Imaging a Future for the Big Sky Optics Cluster

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Introduction and Purpose

In 2002 RTS analyzed and mapped the presence of IT firms and their support infrastructure as part of its cluster development strategy for the Governor's Office of Economic Development (GOED). During the course of this analysis we discovered 11 companies in Montana that engaged in research and manufacturing of high-technology optical products. At that time the focus was on laser products and components, but also included thermoelectric controls, electro-optic sensors, sensor instrumentation and a number of other products. Even more interesting, ten of the firms were located in Bozeman, in close proximity to Montana State University where the Optical Technology Center (OpTeC) and the Spectrum Lab conduct research in electro-optics and develop multi-spectral optical concepts into prototype systems. The two centers worked closely with each other and the Center for Computational Biology (CCB), also at Montana State University. The local companies appeared to have strong ties to the university centers and often collaborated with them in the development of new application potentials in optical fields. The optics-related companies were very research-intensive and accounted for a total of approximately 250 mostly high-tech jobs in Bozeman.

Although this group of companies did not show a tight fit within what were then generally accepted IT sector or cluster definitions we decided to "wedge" them into the on-going IT cluster analysis for three reasons.

1. A huge number of the optics-related technology domain applications were in IT, telecommunications, and computing-based products, services and companies.

2. Because almost all the firms were located in a small geographic area that also contained a research university with two R&D centers with optics-related missions and that often support these companies, in our opinion, this represented the kind of robust concentration of knowledge-based companies and resources that could grow into a major economic development opportunity not just for the region, but for the state as a whole.

3. We wanted to make sure this group of firms was noted somewhere as an asset. At the time this concentration of potential high impact firms was not really on anyone's radar outside of Bozeman so it was not widely regarded as a potentially significant economic development asset. We wanted to make sure this optics-related existence was captured and noted even though it was beyond the purview of our IT cluster analysis to pursue a separate development strategy. In the original IT cluster analysis we devoted a short section to this group of firms and benchmarked it against the optics cluster in Colorado that at the time included about 150 firms.

This group has continued to follow a cluster development path since that time. At present the Montana Manufacturing Extension Center (MMEC) has identified 27 optics

and photonics firms in the state. The group in Bozeman has more than doubled in size and now contains at least 28 companies. Like IT, optics and photonics technology as an industry – as a technology platform – as a product – as a service – is now ubiquitous. In addition to being an industry in and of itself, it has become an enabler for all the others.

Building on the insightful MMEC work, this report supports this burgeoning Montana economic development opportunity by offering an assessment of this optics cluster and a strategy for the state to support its continued development based on an understanding of the competitiveness needs and opportunities for its companies and the optics cluster innovation infrastructure.

Defining Terms

Industry versus Cluster

The terms "industry" and "cluster" are not used interchangeably. Although there are many versions, "Industry" is typically defined as some form of organized economic activity connected with the production, manufacture, or construction of a particular product or service or range of products or services. This analysis employs a variation of the "cluster" definition developed and used by RTS in numerous publications over the last seventeen years including two publications for the National Governor's Association, *A Governor's Guide to Cluster-Based Economic Development* (2002) and *Innovation America: Cluster-Based Strategies for Growing State Economies* (2007). "Cluster"" herein is defined as a *"geographic concentration of interrelated competitive firms and institutions of sufficient scale to generate external economies…making the whole greater than the sum of its parts."*

Clusters exist whether or not states and regions adopt strategies to address their needs. Industry clusters do not *need* a public sector strategy in order to exist, but the right strategies can help the businesses in them become more successful and competitive. A cluster occurs where a group of businesses, drawing on similar resources, exist in relationships with other nearby businesses and institutions that contribute to their competitiveness. This is why such a wide variety of clusters occur, ranging from the "high tech" clusters of microelectronics, semiconductor, and software businesses in Silicon Valley, California, to the Automotive industry in Detroit, Michigan, to the Houseboat Building industry in Eastern Kentucky or the Ceramics industry in western New York. Any concentration of similar businesses that draw on a common pool of suppliers, services, educational institutions, workforce skills, natural resources, or other assets that can be found in a region may be a cluster. Nobody engineered them, or created them in most cases, but they happened anyway.

This report identifies and describes the Montana's optics industry sector. It also examines the potential of an optics cluster within the state for three reasons.

1. A region's clusters tend to be the primary wealth generators in a region's economy.

2. Clusters often generate innovation and technological dynamism and produce higher wage jobs in the economy.

3. Clusters can be the basis for intelligent and cost-effective public strategies.

Optics, Photonics, et al…

While there are numerous accepted definitions of optics and photonics, there are no single standard definitions. Although the scientific and engineering literature will often distinguish between optics and photonics, within the current industry, economic development and public policy literature and media, the terms optics, photonics, and optoelectronics are most often used synonymously. Certainly optics as a concept has a long history beginning in the early 18th century with Isaac Newton's text on the fundamental principles of reflection and refraction. It is generally viewed as being ushered into the modern era as a field with the publications of Einstein and Planck and eventually the invention of the first laser in 1960. The rest is history with a development path including fiber optics, laser surgery, optical lithography, laser material processing, high-resolution microscopes, new lighting technologies and so on.

