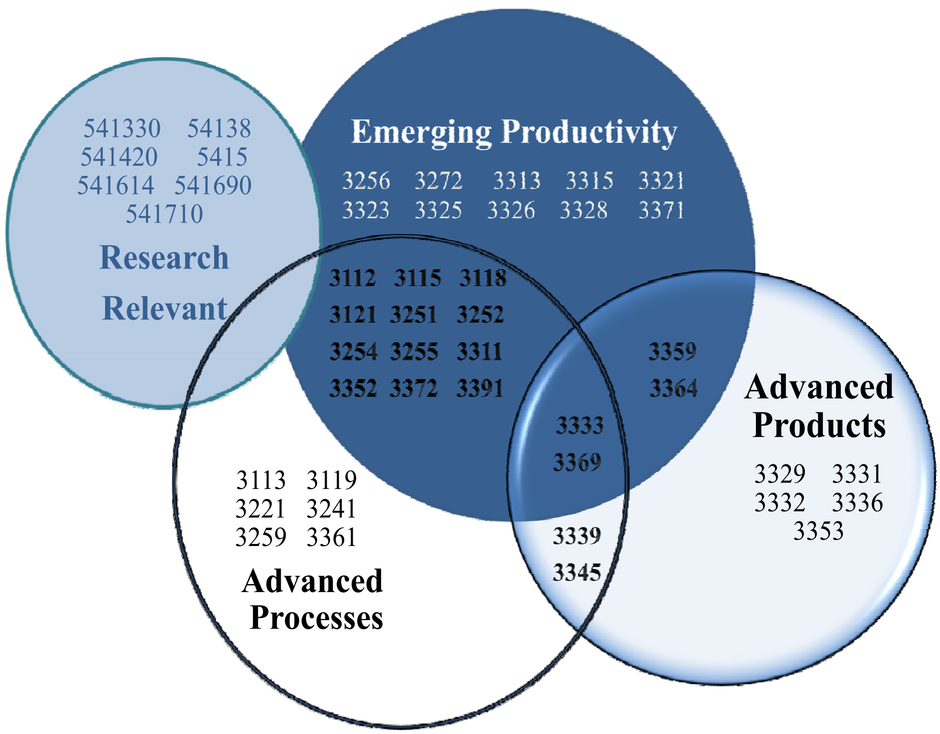
16. This denominator includes the gross earnings of all production workers on the payrolls of operating manufacturing establishments paid in the calendar year.

17. This is limited to the average number of production workers (not total employees) at a given firm in a year.

ing" in their titles, yet still play a vital role in advanced manufacturing. Research and development is one such example.

These criteria also acted as grouping mechanisms, forming three clusters: advanced products and processes (APP), emerging manufacturing, and research relevant. Figure 12 below shows all the NAICS codes contained within the advanced manufacturing industry and which criteria they met. The NAICS codes in black text are included in the APP cluster by meeting more than one criteria or using advanced processes or products. The emerging manufacturing cluster has NAICS codes in white and the research relevant NAICS codes, which reside exclusively in the research relevant circle, are in blue.

FIGURE 12. Advanced Manufacturing Industry Criteria



Source: Anderson Economic Group, LLC

ESTIMATING MISSING EMPLOYMENT AND PAYROLL DATA

For some NAICS industries, specific employment and payroll data were withheld by the Census. In total, 20 codes required AEG estimation for one or both of the years reported. We used the following methodology to estimate missing employment and payroll data.

Employment Numbers. The Census Bureau often withholds specific payroll and employment data when releasing it would provide information about individual businesses. Instead of a specific number, a range is given for the employment.

When confronted with this situation, we looked at the total employment in the three or five digit NAICS category (depending on the code in question). We used this total number, and any more detailed subcategory data given for the industry, to determine an appropriate estimate for the industry without an exact employment figure. We then checked these figures in relation to previous or subsequent years to determine if it followed the trend of the NAICS industry in question. This allowed us to make our estimate as precise as possible.

Payroll Data. For missing payroll numbers we used the average wage of the first available higher level of industry data (three digit industries) provided. Occasionally when payroll information was given for several years, but not for one year, we used the industry average of the year closest to it in order to estimate total payroll. Note we were only able to use prior years where NAICS codes remained unchanged (many NAICS code classifications changed between 2002 and 2003).

Table A-1 Industries Included in URC Definition of Advanced Manufacturing

NAICS	Description	Productivity Ratio	Emerging Productivity	Auto Alley Definition	Research Relevant
3112	Grain & Oilseed Milling	X	X		
3113	Sugar & Confectionery Product Mfg	X			
3115	Dairy Product Mfg	X	X		
3118	Bakeries & Tortilla Mfg	X	X		
3119	Other Food Mfg	X			
3121	Beverage Mfg	X	X		
3221	Pulp, Paper & Paperboard Mills	X			
3241	Petroleum & Coal Products Mfg	X			
3251	Basic Chemical Mfg	X	X		
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg	X	X		
3254	Pharmaceutical & Medicine Mfg	X	X		
3255	Paint, Coating & Adhesive Mfg	X	X		
3256	Soap, Cleaning Compound, & Toilet Preparation mfg		X		
3259	Other Chemical Product & Prep Mfg	X			
3272	Glass & Glass Product Mfg		X		
3311	Iron & Steel Mills & Ferroalloy Mfg	X	X		
3313	Alumina & Aluminum Production & Processing		X		
3314	Nonferrous Metal (except aluminum) Production	X	X		
3315	Foundries		X		
3321	Forging & Stamping		X		
3323	Architectural & Structural Metals Mfg		X		
3325	Hardware Mfg		X		
3326	Spring & Wire Product Mfg		X		
3328	Coating, Engraving, Heat Treating, & Allied Activities		X		
3329	Other Fabricated Metal Product Mfg			X	
3331	Agriculture, Construction & Mining Machinery Mfg			X	
3332	Industrial Machinery Mfg			X	
3333	Commercial & Service Industry Machinery Mfg	X	X	X	
3336	Engine, Turbine & Power Transmission Mfg			X	
3339	Other General Purpose Machinery Mfg	X		X	
3345	Navigational, Measuring, Medical & Control Instruments Mfg	X		X	
3352	Household Appliance Mfg	X	X		
3353	Electrical Equipment Mfg			X	
3359	Other Electrical Equipment & Component Mfg		X	X	
3361	Motor Vehicle Mfg	X			
3364	Aerospace product & parts mfg		X	X	
3369	Other Transportation Equipment Mfg	X	X	X	
3371	Household & Institutional Furniture & Kitchen Cabinet mfg		X		
3372	Office Furniture (including fixtures)	X	X		
3391	Medical Equipment & Supplies Mfg	X	X		
541330	Engineering Services				X
54138	Testing Laboratories				X
541420	Industrial Design Services				X
5415	Computer Systems Design & Related Services				X
541614	Process, Physical Distribution & Logistics Consulting Services				X
541690	Scientific & Technical Consulting Services				X
541710	R&D in Physical, Engineering & Life Sciences				X

Source: Anderson Economic Group, LLC

Table A-2. Productivity of Manufacturing Industry Sectors, 2008

Industry included as advanced, if greater than U.S. average productivity ratio for manufacturing industries

		Productivity Ratio M ($Value Added/$Production Worker Wages) US manufacturing average: 6.49		Productivity Ratio P ($Value Added/Production Workers) US manufacturing average: 254.60		Industry Inclusion Based on
NAICS	Description	MI	U.S	MI	U.S	(M, P or both)
3112	Grain & Oilseed Milling	11.40	15.35	$ 609.63	$ 734.15	M,P
3113	Sugar & Confectionery Product Mfg	8.45	7.26	$ 266.10	$ 278.56	M,P
3115	Dairy Product Mfg	19.78	6.94	$ 951.97	$ 283.23	M,P
3118	Bakeries & Tortilla Mfg	8.28	6.35	$ 269.28	$ 197.36	M,P
3119	Other Food Mfg	9.31	11.85	$ 256.67	$ 366.88	M,P
3121	Beverage Mfg	15.62	14.41	$ 700.37	$ 609.91	M,P
3221	Pulp, Paper & Paperboard Mills	4.65	6.96	$ 265.40	$ 432.60	P
3241	Petroleum & Coal Products Mfg	7.10	18.85	$ 414.91	$ 1,342.93	M,P
3251	Basic Chemical Mfg	8.34	13.68	$ 520.36	$ 906.03	M,P
3252	Resin, synthetic rubber, & artificial & synthetic fibers & filaments mfg	6.21	8.35	$ 365.42	$ 427.26	P
3254	Pharmaceutical & Medicine Mfg	13.49	23.48	$ 677.35	$ 1,212.01	M,P
3255	Paint, Coating & Adhesive Mfg	11.10	10.38	$ 461.34	$ 428.67	M,P
3259	Other chemical product & prep mfg	6.80	8.02	$ 288.07	$ 350.54	M,P
3311	Iron & steel mills & ferroalloy mfg	5.17	7.36	$ 345.49	$ 492.53	P
3314	Nonferrous metal (except aluminum) production	15.73	7.70	$ 744.78	$ 364.62	M,P
3333	Commercial & service industry machinery mfg	7.50	6.63	$ 245.92	$ 253.38	M
3339	Other general purpose machinery mfg	5.48	6.07	$ 262.05	$ 245.89	P
3345	Navigational, measuring, medical & control instruments mfg	5.19	12.38	$ 265.64	$ 584.77	P
3352	Household appliance mfg	7.11	5.34	$ 271.19	$ 184.48	M,P
3361	Motor vehicle mfg	5.76	5.57	$ 446.79	$ 375.11	P
3369	Other transportation equipment mfg	11.21	9.15	$ 398.51	$ 368.53	M,P
3372	Office furniture (including fixtures)	9.00	4.84	$ 338.69	$ 159.72	M,P
3391	Medical equipment & supplies mfg	9.59	9.24	$ 306.48	$ 320.97	M,P

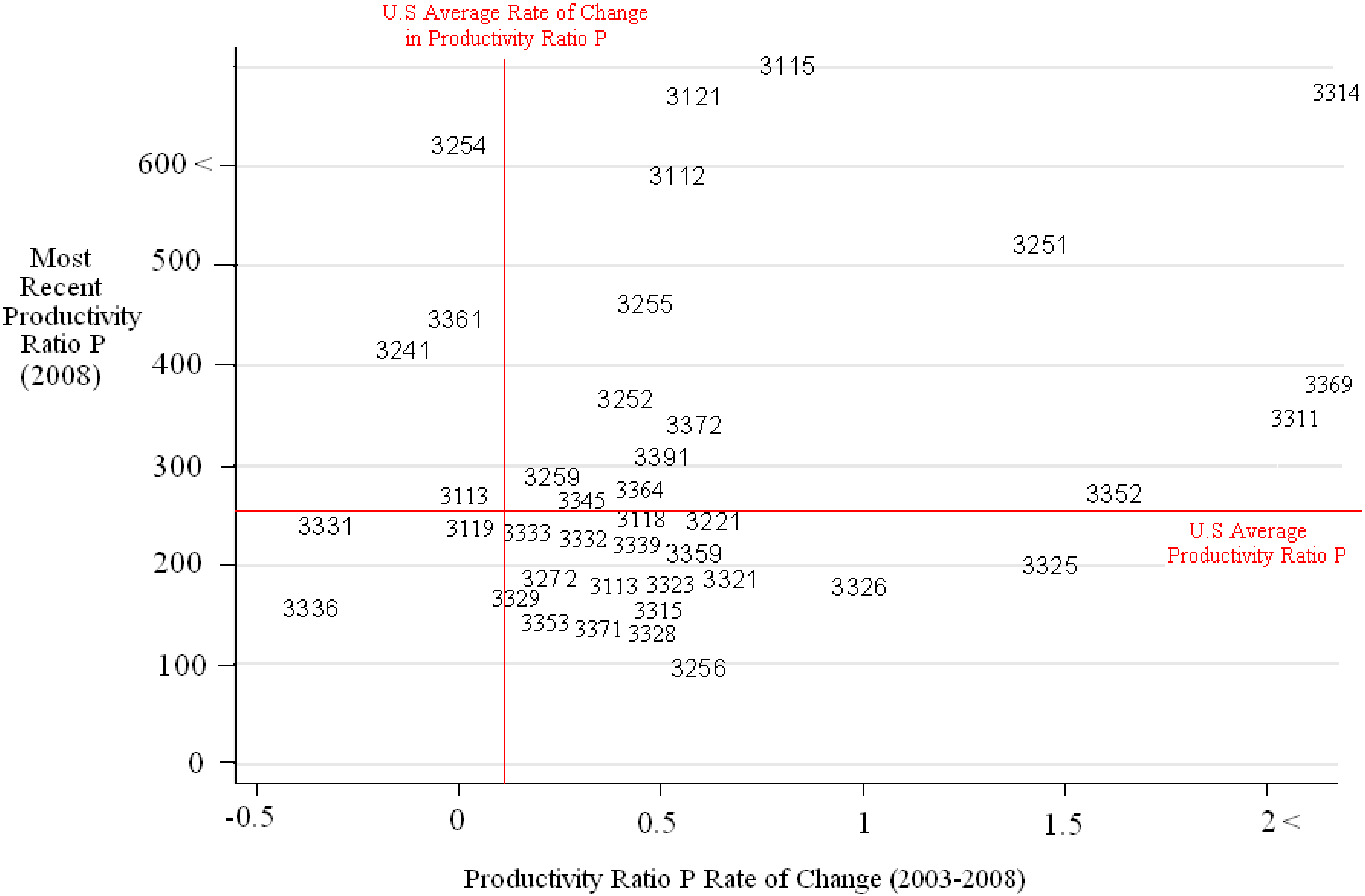
Source: Analysis by Anderson Economic Group, LLC of 2008 U.S Census Bureau data

Table A-3. Increase in Productivity of Manufacturing Industry Sectors in Michigan, 2003-2008

Industry is included as emerging, if greater than the U.S. average rate of productivity increase in manufacturing industries