The terms photonics and optoelectronics have phased into common usage in order to capture the modern versions of science, engineering and technology domains that fuse optics with electronics. For photonics, the definitions are all over the map and vary from straightforward…

Photonics Directory (www.photonics.com) "the technology of generating and harnessing light and other radiant energy whose quantum unit is the photon."…

…to precise…

U.S. National Research Council (1998) – "the field of science and engineering encompassing the physical phenomena and technologies associated with the generation, transmission, manipulation, detection, and utilization of light."…

…to broad…

UK Department of Trade and Industry 2007 – "those organizations for which the manufacture or use of photonic enabled products is a key aspect of their business." Photonic enabled products are defined as "products that would not be possible without their photonic content."

The terms in use for these kinds of endeavors vary from state to state and cluster to cluster – for instance, "optics" in Arizona and New Mexico and "photonics" in Colorado and New York. For the purposes of this analysis and strategy we have opted to use "optics" as the descriptor for the cluster and the associated innovation and research domains unless otherwise noted for two reasons. First, as mentioned above, while including photonics and optoelectronics, historically, the optics field connotes a longer and wider science, engineering and technology perspective. Second, and most

importantly, that is the term the private sector and university firms, organizations and people in Montana that have built this capacity and generated this activity use to describe themselves.

The Optics Industry

As a ubiquitous enabling technology domain, optics is already established with a wide and deep technology platform that encompasses a group of technologies with a multitude of existing applications as well as the promise of an untold number of future technologies and applications. However, as an industry optics is still emerging. While its significance is easily understood, attempts to define it as industry are elusive because its existing base of technologies and applications are continuing to evolve while new technologies and applications are constantly and rapidly being created.

Description

Perhaps the most rigorously considered and most structured optics/photonics industry definitions have been sponsored by the European Commission. (Along those same lines, there is no standard or generally accepted definition currently in use in the United States.) The group responsible for driving the European optics agenda is the European Technology Platform Photonics21. Photonics21 devoted considerable effort and resources to crafting a definition of the photonics industry. Note, Europe has opted to use "photonics" as opposed to "optics" as its descriptor.

Photonics21's photonics industry description is contained in a 2007 report, *Photonics in Europe: Economic Impact* performed by Optech Consulting. That report divided the photonic industry into ten sectors that produce photonics technologies, components and systems that are then used in end-user products, processes and services. Each sector has a series of segments as shown below in Table 1.

Market Size

As cited in a March 2011 Photonics21-sponsored analysis prepared for the European Commission et al, using the photonics industry definition developed by Optech Consulting in their 2007 report (Table 1), the total world market for photonics products in 2008 was estimated at €277bn or about $370bn in 2008 US dollars at current exchange rates.[1] The two largest sectors – flat panel displays and information technology comprised about 44% of the total 2008 market at $96bn and $65.4bn, respectively while the global 2008 defense photonics market was estimated at $28bn.[2] The authors estimated an annual real global photonic market growth rate of 10% for the 2005-08 period. By way of comparison, for this same time period, worldwide gross national income grew at 4.4%.[3]

[1] Maurits Butter, Miriam Leis, John Lincoln, Mick McLean, Marjin Sandtke, Alastair Wilson, *The Leverage Effect of Photonics Technologies: the European Perspective* (European Commission, 2011. p 20.)

[2] Ibid.

[3] Ibid.

Table 1 Photonics Sectors and Segments[4]

Production Technology
- Laser Materials Processing Systems
- Lithography Systems (IC, FPD, Mask)
- Lasers for Production Technology
- Objective Lenses for Wafer Steppers

Optical Measurement and Machine Vision
- Machine Vision Systems and Components
- Spectrometers and Spectrometer Modules
- Binary Sensors
- Meas. Systems for Semiconductor Industry
- Meas. Systems for Optical Communications
- Meas. Systems for Other Applications

Medical Technology and Life Science
- Lenses for Eyeglasses and Contact Lenses
- Laser Systems for Medical Therapy and Cosmetics
- Endoscope Systems
- Microscopes and Surgical Microscopes
- Medical Imaging Systems (only Photonics-Based Systems)
- Ophthalmic and Other in Vivo-Diagnostic Systems
- Systems for In-Vitro-Diagnostics, Pharmac. & Biotech R&D

Optical Communications
- Optical Networking Systems
- Components for Optical Networking Systems

IT: Consumer Electronics, Office Automation, Printing
- Optical Disk Drives
- Laser Printers and Copiers, PODs, Fax and MFPs
- Digital Cameras and Camcorders, Scanners
- Barcode Scanners
- Systems for Commercial Printing
- Lasers for IT
- Sensors (CCD, CMOS)

Lighting
- Lamps
- LEDs
- OLEDs

Flat Panel Displays
- LCD Displays
- Plasma Displays
- OLEDs and Other Displays
- Display Glass and Liquid Crystals

Solar Energy
- Solar Cells
- Solar Modules

Defence Photonics
- Vision and Imaging Systems, Including Periscopic Sights
- Infrared and Night Vision Systems
- Ranging Systems
- Munition / Missile Guiding Systems
- Military Space Surveillance Systems
- Avionics Displays
- Image Sensors
- Lasers

Optical Systems and Components
- Optical Components and Optical Glass
- Optical Systems ("Classical" Optical Systems)
- Optical & OE Systems & Components Not Elsewhere Classified

Optech Consulting - October 2007

National And Multinational Optics Industry Development Approaches And Strategies

At the international level, the most prominent optics industry effort is the aforementioned Photonics21 initiative. Photonics21 is a European Technology Platform formed in 2005 to unite Europe's photonics industry and research institutions. The group has over 1800 members. Augmenting its 2007 definition of the photonics industry sectors and segments, in March of 2011 the European Commission published a Photonics21 sponsored analysis that configured a series of six value chains in which photonics is the core technology.[5]

[4] Arnold A. Mayer, *Photonics in Europe: Economic Impact* (Dusseldorph, Germany: European Technology Platform Photonics21, 2007. p.9.)

[5] Maurits Butter, Miriam Leis, John Lincoln, Mick McLean, Marjin Sandtke, Alastair Wilson, *The Leverage Effect of Photonics Technologies: the European Perspective* (European Commission, 2011.)

The organization now bases its overall approach on addressing these value chains. They are:

1. Scanning, Sensing and Imaging
2. Information, Communications and Networks
3. Screens and Displays
4. Advanced Lighting
5. Photonic Energy Systems
6. Laser Systems.

Subsequent to the release of the above analysis Photonics21 released a statement of its vision for photonics as a key enabling technology of Europe *(Photonics – Our Vision for a Key Enabling Technology of Europe,* European Technology Platform Photonics21*,* May 2011) and then in September of 2011 issued a press release to announce its commitment to a proposed public-private photonics partnership with the European Commission. One of the major goals of the partnership would be to improve Europe's photonics innovation potential by addressing the photonics innovation value chain gap between "successful science and pilot scale industrial deployments." According to Photonics21, the proposal targets a 7 billion euros investment level by 2020 with 5.6 billion euros contributed by the photonics industry and 1.4 billion euros provided by the European Commission.

At present the US has no photonics or optics industry innovation strategy or development policy at the national level nor is it regarded a trackable category from an industrial activity standpoint. As mentioned below however, there are a number of photonics or optics cluster development strategies in play in the US at the state and regional level.

An Optics/Photonics Cluster Inventory

Presented below is a domestic and international inventory of optics/photonics clusters and/or cluster support organizations. The various entities are gathered through several sources including the European Commission, The International Society for Optics and Photonics (SPIE), academic papers, and a rigorous Internet search. Some are identified through critical analysis by researchers while others are "self-selected" in that they identify themselves as a cluster support entity. They run the gamut from very substantive optics/photonics clusters and organizations that support them to "aspirational" entities that are formed to attempt to induce cluster development.

Table 2: US Optics Clusters and Organizations[6]

US Optics Clusters and Organizations	Location
Arizona Optics Industry Association	Tucson, AZ
Colorado Photonics Industry Association	Boulder, CO
Connecticut Optics and Photonics Association	Hartford, CT
Florida Photonics Cluster	Orlando, FL
New Mexico Optics Industry Association	Albuquerque, NM
New York Photonics Industry Association	Rochester, NY
Rochester Regional Photonics Cluster, Inc.	Rochester, NY
Carolina Microptics Triangle	Charlotte, NC
Carolinas Photonics Consortium	Greenville, SC

Table 3: International Optics Clusters and Organizations[7]

International Optics Clusters and Organizations	Location
Asia Pacific Region	
Victorian Photonics Network	Australia
Optics Valley of China	China
Korean Association for Photonics Industry Development	Korea
Singapore Photonics + Optics	Singapore
Canada	
Ontario Photonics Technology Industry Cluster	Ontario, Canada
Ottawa Photonics Cluster	Ontario, Canada
Quebec Photonic Network	Quebec, Canada
Europe	
Austrian Photonics Platform	Austria
Cluster Wallons "Photonique"	Belgium
Tampere Centre of Expertise	Finland
Joensuu Science Park Ltd. Expert Services - N. Karelia Center of Expertise	Finland
Optoelectronics Research Centre	Finland
Laser Competence Centre (LCC)	Finland

[6] Sources for Tables 2 & 3: European Commission, Photonics Unit, 2101; International Society for Optics and Photonics, Regional Technology Strategies.