		Productivity Ratio M ($Value Added/$Production Worker Wages) Average U.S Manufacturing Productivity Increase: 14%			Productivity Ratio P ($Value Added/Production Worker) Average U.S Manufacturing Productivity Increase: 30%		
NAICS	**Description**	**MI 03**	**MI 08**	**% Change**	**MI 03**	**MI 08**	**% Change**
3112	Grain & Oilseed Milling	8.47	11.40	35%	$ 422.92	$ 609.63	44%
3115	Dairy Product Mfg	14.86	19.78	33%	$ 555.21	$ 951.97	71%
3118	Bakeries & Tortilla Mfg	7.23	8.28	14%	$ 217.41	$ 269.28	24%
3121	Beverage Mfg	13.56	15.62	15%	$ 474.18	$ 700.37	48%
3251	Basic Chemical Mfg	3.74	8.34	123%	$ 222.74	$ 520.36	134%
3252	Resin, Syn rubber, & Artificial Syn Fibers & Filaments Mfg	6.08	6.21	2%	$ 278.74	$ 365.42	31%
3255	Paint, Coating, & Adhesive Nfg	8.86	11.10	25%	$ 339.60	$ 461.34	36%
3256	Soap, Cleaning Compound, & Toilet Preparation Mfg	1.42	2.42	70%	$ 64.36	$ 96.15	49%
3272	Glass & Glass Product Mfg	4.54	5.90	30%	$ 165.99	$ 185.23	12%
3311	Iron & Steel Mills & Ferroalloy Mfg	2.25	5.17	130%	$ 108.10	$ 345.49	220%
3313	Alumina & Aluminum Production & Processing	3.74	4.42	18%	$ 127.96	$ 169.46	32%
3314	Nonferrous Metal (except aluminum) Production & Processing	3.91	15.73	302%	$ 150.21	$ 744.78	396%
3315	Foundries	2.54	3.40	34%	$ 111.08	$ 152.74	37%
3321	Forging & Stamping	3.28	4.74	44%	$ 117.34	$ 183.26	56%
3323	Architectural & Structural Metals Mfg	3.67	4.71	28%	$ 125.76	$ 178.98	42%
3325	Hardware Mfg	3.09	6.35	105%	$ 84.23	$ 198.45	136%
3326	Spring & Wire Product Mfg	3.27	5.29	62%	$ 93.94	$ 177.92	89%
3328	Coating, Engraving, Heat Treating, & Allied Activities	3.38	4.06	20%	$ 101.83	$ 131.82	29%
3333	Commercial & Service Industry Machinery Mfg	4.49	7.50	67%	$ 160.25	$ 245.92	53%
3352	Household Appliance Mfg	3.08	7.11	131%	$ 107.47	$ 271.19	152%
3359	Other Electrical Equipment & Component Mfg	4.33	5.53	28%	$ 142.37	$ 211.21	48%
3364	Aerospace Product & Parts Mfg	4.43	5.17	17%	$ 194.57	$ 248.13	28%
3369	Other Transportation Equipment Mfg	4.10	11.21	174%	$ 119.62	$ 398.51	233%
3371	Household & Institutional Furniture & Kitchen Cabinet Mfg	3.71	3.67	-1%	$ 98.03	$ 127.48	30%
3372	Office Furniture (including fixtures) Mfg	7.35	9.00	22%	$ 228.35	$ 338.69	48%
3391	Medical Equipment & Supplies Mfg	7.36	9.59	30%	$ 218.72	$ 306.48	40%

Source: Analysis by Anderson Economic Group, LLC of 2008 & 2003 U.S Census Bureau data


U.S Average Rate of Change in Productivity Ratio P
U.S Average Productivity Ratio P
Most Recent Productivity Ratio P (2008)
Productivity Ratio P Rate of Change (2003-2008)
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500
400
300
200
100
0
-0.5
0
0.5
1
1.5
2 <
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Appendix B: Exhibits

The following exhibits are included in this section:

1. Table B-1, "Employment & Payroll in Michigan's Advanced Manufacturing Industries," on page B-2
2. Table B-2, "Advanced Manufacturing Payroll in Michigan, Midwest, and United States, 2007," on page B-3
3. Table B-3, "Advanced Manufacturing Payroll in Michigan, Midwest, and United States, 2003," on page B-4
4. Table B-4, "Advanced Manufacturing Employment in Michigan, Midwest, and United States, 2007," on page B-5
5. Table B-5, "Advanced Manufacturing Employment in Michigan, Midwest, and United States, 2003," on page B-6

Appendix Table B-1: Employment & Payroll in Michigan's Advanced Manufacturing Industries

Cluster	Industry Description	Employees 2003	Employees 2007	Annual Payroll (thousands) 2003	Annual Payroll (thousands) 2007
Advanced Products & Processes					
3112	Grain & Oilseed Milling	2,854	1,886	$ 142,070	$ 118,528
3113	Sugar & Confectionery Product Mfg	1,449	1,369	$ 37,904	$ 45,960
3115	Dairy Product Mfg	5,122	4,096	$ 210,645	$ 196,042
3118	Bakeries & Tortilla Mfg	7,444	6,205	$ 202,828	$ 192,254
3119	Other Food Mfg	3,317	3,025	$ 107,049	$ 110,788
3121	Beverage Mfg	4,017	4,171	$ 148,518	$ 181,217
3221	Pulp, Paper & Paperboard Mills	5,781	4,516	$ 329,526	$ 288,166
3241	Petroleum & Coal Products Mfg	1,323	1,642	$ 96,673	$ 117,126
3251	Basic Chemical Mfg	5,638	3,951	$ 361,478	$ 277,924
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg	3,614	4,710	$ 230,081	$ 363,196
3254	Pharmaceutical & Medicine Mfg	7,821	6,973	$ 409,655	$ 469,093
3255	Paint, Coating & Adhesive Mfg	4,139	3,662	$ 200,861	$ 205,174
3259	Other Chemical Product & Prep Mfg	3,701	3,521	$ 179,700	$ 200,324
3311	Iron & Steel Mills & Ferroalloy Mfg	5,752	4,194	$ 338,603	$ 287,867
3314	Nonferrous Metal (except aluminum) Production	2,026	1,933	$ 86,983	$ 118,203
3329	Other Fabricated Metal Product Mfg	14,927	12,840	$ 589,351	$ 561,613
3331	Agriculture, Construction & Mining Machinery Mfg	2,110	2,650	$ 82,470	$ 128,088
3332	Industrial Machinery Mfg	6,904	6,182	$ 338,839	$ 320,391
3333	Commercial & Service Industry Machinery Mfg	2,051	2,050	$ 82,179	$ 95,473
3336	Engine, Turbine & Power Transmission Mfg	7,588	6,385	$ 425,693	$ 412,428
3339	Other General Purpose Machinery Mfg	19,582	18,426	$ 1,109,199	$ 1,135,454
3345	Navigational, Measuring, Medical & Control Instruments Mfg	9,525	11,257	$ 498,313	$ 700,900
3352	Household Appliance Mfg	4,083	1,509	$ 156,603	$ 99,482
3353	Electrical Equipment Mfg	3,395	2,385	$ 138,848	$ 114,884
3359	Other Electrical Equipment & Component Mfg	4,196	3,323	$ 155,843	$ 145,468
3361	Motor Vehicle Mfg	43,447	39,870	$ 3,125,751	$ 3,122,161
3364	Aerospace product & parts mfg	3,749	3,510	$ 193,535	$ 223,445
3369	Other Transportation Equipment Mfg	1,826	2,438	$ 68,071	$ 103,960
3372	Office Furniture (including fixtures)	20,964	15,374	$ 807,275	$ 836,939
3391	Medical Equipment & Supplies Mfg	7,606	8,434	$ 356,438	$ 418,291
Total		**215,951**	**192,487**	**$ 11,210,982**	**$ 11,590,839**
Emerging Manufacturing					
3256	Soap, Cleaning Compound, & Toilet Preparation	3,710	3,160	$ 260,403	$ 140,013
3272	Glass & Glass Product Mfg	7,021	6,254	$ 319,295	$ 266,844
3313	Alumina & Aluminum Production & Processing	2,991	2,707	$ 115,899	$ 123,608
3315	Foundries	16,029	12,027	$ 734,015	$ 574,205