[7] Sources for Tables 2 & 3: European Commission, Photonics Unit, 2101; International Society for Optics and Photonics, Regional Technology Strategies.

International Optics Clusters and Organizations (Continued)[8]	Location
Route Des Lasers	France
POPSUD - OPITEC	France
Optics Valley France	France
ELOPSYS – Poole de Compètitivitè	France
Poole ORA (Optics Rhone-Alps)	France
Rhenaphotonics – Alsace Optics and Photonics Poole	France
PhotonAIX e.V.	Germany
Bayern Photonics e.V.	Germany
HansePhtonik e.V.	Germany
Optec-Berlin-Brandenburg e.V.	Germany
Optence e.V.	Germany
OpTech-Net e.V.; Duisburg	Germany
OptecNet Deutschland e.V.	Germany
OptoNet e.V.	Germany
Photonic Net	Germany
Photonics BW	Germany
ANTICIPA - Technopoole du Tregor	Germany
PHOTONICSGR - Greek Photonics Platform	Ireland
Optics & Photonics Cluster in Ireland	Italy
PHORIT – Italian Photonics Platform	Netherlands
Potonics Cluster Netherlands	Netherlands
Wroclaw Research Centre EIT+	Poland
KLASTER "Knowledge and Innovation Community for Information and Communication Technologies"	Poland
Mazovian Photonics Technology Cluster - OPTOKLASTER	Poland
Polish Photonics Platform	Slovenia
Southern European Cluster in Photonics and Optics	Spain
FOTONIKA21 Slovenian Photonics Platform	Spain
Fotonica21 Spanish Photonics Platform	Spain
PhotonicSweden - The Swedish Photonics Platform	Sweden
SLN Swiss Laser and Photonics Network	Switzerland
Swiss Photonics and Laser Network	Switzerland
Electronics, Sensors, Photonics Knowledge Transfer Network	UK
Photonics Cluster UK	UK
Scottish Optoelectronics Association	UK
The Welsh Opto-Electronics Forum	UK
UK CPO - UK consortium for Photonics & Optics	UK
SEPNET Ltd. Photonics Network / South East Photonics Network	UK

[8] Sources for Tables 2 & 3: European Commission, Photonics Unit, 2101; International Society for Optics and Photonics, Regional Technology Strategies.

Defining the Optics Industry in Montana

In the U.S. there is no standard definition yet for optics or photonics as an industrial sector or subsector. Attempting to actually define all of this, as an industry comprised of discrete NAICS codes, is an impossible task for two reasons. First, because the technologies are developing so rapidly and applications are multiplying and morphing so quickly, any attempt at a definition would be a moving target. Second, and more importantly, under the current NAICS code taxonomy, many of the subsector codes that might logically be applied to capture the optics/photonics industry also include firms, and in many cases a majority of firms, that would not be part of the optics industry. For example, depending on the specific optics technology or market orientation an optics firm might place itself in the NAICS code for Engineering Services (541330) or Research and Development in the Physical, Engineering, and Life Sciences except Biotechnology (541712) or Welding and Soldering Equipment Manufacturing (333992). All three of these subsectors will include firms not associated with the optics industry.

As a result of the NAICS-based definition dilemma, analysts may use NAICS codes for guidance, but for the most part they then build up their particular industry or cluster description organically by identifying firms, one-by-one that appear to engage in optics or photonics-related commerce. Even then, in many cases, firms cannot be clearly assigned to a NAICS code. In the course of this work they have occasionally constructed working definitions based on what they have found in their market or state. The working definition for this assessment combines two approaches. First, it populates the cluster with known establishments that have self-selected as optics firms and then identifies their NAICS codes. It then triangulates among several analyses that identified NAICS codes in which optics firms resided (Connecticut, Arizona, Florida) and compiles this list and then merges with the NAICS codes for known Montana optics firms. The resulting NAICS-based template is then used to identify the names of Montana firms in each of these NAICS subsectors. The firms are then vetted one-by-one to determine if they are a "fit" that should be included in the Montana optics industry or cluster definition.

As was the case with the emergence of Information Technology in the 80's and 90's as both a new and evolving industry and as a ubiquitous, enabling technology across many sectors and applications, there are optics intensive user firms in just about every industrial sector and sub-sector. For the purposes of qualifying the optics cluster in Montana we will focus on the core of this cluster – on firms that generate optics products or services or the technologies in which they are embodied and the innovation infrastructure that enables this activity. Additionally, the cluster definition is subject to refinement and may be amended to include groups within significant Montana optics user market segments as additional findings come to light during the course of this analysis.