Appendix Table B-1: Employment & Payroll in Michigan's Advanced Manufacturing Industries

		Employees		Annual Payroll (thousands)	
Cluster	Industry Description	2003	2007	2003	2007
3321	Forging & Stamping	6,034	6,110	$ 245,157	$ 278,206
3323	Architectural & Structural Metals Mfg	10,049	8,977	$ 405,810	$ 391,697
3325	Hardware Mfg	6,544	2,445	$ 256,473	$ 109,459
3326	Spring & Wire Product Mfg	2,899	2,551	$ 108,380	$ 102,967
3328	Coating, Engraving, Heat Treating, & Allied Activities	14,671	13,602	$ 496,936	$ 526,579
3371	Household & Institutional Furniture & Kitchen Cabinet mfg	7,509	6,421	$ 242,925	$ 233,558
Total		**77,457**	**64,254**	**$ 3,185,293**	**$ 2,747,136**
Research Relevant					
541330	Engineering Services	55,246	50,494	$ 3,861,488	$ 3,870,315
54138	Testing Laboratories	6,000	4,864	$ 380,399	$ 331,173
541420	Industrial Design Services	1,018	1,052	$ 56,690	$ 52,461
5415	Computer Systems Design & Related Services	25,213	29,749	$ 1,590,767	$ 1,888,446
541614	Process, Physical Distribution & Logistics Consulting Services	3,745	3,949	$ 155,892	$ 215,146
541690	Scientific & Technical Consulting Services	1,334	1,373	$ 69,446	$ 69,600
541710	R&D in Physical, Engineering & Life Sciences	40,142	33,129	$ 3,764,067	$ 3,688,034
Total		**132,698**	**124,610**	**$ 9,878,749**	**$ 10,115,175**
MI Advanced Manufacturing Industry Totals		**426,106**	**381,351**	**$ 24,275,024**	**$ 24,453,150**

Appendix Table B-2: Advanced Manfacturing Payroll in Michigan, Midwest, and United States, 2007

Cluster	Industry Description	Michigan	Midwest: Illinois	Midwest: Indiana	Midwest: Ohio	Midwest: Wisconsin	Entire Midwest	U.S
Advanced Products & Processes								
3112	Grain & Oilseed Milling	$ 118,528	$ 378,607	$ 158,215	$ 130,512	$ 65,672	$ 851,534	$ 2,952,628
3113	Sugar & Confectionery Product Mfg	$ 45,960	$ 414,354	$ 43,493	$ 51,804	$ 92,829	$ 648,440	$ 2,890,080
3115	Dairy Product Mfg	$ 196,042	$ 211,698	$ 119,357	$ 7,772	$ 752,221	$ 1,287,090	$ 5,683,054
3118	Bakeries & Tortilla Mfg	$ 192,254	$ 583,201	$ 280,852	$ 3,059	$ 144,783	$ 1,204,149	$ 8,931,469
3119	Other Food Mfg	$ 110,788	$ 482,601	$ 164,253	$ 4,910	$ 228,472	$ 991,024	$ 6,412,129
3121	Beverage Mfg	$ 181,217	$ 127,637	$ 185,748	$ 4,026	$ 130,879	$ 629,507	$ 6,546,129
3221	Pulp, Paper & Paperboard Mills	$ 288,166	$ 48,454	$ 53,251	$ 1,286	$ 889,018	$ 1,280,175	$ 8,244,556
3241	Petroleum & Coal Products Mfg	$ 117,126	$ 383,427	$ 243,176	$ 2,026	$ 45,952	$ 791,707	$ 8,510,322
3251	Basic Chemical Mfg	$ 277,924	$ 414,396	$ 161,118	$ 6,412	$ 97,615	$ 957,465	$ 11,619,628
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg	$ 363,196	$ 234,796	$ 202,350	$ 7,749	$ 71,347	$ 879,438	$ 5,623,367
3254	Pharmaceutical & Medicine Mfg	$ 469,093	$ 1,427,230	$ 855,855	$ 2,436	$ 155,662	$ 2,910,276	$ 18,915,925
3255	Paint, Coating & Adhesive Mfg	$ 205,174	$ 302,014	$ 79,689	$ 2,739	$ 125,781	$ 715,397	$ 3,292,590
3259	Other Chemical Product & Prep Mfg	$ 200,324	$ 248,017	$ 118,202	$ 3,984	$ 68,133	$ 638,660	$ 5,173,088
3311	Iron & Steel Mills & Ferroalloy Mfg	$ 287,867	$ 491,589	$ 1,344,381	$ 1,331	$ 51,044	$ 2,176,212	$ 7,482,425
3314	Nonferrous Metal (except aluminum) Production	$ 118,203	$ 349,092	$ 145,105	$ 7,883	$ 17,001	$ 637,284	$ 3,296,079
3329	Other Fabricated Metal Product Mfg	$ 561,613	$ 812,689	$ 441,274	$ 1,714	$ 422,095	$ 2,239,385	$ 12,346,796
3331	Agriculture, Construction & Mining Machinery Mfg	$ 128,088	$ 1,025,913	$ 156,306	$ 4,889	$ 743,726	$ 2,058,922	$ 9,788,712
3332	Industrial Machinery Mfg	$ 320,391	$ 392,989	$ 167,550	$ 1,893	$ 468,384	$ 1,351,207	$ 7,600,284
3333	Commercial & Service Industry Machinery Mfg	$ 95,473	$ 388,280	$ 97,107	$ 3,751	$ 142,429	$ 727,040	$ 4,829,321
3336	Engine, Turbine & Power Transmission Mfg	$ 412,428	$ 512,381	$ 438,349	$ 11,343	$ 506,053	$ 1,880,554	$ 5,165,796
3339	Other General Purpose Machinery Mfg	$ 1,135,454	$ 981,791	$ 410,478	$ 8,269	$ 656,510	$ 3,192,502	$ 14,756,026
3345	Navigational, Measuring, Medical & Control Instruments Mfg	$ 700,900	$ 828,611	$ 258,513	$ 5,350	$ 966,060	$ 2,759,434	$ 28,013,002
3352	Household Appliance Mfg	$ 99,482	$ 127,072	$ 136,972	$ 1,893	$ 216,312	$ 581,731	$ 2,568,869
3353	Electrical Equipment Mfg	$ 114,884	$ 569,317	$ 133,532	$ 1,429	$ 743,988	$ 1,563,150	$ 6,637,214
3359	Other Electrical Equipment & Component Mfg	$ 145,468	$ 353,223	$ 142,775	$ 35,627	$ 197,652	$ 874,745	$ 6,911,576
3361	Motor Vehicle Mfg	$ 3,122,161	$ 548,963	$ 1,019,847	$ 2,820	$ 380,067	$ 5,073,858	$ 13,678,772
3364	Aerospace product & parts mfg	$ 223,445	$ 394,076	$ 546,601	$ 770	$ 13,858	$ 1,178,750	$ 28,725,435

Appendix Table B-2: Advanced Manfacturing Payroll in Michigan, Midwest, and United States, 2007

Cluster	Industry Description	Michigan	Midwest: Illinois	Indiana	Ohio	Wisconsin	Entire Midwest	U.S
3369	Other Transportation Equipment Mfg	$ 103,960	$ 27,703	$ 41,426	$ 14,580	$ 214,756	$ 402,425	$ 2,149,717
3372	Office Furniture (including fixtures)	$ 836,939	$ 284,207	$ 307,439	$ 10,368	$ 200,959	$ 1,639,912	$ 5,657,459
3391	Medical Equipment & Supplies Mfg	$ 418,291	$ 13,344,328	$ 8,453,214	$ 342,625	$ 262,217	$ 22,820,675	$ 16,800,952
	Total	**$ 11,590,839**	**$ 26,688,656**	**$ 16,906,428**	**$ 685,250**	**$ 9,071,475**	**$ 64,942,648**	**$ 271,203,400**
Emerging Manufacturing								
3256	Soap, Cleaning Compound, & Toilet Preparation mfg	$ 140,013	$ 465,468	$ 99,573	$ 4,243	$ 266,282	$ 975,579	$ 5,354,573
3272	Glass & Glass Product Mfg	$ 266,844	$ 122,850	$ 200,636	$ 1,673	$ 116,891	$ 708,894	$ 4,208,981
3313	Alumina & Aluminum Production & Processing	$ 123,608	$ 83,670	$ 305,445	$ 7,748	$ 30,716	$ 551,187	$ 3,126,206
3315	Foundries	$ 574,205	$ 362,841	$ 575,078	$ 4,775	$ 809,027	$ 2,325,926	$ 6,867,955
3321	Forging & Stamping	$ 278,206	$ 604,885	$ 193,693	$ 9,022	$ 347,204	$ 1,433,010	$ 5,645,758
3323	Architectural & Structural Metals Mfg	$ 391,697	$ 709,491	$ 498,518	$ 1,567	$ 669,980	$ 2,271,253	$ 16,551,310
3325	Hardware Mfg	$ 109,459	$ 134,304	$ 138,877	$ 2,089	$ 101,072	$ 485,801	$ 1,711,081
3326	Spring & Wire Product Mfg	$ 102,967	$ 190,278	$ 104,996	$ 9,953	$ 75,994	$ 484,188	$ 1,984,922
3328	Coating, Engraving, Heat Treating, & Allied Activities	$ 526,579	$ 421,204	$ 335,766	$ 4,541	$ 231,428	$ 1,519,518	$ 5,305,770
3371	Household & Institutional Furniture & Kitchen Cabinet Mfg	$ 233,558	$ 295,693	$ 492,908	$ 45,611	$ 345,962	$ 1,413,732	$ 10,386,333
	Total	**$ 2,747,136**	**$ 3,390,684**	**$ 2,945,490**	**$ 91,222**	**$ 2,994,556**	**$ 12,169,088**	**$ 61,142,889**
Research Relevant								
541330	Engineering Services	$ 3,870,315	$ 2,110,146	$ 925,691	$ 1,819,226	$ 743,329	$ 9,468,707	$ 71,439,892
54138	Testing Laboratories	$ 331,173	$ 321,450	$ 81,694	$ 245,169	$ 68,536	$ 1,048,022	$ 5,615,447
541420	Industrial Design Services	$ 52,461	$ 23,825	$ 4,999	$ 36,335	$ 12,393	$ 130,013	$ 837,714
5415	Computer Systems Design & Related Services	$ 1,888,446	$ 4,448,292	$ 656,212	$ 2,390,710	$ 725,161	$ 10,108,821	$ 101,700,000
541614	Process, Physical Distribution & Logistics Consulting Services	$ 215,146	$ 268,492	$ 74,150	$ 171,611	$ 68,139	$ 797,538	$ 4,426,111
541690	Scientific & Technical Consulting Services	$ 69,600	$ 323,839	$ 47,194	$ 99,569	$ 50,483	$ 590,685	$ 7,636,962
541710	R&D in Physical, Engineering & Life Sciences	$ 3,688,034	$ 1,621,559	$ 595,161	$ 1,664,005	$ 389,422	$ 7,958,181	$ 57,633,341
	Total	**$ 10,115,175**	**$ 9,117,603**	**$ 2,385,101**	**$ 6,426,625**	**$ 2,057,463**	**30,101,967**	**249,289,467**
	MI Advanced Manufacturing Industry Totals	**$ 24,453,150**	**$ 39,196,943**	**$ 22,237,019**	**$ 7,203,097**	**$ 14,123,494**	**$ 107,213,703**	**$ 581,635,756**

Appendix Table B-3: Advanced Manfacturing Payroll in Michigan, Midwest, and United States, 2003

Cluster	Industry Description	Michigan	Midwest: Illinois	Indiana	Ohio	Wisconsin	Entire Midwest	U.S.
Advanced Manufacturing								
3112	Grain & Oilseed Milling	$ 142,070	$ 282,104	$ 116,906	$ 146,742	$ 47,095	$ 734,917	$ 2,437,554
3113	Sugar & Confectionery Product Mfg	$ 37,904	$ 395,390	$ 37,970	$ 58,425	$ 57,894	$ 587,583	$ 2,659,212
3115	Dairy Product Mfg	$ 210,645	$ 182,389	$ 118,949	$ 234,299	$ 615,388	$ 1,361,670	$ 5,202,955
3118	Bakeries & Tortilla Mfg	$ 202,828	$ 588,476	$ 252,162	$ 446,522	$ 188,659	$ 1,678,647	$ 9,190,474
3119	Other Food Mfg	$ 107,049	$ 414,686	$ 190,668	$ 255,854	$ 205,211	$ 1,173,468	$ 5,416,753
3121	Beverage Mfg	$ 148,518	$ 180,919	$ 62,029	$ 204,146	$ 134,036	$ 729,648	$ 5,747,221
3221	Pulp, Paper & Paperboard Mills	$ 329,526	$ 87,792	$ 54,325	$ 262,806	$ 949,178	$ 1,683,627	$ 8,938,977
3241	Petroleum & Coal Products Mfg	$ 96,673	$ 316,642	$ 139,869	$ 269,398	$ 26,171	$ 848,753	$ 6,486,710
3251	Basic Chemical Mfg	$ 361,478	$ 336,114	$ 116,020	$ 487,309	$ 118,332	$ 1,419,253	$ 10,593,956
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg	$ 230,081	$ 242,514	$ 165,661	$ 271,041	$ 45,528	$ 954,825	$ 5,454,969
3254	Pharmaceutical & Medicine Mfg	$ 409,655	$ 1,761,324	$ 806,642	$ 231,723	$ 98,525	$ 3,307,869	$ 17,414,292
3255	Paint, Coating & Adhesive Mfg	$ 200,861	$ 291,155	$ 79,751	$ 436,816	$ 90,117	$ 1,098,700	$ 3,187,785
3259	Other Chemical Product & Prep Mfg	$ 179,700	$ 262,058	$ 124,693	$ 264,937	$ 55,457	$ 886,845	$ 5,420,100
3311	Iron & Steel Mills & Ferroalloy Mfg	$ 338,603	$ 283,288	$ 1,468,561	$ 1,001,213	$ 42,093	$ 3,133,758	$ 6,627,550
3314	Nonferrous Metal (except aluminum) Production	$ 86,983	$ 283,863	$ 140,983	$ 164,600	$ 29,543	$ 705,972	$ 2,724,592
3329	Other Fabricated Metal Product Mfg	$ 589,351	$ 697,442	$ 391,694	$ 962,493	$ 311,619	$ 2,952,599	$ 10,657,356
3331	Agriculture, Construction & Mining Machinery Mfg	$ 82,470	$ 811,431	$ 130,146	$ 203,508	$ 566,539	$ 1,794,094	$ 6,947,540
3332	Industrial Machinery Mfg	$ 338,839	$ 380,223	$ 131,812	$ 440,600	$ 416,879	$ 1,708,353	$ 7,137,253
3333	Commercial & Service Industry Machinery Mfg	$ 82,179	$ 325,831	$ 87,222	$ 227,631	$ 110,445	$ 833,308	$ 4,495,794
3336	Engine, Turbine & Power Transmission Mfg	$ 425,693	$ 444,795	$ 339,359	$ 206,080	$ 439,657	$ 1,855,584	$ 4,318,058
3339	Other General Purpose Machinery Mfg	$ 1,109,199	$ 877,041	$ 347,672	$ 1,159,015	$ 546,978	$ 4,039,905	$ 12,470,698
3345	Navigational, Measuring, Medical & Control Instruments Mfg	$ 498,313	$ 629,382	$ 315,574	$ 598,010	$ 473,244	$ 2,514,523	$ 24,797,329
3352	Household Appliance Mfg	$ 156,603	$ 255,509	$ 188,053	$ 513,535	$ 219,451	$ 1,333,151	$ 3,156,560
3353	Electrical Equipment Mfg	$ 138,848	$ 502,766	$ 154,181	$ 369,604	$ 657,117	$ 1,822,516	$ 5,871,648
3359	Other Electrical Equipment & Component Mfg	$ 155,843	$ 370,155	$ 123,820	$ 276,817	$ 171,217	$ 1,097,852	$ 6,449,986
3361	Motor Vehicle Mfg	$ 3,125,751	$ 372,147	$ 796,752	$ 1,918,516	$ 422,547	$ 6,635,713	$ 14,006,283