Based on the NAICS codes associated with the list of self identified optics firms and on other codes gleaned from other definitions as described above, here is the initial list of NAICS codes that might include establishments that qualify as optics firms.

Table 4: Optics Industry Definition

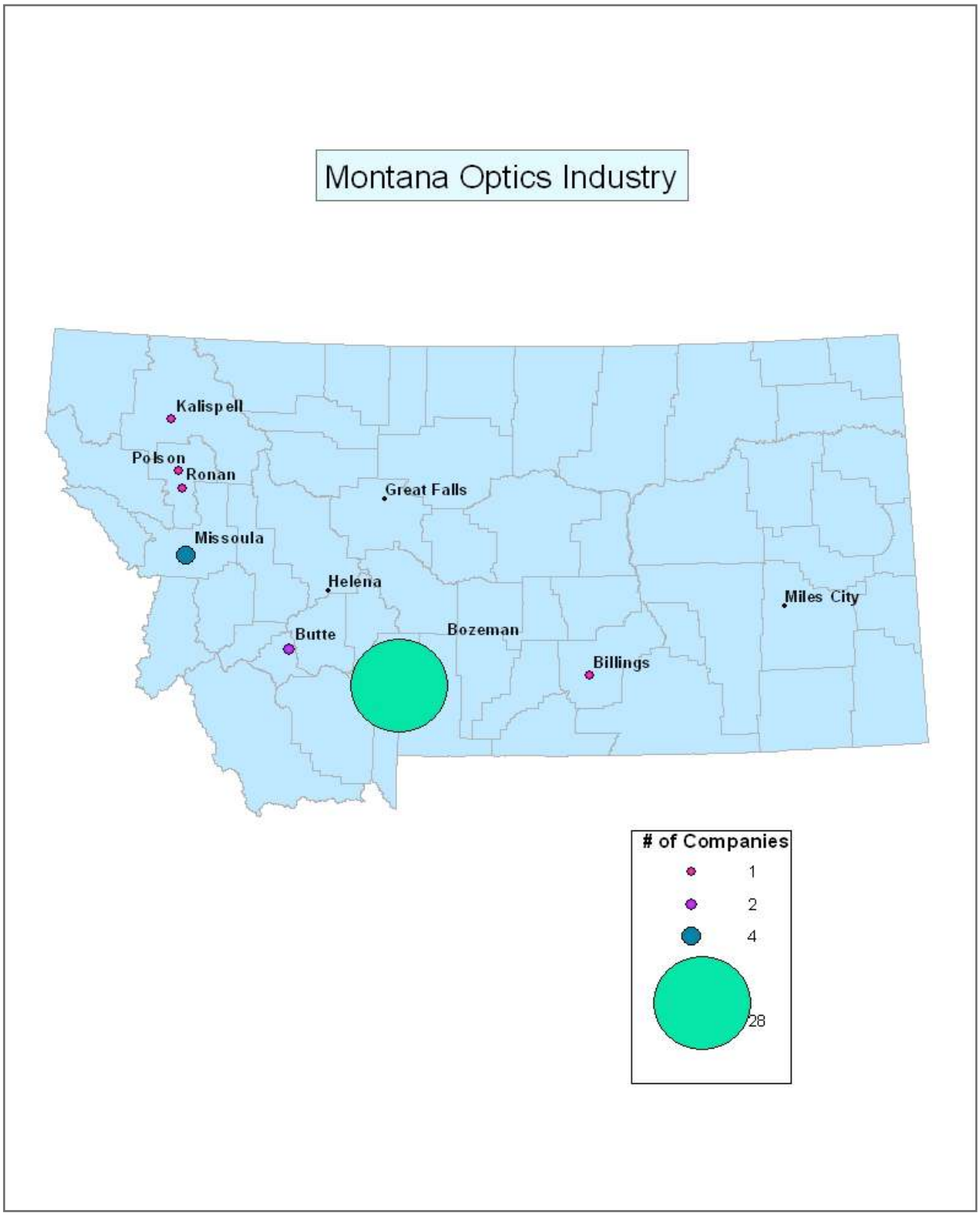
NAICS	Optics Cluster Definition
313210	Broadwoven Fabric Mills
323111	Commercial Gravure Printing
325188	All Other Basic Inorganic Chemical Mfg
332312	Fabricated Structural Metal Mfg
332993	Ammunition (except Small Arms Mfg)
333314	Optical Instruments & Lens Manufacturing
334512	Auto Environ Ctrl Mfg for Residential, Commercial, & Appliance Use
334513	Displaying & Controlling Industrial Process Variables
334519	Other Measuring & Controlling Device Mfg
335122	Commercial, Industrial, & Institutional Electric Lighting Fixture Mfg
335129	Other Lighting Equipment Mfg
335931	Current-Carrying Wiring Device Mfg
336321	Vehicular Lighting Equipment Mfg
336992	Military Armored Vehicle, Tank, & Tank Component Mfg
339112	Surgical & Medical Instrument Mfg
339115	Ophthalmic Goods Mfg
339999	All Other Miscellaneous Mfg
517919	All Other Telecommunications
541330	Engineering Services
541511	Custom Computer Programming Services
541712	R&D in the Physical, Engineering, & Life Sciences
541720	R&D in the Social Sciences & Humanities
561990	All Other Support Services