Appendix Table B-3: Advanced Manfacturing Payroll in Michigan, Midwest, and United States, 2003

Cluster	Industry Description	Michigan	Midwest: Illinois	Midwest: Indiana	Midwest: Ohio	Midwest: Wisconsin	Entire Midwest	U.S.
3364	Aerospace product & parts mfg	$ 193,535	$ 302,353	$ 459,159	$ 902,554	$ 17,363	$ 1,874,964	$ 22,306,143
3369	Other Transportation Equipment Mfg	$ 68,071	$ 22,772	$ 32,957	$ 136,279	$ 253,783	$ 513,861	$ 1,651,102
3372	Office Furniture (including fixtures)	$ 807,275	$ 257,814	$ 281,092	$ 175,370	$ 165,900	$ 1,687,451	$ 5,238,649
3391	Medical Equipment & Supplies Mfg	$ 356,438	$ 349,797	$ 605,314	$ 516,973	$ 263,856	$ 2,092,378	$ 13,584,148
	Total	**$ 11,210,982**	**$ 12,508,172**	**$ 8,259,996**	**$ 13,342,816**	**$ 7,739,822**	**$ 53,061,787**	**$ 240,591,647**
Emerging Manufacturing								
3256	Soap, Cleaning Compound, & Toilet Preparation mfg	$ 260,403	$ 394,623	$ 113,481	$ 319,057	$ 227,154	$ 1,314,718	$ 4,989,449
3272	Glass & Glass Product Mfg	$ 319,295	$ 121,295	$ 249,886	$ 396,178	$ 111,916	$ 1,198,570	$ 4,278,856
3313	Alumina & Aluminum Production & Processing	$ 115,899	$ 70,201	$ 289,820	$ 194,334	$ 26,855	$ 697,109	$ 2,825,549
3315	Foundries	$ 734,015	$ 379,590	$ 654,639	$ 908,689	$ 724,468	$ 3,401,401	$ 6,642,668
3321	Forging & Stamping	$ 245,157	$ 570,625	$ 185,485	$ 623,357	$ 275,664	$ 1,900,288	$ 4,744,162
3323	Architectural & Structural Metals Mfg	$ 405,810	$ 563,226	$ 418,194	$ 599,609	$ 469,145	$ 2,455,984	$ 13,080,366
3325	Hardware Mfg	$ 256,473	$ 178,989	$ 126,906	$ 153,532	$ 102,251	$ 818,151	$ 2,018,197
3326	Spring & Wire Product Mfg	$ 108,380	$ 200,498	$ 101,324	$ 159,529	$ 101,514	$ 671,245	$ 1,934,557
3328	Coating, Engraving, Heat Treating, & Allied Activities	$ 496,936	$ 371,596	$ 264,894	$ 468,575	$ 197,372	$ 1,799,373	$ 4,469,103
3371	Household & Institutional Furniture & Kitchen Cabinet mfg	$ 242,925	$ 308,715	$ 446,867	$ 514,889	$ 357,978	$ 1,871,374	$ 10,152,053
	Total	**$ 3,185,293**	**$ 3,159,358**	**$ 2,851,496**	**$ 4,337,749**	**$ 2,594,317**	**$ 16,128,213**	**$ 55,134,960**
Research Relevant								
541330	Engineering Services	$ 3,861,488	$ 1,617,231	$ 695,951	$ 1,327,466	$ 605,010	$ 8,107,146	$ 51,970,367
54138	Testing Laboratories	$ 380,399	$ 278,669	$ 63,459	$ 182,333	$ 48,935	$ 953,795	$ 4,191,797
541420	Industrial Design Services	$ 56,690	$ 23,379	$ 6,204	$ 26,616	$ 14,803	$ 127,692	$ 577,484
5415	Computer Systems Design & Related Services	$ 1,590,767	$ 2,825,863	$ 520,990	$ 2,036,185	$ 512,369	$ 7,486,174	$ 72,011,489
541614	Process, Physical Distribution & Logistics Consulting Services	$ 155,892	$ 141,625	$ 61,921	$ 125,133	$ 58,672	$ 543,243	$ 3,088,638
541690	Scientific & Technical Consulting Services	$ 69,446	$ 203,420	$ 17,785	$ 57,059	$ 16,621	$ 364,331	$ 3,538,350
541710	R&D in Physical, Engineering & Life Sciences	$ 3,764,067	$ 1,653,128	$ 683,186	$ 1,404,173	$ 218,236	$ 7,722,790	$ 43,163,281
	Total	**$ 9,878,749**	**$ 6,743,315**	**$ 2,049,496**	**$ 5,158,965**	**$ 1,474,646**	**$ 25,305,171**	**178,541,406**
MI Advanced Manufacturing Industry Totals		**$ 24,275,024**	**$ 22,410,845**	**$ 13,160,988**	**$ 22,839,530**	**$ 11,808,785**	**$ 94,495,172**	**$ 474,268,013**

Appendix Table B-4: Advanced Manfacturing Employment in Michigan, Midwest, and United States, 2007