With at least the parameters of an industry definition established, our first step was to query Hoover's online business directory, a Dun & Bradstreet company, for companies associated with the above NAICS codes. Each company was then researched one by one to determine whether or not its products and/or services were in alignment with the established definition. In some cases, calls were made to confirm the company's current activity and/or location. We removed companies that were no longer in business and those that were outside of our scope. In this regard, because our focus is on the optics industry's core value-creating companies, we chose not to include ophthalmology and optometry offices, service labs and product distributors though they are included in some industry and especially cluster definitions as they are part of some of the marketing, distribution and end-user chains. The remaining 38 companies included in Table 5 form the basis for the optics industry in Montana. The geographic distribution of these companies is depicted below in Figure 1.

Table 5: Montana Optics Companies

Company	City
ADVR Inc	Bozeman
Altos Photonics	Bozeman
Bridger Photonic Inc	Bozeman
Christensen Research LP	Missoula
Chrono-Chrome Inc	Bozeman
DRS Technical Services Inc	Polson
Electronic Realization	Bozeman
Fluorescence Innovations	Bozeman
Fusion Technologies	Billings
GFT Technologies Inc	Bozeman
Gradient Geophysics Inc / Gradient Geothermal Inc	Missoula
GT Equipment Technologies	Missoula
Horne Technologies	Bozeman
ILX Lightwave Corporation	Bozeman
Image Labs	Bozeman
Lattice Materials LLC	Bozeman
Litron Lasers	Bozeman
Montana Instruments Corporation	Bozeman
MSE Technology Applications Inc	Butte
New Gate Technologies Inc	Bozeman
New Wave Research Incorporated	Bozeman
Nu-Trek	Bozeman
NWB Sensors	Bozeman
Phenix FO	Bozeman
Phoretic Technologies Inc	Kalispell
Photon Machines	Bozeman
Quantel Laser	Bozeman
Quantum Composers	Bozeman
Resodyn Corporation	Butte
Resonon	Bozeman
S & K Electronics Inc	Ronan
S2 Corporation	Bozeman
Scientific Materials Corporation / FLIR Systems	Bozeman
SensoPath Technologies Inc	Bozeman
Snider Technology Inc	Bozeman
TerraEchos Inc	Missoula
Wavelength Electronics Inc	Bozeman
Zdye LLC	Bozeman

Figure 1: Geographic Distribution of Montana Optics Companies



Does Montana Have The Ingredients for an Optics Cluster?

The short answer is, "Yes." In absolute terms the Montana cluster is not the scale of perhaps the most well known cluster in southern Arizona, which, according to the Arizona Optics Industry Association (AOIA), boasts 160 companies[9]. However, at least three of the critical ingredients are present that define developed clusters: a geographically dense (in this case, very dense) concentration of optics companies, a burgeoning infrastructure that includes a third ingredient, talent production, and an innovation hub.

Table 6: Comparisons - Gallatin County, Montana to Maricopa and Pima Counties, Southern Arizona[10]

Non-Farm Establishments 2010	Optics Estabs	Estabs	Opt Estabs/ All Estabs	%	MT/AZ
Gallatin County, MT	28	4,759	0.00588	0.5884%	**3.86**
Maricopa & Pima Counties, AZ	160	104,839	0.00153	0.1526%	
Maricopa		84,520			
Pima		20,319			
Non-Farm Employment 2010	**Optics Estabs**	**Employ**	**Opt Estabs/ All Employ**	**%**	**MT/AZ**
Gallatin County, MT	28	37,337	0.00075	0.0750%	**8.03**
Maricopa & Pima Counties, AZ	160	1,712,987	0.00009	0.0093%	
Maricopa		1,411,836			
Pima		301,151			
Population 2010	**Optics Estabs**	**Population**	**Opt Estabs/ Population**	**%**	**MT/AZ**
Gallatin County, MT	28	89,513	0.00031	0.0313%	**9.38**
Maricopa & Pima Counties, AZ	160	4,797,380	0.00003	0.0033%	
Maricopa		3,817,117			
Pima		980,263			

Twenty-eight of the 38 Montana optics industry companies are located in or around Bozeman (Gallatin County), Montana. In order to generate a rough sense of the density of the Gallatin County optics cluster compared to the one in southern Arizona, RTS compared its estimated number of optics establishments in Gallatin County to the number of optics establishments in southern Arizona normalized with three different measures: optics firms as percent of total non-farm establishments for the area, optics

[9] http://www.biztucson.com/biznews/cover-story/170-driving-tucson-optics, Friday 27 February 2009

[10] Regional Technology Strategies; U.S. Census Bureau: State and County QuickFacts.

firms per capita, and optics firms per non-farm employment. Although AOIA ascribed 160 optics companies to all of southern Arizona, only Maricopa County (Phoenix) and Pima County (Tucson) were used for the establishments, employment, and population counts.