Cluster	Industry Description	Michigan	Midwest				Entire Midwest	U.S.
			Illinois	Indiana	Ohio	Wisconsin		
Advanced Products & Processes								
3112	Grain & Oilseed Milling	1,886	6,997	2,558	2,437	1,395	15,273	58,049
3113	Sugar & Confectionery Product Mfg	1,369	7,930	1,775	1,885	2,077	15,036	73,457
3115	Dairy Product Mfg	4,096	4,622	2,758	4,304	18,120	33,900	129,692
3118	Bakeries & Tortilla Mfg	6,205	16,840	8,902	13,116	5,558	50,621	284,998
3119	Other Food Mfg	3,025	11,178	4,055	7,575	5,665	31,498	162,852
3121	Beverage Mfg	4,171	3,472	2,628	4,384	2,848	17,503	135,979
3221	Pulp, Paper & Paperboard Mills	4,516	847	1,014	4,395	15,487	26,259	130,068
3241	Petroleum & Coal Products Mfg	1,642	4,555	3,341	4,314	708	14,560	103,577
3251	Basic Chemical Mfg	3,951	6,144	2,734	10,118	1,943	24,890	165,025
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg	4,710	3,446	3,027	4,193	1,658	17,034	88,601
3254	Pharmaceutical & Medicine Mfg	6,973	14,246	11,337	3,387	2,359	38,302	241,339
3255	Paint, Coating & Adhesive Mfg	3,662	5,608	1,823	7,994	2,252	21,339	62,493
3259	Other Chemical Product & Prep Mfg	3,521	5,205	3,071	6,059	1,460	19,316	103,219
3311	Iron & Steel Mills & Ferroalloy Mfg	4,194	6,651	19,867	14,186	784	45,682	109,998
3314	Nonferrous Metal (except aluminum) Production	1,933	5,500	2,664	4,636	375	15,108	60,466
3329	Other Fabricated Metal Product Mfg	12,840	16,668	10,631	21,973	9,619	71,731	271,223
3331	Agriculture, Construction & Mining Machinery Mfg	2,650	21,640	3,803	5,289	14,019	47,401	205,545
3332	Industrial Machinery Mfg	6,182	7,520	3,134	8,175	8,423	33,434	130,022
3333	Commercial & Service Industry Machinery Mfg	2,050	7,667	2,252	4,256	3,032	19,257	95,729
3336	Engine, Turbine & Power Transmission Mfg	6,385	10,796	8,629	5,032	9,863	40,705	102,482
3339	Other General Purpose Machinery Mfg	18,426	18,409	8,758	26,965	13,233	85,791	285,029
3345	Navigational, Measuring, Medical & Control Instruments Mfg	11,257	13,415	5,081	12,957	12,700	55,410	384,966
3352	Household Appliance Mfg	1,509	2,684	2,944	141	4,428	11,706	65,666
3353	Electrical Equipment Mfg	2,385	10,653	3,236	7,329	14,113	37,716	138,332
3359	Other Electrical Equipment & Component Mfg	3,323	7,395	3,904	6,993	4,458	26,073	144,746
3361	Motor Vehicle Mfg	39,870	7,112	14,266	23,573	4,978	89,799	196,493

Appendix Table B-4: Advanced Manfacturing Employment in Michigan, Midwest, and United States, 2007

Cluster	Industry Description	Michigan	Midwest: Illinois	Midwest: Indiana	Midwest: Ohio	Midwest: Wisconsin	Entire Midwest	U.S.
3364	Aerospace product & parts mfg	3,510	5,612	7,252	15,859	306	32,539	408,139
3369	Other Transportation Equipment Mfg	2,438	714	1,143	2,620	4,329	11,244	46,721
3372	Office Furniture (including fixtures)	15,374	6,955	8,980	4,933	4,746	40,988	141,000
3391	Medical Equipment & Supplies Mfg	8,434	8,451	15,177	12,160	6,154	50,376	316,789
	Total	**192,487**	**248,932**	**170,744**	**251,238**	**177,089**	**1,040,490**	**4,842,695**
Emerging Manufacturing								
3256	Soap, Cleaning Compound, & Toilet Preparation mfg	3,160	8,093	1,864	6,827	4,036	23,980	104,422
3272	Glass & Glass Product Mfg	6,254	2,464	4,836	7,670	3,215	24,439	97,876
3313	Alumina & Aluminum Production & Processing	2,707	2,024	5,778	4,119	803	15,431	63,988
3315	Foundries	12,027	9,119	12,676	17,750	18,282	69,854	159,977
3321	Forging & Stamping	6,110	12,762	5,151	15,952	7,750	47,725	124,406
3323	Architectural & Structural Metals Mfg	8,977	16,395	12,687	16,349	15,116	69,524	398,786
3325	Hardware Mfg	2,445	3,087	3,295	3,113	1,890	13,830	41,763
3326	Spring & Wire Product Mfg	2,551	4,527	3,272	4,149	1,872	16,371	53,413
3328	Coating, Engraving, Heat Treating, & Allied Activities	13,602	10,243	8,177	13,287	6,707	52,016	137,183
3371	Household & Institutional Furniture & Kitchen Cabinet mfg	6,421	8,893	15,117	14,970	9,750	55,151	333,974
	Total	**64,254**	**77,607**	**72,853**	**104,186**	**69,421**	**388,321**	**1,515,788**
Research Relevant								
541330	Engineering Services	50,494	27,774	14,314	27,819	11,369	131,770	961,012
54138	Testing Laboratories	4,864	5,324	1,897	5,275	1,608	18,968	107,309
541420	Industrial Design Services	1,052	387	83	595	269	2,386	13,463
5415	Computer Systems Design & Related Services	29,749	53,133	10,269	34,635	10,919	138,705	1,297,710
541614	Process, Physical Distribution & Logistics Consulting Services	3,949	3,677	1,450	3,166	1,564	13,806	70,278
541690	Scientific & Technical Consulting Services	1,373	2,992	919	2,066	1,011	8,361	115,502
541710	R&D in Physical, Engineering & Life Sciences	33,129	18,393	7,257	19,650	5,461	83,890	631,475
	Total	**124,610**	**111,680**	**36,189**	**93,206**	**32,201**	**397,886**	**3,196,749**
	MI Advanced Manufacturing Industry Totals	**381,351**	**438,219**	**279,786**	**448,630**	**278,711**	**1,826,697**	**9,555,232**

Appendix Table B-5: Advanced Manfacturing Employment in Michigan, Midwest, and United States, 2003

Cluster	Industry Description	Michigan	Midwest				Entire Midwest	U.S.
			Illinois	Indiana	Ohio	Wisconsin		
Advanced Products & Processes								
3112	Grain & Oilseed Milling	2,854	6,054	2,506	3,174	1,085	15,673	54,918
3113	Sugar & Confectionery Product Mfg	1,449	11,178	1,414	2,128	1,925	18,094	79,630
3115	Dairy Product Mfg	5,122	4,557	3,036	6,280	17,473	36,468	134,287
3118	Bakeries & Tortilla Mfg	7,444	18,687	8,307	14,515	7,386	56,339	317,040
3119	Other Food Mfg	3,317	10,146	5,482	7,549	5,582	32,076	159,544
3121	Beverage Mfg	4,017	5,068	1,646	4,506	2,836	18,072	131,331
3221	Pulp, Paper & Paperboard Mills	5,781	1,151	1,084	5,120	18,389	31,525	154,903
3241	Petroleum & Coal Products Mfg	1,323	4,842	2,558	4,512	551	13,786	98,334
3251	Basic Chemical Mfg	5,638	6,081	2,302	8,435	2,324	24,780	170,579
3252	Resin, Synthetic Rubber, Artificial, Synthetic Fibers & Filaments Mfg	3,614	4,098	3,229	4,691	1,224	16,856	100,336
3254	Pharmaceutical & Medicine Mfg	7,821	23,127	10,694	4,016	1,861	47,519	251,855
3255	Paint, Coating & Adhesive Mfg	4,139	6,507	1,844	8,227	1,922	22,639	68,327
3259	Other Chemical Product & Prep Mfg	3,701	5,769	2,905	6,065	1,312	19,752	109,721
3311	Iron & Steel Mills & Ferroalloy Mfg	5,752	6,741	23,202	21,783	844	58,322	125,871
3314	Nonferrous Metal (except aluminum) Production	2,026	5,713	3,252	3,609	854	15,454	63,008
3329	Other Fabricated Metal Product Mfg	14,927	16,770	10,917	24,053	8,332	74,999	274,479
3331	Agriculture, Construction & Mining Machinery Mfg	2,110	17,721	3,796	5,451	12,991	42,069	172,356
3332	Industrial Machinery Mfg	6,904	8,066	3,107	9,858	8,564	36,499	144,793
3333	Commercial & Service Industry Machinery Mfg	2,051	7,993	2,247	6,024	2,925	21,240	103,749
3336	Engine, Turbine & Power Transmission Mfg	7,588	8,966	7,472	4,512	9,330	37,868	91,856
3339	Other General Purpose Machinery Mfg	19,582	19,693	9,293	25,607	12,347	86,522	282,913
3345	Navigational, Measuring, Medical & Control Instruments Mfg	9,525	11,477	6,299	12,316	7,353	46,970	403,693
3352	Household Appliance Mfg	4,083	8,499	4,242	13,364	5,231	35,419	90,803
3353	Electrical Equipment Mfg	3,395	12,192	4,110	9,220	13,746	42,663	146,860
3359	Other Electrical Equipment & Component Mfg	4,196	9,986	3,912	7,663	4,351	30,108	161,228
3361	Motor Vehicle Mfg	43,447	7,698	12,955	27,365	6,237	97,702	211,454