When the percent of establishments in each region that represent optics companies was used as a density measure, the Gallatin County optics cluster was about 3.8 times denser than the southern Arizona cluster. When both population counts and employment counts were used to produce a normalized density measure, the Gallatin County optics cluster was over 9 times denser than the southern Arizona optics cluster on a per capita basis and 8 times denser when normalized with employment counts.

The optics company core of the cluster developed in three stages. First was the establishment of Big Sky Laser (now Quantel) in 1981. This was followed by three more firms from 1986-1989 – ILX Lightwave, Lattice Materials Corporation, and Scientific Materials Corp. (now Scientific Materials/FLIR). Another group of five companies was formed in the 1992-1995 period – Wavelength Electronics, Quantum Composers, New Wave Research, Image Labs, and Altos Photonics. Over the next sixteen years the number of optics companies operating in Gallatin Valley grew from 9 to 28. The companies' efforts span a wide range of activities and applications and for the most part are distributed across four, occasionally overlapping, industry segments though there is also some activity in other areas including Medical Technology and IT/Consumer Electronics areas.

1. Optics Production Technology

2. Optical Measurement and Machine Vision

3. Defense Photonics

4. Optical Systems and Components.

Though some of this information will be addressed in more detail in later sections of this analysis, for the purposes of a general characterization of the cluster, several other aspects should be noted.

- The group of companies that comprise the Bozeman/Gallatin Valley concentration engage in a rich mix of production manufacturing, custom design and manufacturing, R&D, and product and process development activities.

- A sizeable majority of the firms in the cluster were formed since 2000 and they tend to be young, small and innovation intensive.

- Many of the companies have a strong connection to Montana State University's Optical Technology Center (OpTeC) and its associated non-profit Spectrum Lab.

- Though there is always competition for talent from the labor pool for any cluster, in spite of their numbers the Bozeman area optics firms tend not to compete in the same market segments for the same customers.

Infrastructure

A common element among clusters that produce numbers and levels of jobs, income, wealth and competitive advantage within regional economies is a well functioning infrastructure. In this case, we define "infrastructure" as "the underlying resource and public and private entities that advance the competitiveness of the firms within the cluster." Fully developed clusters reach a level of activity that induces the formation of entities whose operations are directly tailored to servicing the cluster. This can encompass a wide range of activities but typically includes post-secondary and higher education institutions with offerings targeted to the cluster, public and non-profit research operations that support innovation within the cluster, technical assistance providers with cluster-specific expertise, attorneys and capital providers with very specialized cluster-specific expertise and so on.

Industry associations, alliances, networking organizations and centers are also important cluster infrastructure elements. These entities often end up functioning as robust hubs that connect and leverage talent and innovation resources, transmit and relay technical and business information, and advance the overall interests of the cluster. As presented below, to a great extent the elements to form a strong hub are already in place within Montana's optics cluster.

The Optical Technology Center (OpTeC)

Officially formed in 1995, the Optical Technology Center (OpTeC) at the University of Montana is a virtual multi-disciplinary center that supports and advances education and research in optical science and engineering. To accomplish this, OpTeC includes research groups and students from three MSU departments: Electrical & Computer Engineering; Physics; and Chemistry & Biochemistry. OpTeC functions as the Montana optics cluster's primary information sharing and networking platform for university researchers and faculty, private industry and students. As part of this work in addition to an annual conference that features presentations from students, faculty and research staff on recent optics developments at the university it also sponsors a colloquium over the course of the academic year that addresses a broad range of optics topics and promotes cross-disciplinary interactions of students, faculty, staff and employees from optics cluster companies.

OpTeC plays a prominent role within the optics cluster as its networking center for research and talent production. Many of the companies, especially those formed since 2000, are staffed and led by scientists and engineers from MSU that were, and in many cases still are, active OpTeC participants. A number of these companies also have on-going research, intellectual property creation and licensing relationships with MSU and its faculty through the OpTeC conduit.

Spectrum Lab

Spectrum Lab was "spun out" of OpTeC in 1999 to further develop technologies from Montana State University's research laboratories, to move those technologies into private companies and to provide educational opportunities for MSU students. To this end, Spectrum Lab serves as a kind of optics "applications incubator" for faculty and industry and as a bridge between MSU labs and the private sector. Spectrum Lab is funded through contracts and grants. It has a strong mission track record that includes spinning out two of the cluster's very active companies – Bridger Photonics and S2 Electronics. Spectrum Lab is another prominent element within the cluster's innovation infrastructure. At present it has formal collaborations in progress with four optics cluster companies – ADVR, Bridger Photonics, S2 Corporation, and Scientific Materials Corporation.