Appendix Table B-5: Advanced Manfacturing Employment in Michigan, Midwest, and United States, 2003

Cluster	Industry Description	Michigan	Midwest Illinois	Midwest Indiana	Midwest Ohio	Midwest Wisconsin	Entire Midwest	U.S.
3364	Aerospace product & parts mfg	3,749	5,099	6,497	13,667	375	29,387	375,169
3369	Other Transportation Equipment Mfg	1,826	528	946	2,518	5,550	11,367	40,931
3372	Office Furniture (including fixtures)	20,964	7,425	8,822	5,244	4,548	47,003	153,696
3391	Medical Equipment & Supplies Mfg	7,606	9,477	13,133	13,112	7,111	50,439	305,850
	Total	**215,951**	**271,308**	**171,208**	**284,584**	**174,558**	**1,117,608**	**4,979,514**
Emerging Manufacturing								
3256	Soap, Cleaning Compound, & Toilet Preparation mfg	3,710	8,321	2,543	7,000	3,825	25,399	109,363
3272	Glass & Glass Product Mfg	7,021	3,066	6,188	10,210	3,080	29,565	111,613
3313	Alumina & Aluminum Production & Processing	2,991	1,890	5,867	5,037	739	16,524	66,644
3315	Foundries	16,029	9,820	14,906	19,642	18,871	79,268	171,769
3321	Forging & Stamping	6,034	14,508	5,411	15,040	7,302	48,295	122,595
3323	Architectural & Structural Metals Mfg	10,049	14,714	11,776	16,401	11,925	64,865	365,532
3325	Hardware Mfg	6,544	4,905	4,077	3,459	2,186	21,171	56,766
3326	Spring & Wire Product Mfg	2,899	5,555	3,470	4,859	2,921	19,704	59,312
3328	Coating, Engraving, Heat Treating, & Allied Activities	14,671	10,855	7,240	13,743	6,692	53,201	135,161
3371	Household & Institutional Furniture & Kitchen Cabinet mfg	7,509	10,055	14,781	16,383	10,376	59,104	365,907
	Total	**77,457**	**83,689**	**76,259**	**111,774**	**67,917**	**417,096**	**1,564,662**
Research Relevant								
541330	Engineering Services	55,246	26,122	12,277	24,891	11,073	129,609	835,133
54138	Testing Laboratories	6,000	5,288	1,535	5,013	1,421	19,257	94,523
541420	Industrial Design Services	1,018	420	129	712	362	2,641	10,378
5415	Computer Systems Design & Related Services	25,213	41,450	9,300	32,735	8,567	117,265	1,058,987
541614	Process, Physical Distribution & Logistics Consulting Services	3,745	2,603	1,545	2,657	1,517	12,067	60,364
541690	Scientific & Technical Consulting Services	1,334	2,355	455	1,233	444	5,821	58,369
541710	R&D in Physical, Engineering & Life Sciences	40,142	20,185	7,023	20,397	3,854	91,601	561,184
	Total	**132,698**	**98,423**	**32,264**	**87,638**	**27,238**	**378,261**	**2,678,938**
MI Advanced Manufacturing Industry Totals		**426,106**	**453,420**	**279,731**	**483,996**	**269,712**	**1,912,964**	**9,223,114**

Appendix C: About the Authors

CAROLINE M. SALLEE

Ms. Sallee is a consultant and director of the Chicago office at Anderson Economic Group, working in the Public Policy, Fiscal, and Economic Analysis practice area. Ms. Sallee's background is in applied economics and public finance.

Ms. Sallee is the primary author of the first three *Annual Economic Impact Reports* for Michigan's University Research Corridor. Her recent work includes fiscal and economic impact studies for Michigan State University and Wayne State University, and the benchmarking of Michigan's business taxes with other states in a project for the Michigan House of Representatives.

Prior to joining Anderson Economic Group, Ms. Sallee worked for the U.S. Government Accountability Office (GAO) as a member of the Education, Workforce and Income Security team. She also has worked as a market analyst for Hábitus, a market research firm in Quito, Ecuador, and as a legislative assistant for two U.S. Representatives.

Ms. Sallee holds a master's degree in public policy from the Gerald R. Ford School of Public Policy at the University of Michigan and a Bachelor of Arts degree in economics and history from Augustana College.

ALEX L. ROSAEN

Mr. Rosaen is a consultant at Anderson Economic Group, working in the Public Policy and Economics practice area. Mr. Rosaen's background is in applied economics and public finance.

Prior to joining Anderson Economic Group, Mr. Rosaen worked for the Office of Retirement Services (part of the Michigan Department of Management and Budget) for the Benefit Plan Design group. He also has worked as a mechanical engineer for Williams International in Walled Lake, Michigan.

Mr. Rosaen holds a Master of Public Policy degree from the Gerald R. Ford School of Public Policy at the University of Michigan. He also has a Master of Science degree and a Bachelor of Science degree in mechanical engineering from the University of Michigan.

ERIN AGEMY

Ms. Agemy is an analyst at Anderson Economic Group, working in the Public Policy and Economics, and Finance and Business Valuation practice areas.

While with AEG, Ms. Agemy has worked on economic impact and fiscal impact analysis for counties in Michigan and Florida. She is also currently contributing to the book, *Economics of Business Valuation*, a forthcoming publication of Stanford University Press.

Prior to joining AEG, Ms. Agemy worked as a contract consultant providing research and detailed data analysis to economic and financial consulting firms in Michigan and Ohio. She was also one of four students selected to be graduate fellows at the Mercatus Center in Arlington, Virginia. While there she contributed to their Gulf Coast Recovery Project, which received the Templeton Freedom Award for Special Achievement. Ms. Agemy has also conducted original fieldwork on the political economy of charter schools in New Orleans, which she presented at an international conference for the Association of Private Enterprise Education.

Ms. Agemy holds a masters degree in economics from George Mason University and a Bachelors of Science degree in Political Economy from Hillsdale College.