Montana Manufacturing Extension Center

Montana Manufacturing Extension Center (MMEC) at Montana State University's College of Engineering in Bozeman is a statewide manufacturing assistance center that provides technical support and training to Montana businesses. MMEC is also a part of the National Institute of Standards and Technology (NIST) nationwide network of centers created to assist small and mid-size manufacturers, the Manufacturing Extension Partnership (MEP). MMEC offers a wide array of services to Montana manufacturers including business management, design and product development, lean enterprise, process improvement, and quality systems services as well as a variety of training courses. While MMEC works throughout Montana and services all manufacturing sectors, it has played an on-going role as a highly valued technical assistance resource for those optics companies with a production and manufacturing focus. MMEC engineers have specialized optics-related manufacturing expertise and the center itself has developed into an integral part of the optics cluster infrastructure.

TechLink and MilTech

Established in 1996 at Montana State University and funded primarily through the US Department of Defense (DoD), TechLink connects companies throughout the country with DoD research laboratories for licensing, development, transfer and commercialization of new technologies including photonics and sensor technologies. It also assists Montana companies in the preparation of SBIR and STTR proposals for submission to any federal agency.

MilTech is a DoD sponsored effort that provides technical and management assistance to small companies to accelerate the transition of technology to the US warfighter more quickly, reliably and cost-effectively. This national program is a partnership between TechLink and MMEC.

Though both TechLink and MilTech operations are national in scope, Montana optics companies benefit from both programs being headquartered in Bozeman in at least three ways. First, DoD is a major customer for several of the cluster companies. Second, much

of the on-going R&D and product development within the cluster is geared toward DoD applications. Third, DoD is in itself a source of funds through grants and contracts for Montana optics cluster R&D efforts.

Cluster Profile and Development Assessment

RTS designed and deployed a short 10 question Internet-based survey to sketch out a profile of the state's optic cluster companies – who they were, what they did, and their perceptions about their most pressing business issues (see Appendix A). This was followed by a series of on-site face-to-face interviews to generate a more detailed understanding of the competitiveness issues the firms were facing as well the resources they understood to be at their disposal and connectivity and relationships among the firms.

The information gleaned from the survey responses and interview results was then used to compile an Optics Company Group Profile and to craft a Cluster Competitiveness Factor Profile, both of which are presented below. Information was gathered from 12 of the 28 (43%) Bozeman optics cluster companies (this response level also represents 32% of the Montana optics industry total). Face-to-face interviews were also conducted with seven of these respondents as well as the two previously described major optics infrastructure elements that connect to the university community and to the companies - OpTeC and Spectrum Lab.

Optics Company Respondents Group Profile

Company Characteristics

All the respondents were from Gallatin County/Bozeman area. Sixty-four percent of the respondents had just a single office while 36% had additional offices – all located out of state.

Sixty-three percent of the companies reported less than 20 employees while 18% had 21 to 50 employees and another 18% had 50 to 100 employees.

The companies represented a variety of product or service areas including production of laser components, lasers and laser systems, R&D and prototype development, instrument manufacturing, custom instrument manufacturing, and measurement services. Most of the firms (70%) reported in-state sales but at very modest levels. In terms of sales volume, roughly 55% of their sales were in out-of-state US markets and 39% of sales were in international markets. Only 6% of sales were to Montana customers.

Forty-five percent of the companies had received SBIR/STTR awards with three quarters of those firms also receiving Phase II awards.

Business Needs and Issues

The respondents' were asked to select their most pressing business issues from the following list.

- Experienced/specialized employee recruitment
- Worker training
- Access to capital
- Strategic partners
- Business/market development
- Distribution and logistics
- Access to specialized suppliers or materials
- Intellectual property management
- Manufacturing or process issues
- Access to specialized scientific or engineering expertise
- Administrative assistance
- Human resources assistance
- Using/maximizing impact of social media
- Other- please specify

The following four needs were flagged by at least one third of the firms.

1. Experienced/specialized employee recruitment (64%)

1. Business/market development (64%)

2. Access to capital (45%)

3. Strategic partnering (36%)

Experienced/specialized employee recruitment and *Business/market development* tied for first, each with 64%. Next was *Access to capital*, which was selected by 45% of the respondents followed *Strategic partnering,* selected by 36% of the responding firms.

Three need categories were identified by just over 18% of the respondents, *Intellectual property management, Manufacturing or process issues, and Access to specialized scientific and engineering expertise*.

Just under 10% of the respondents identified *Worker training, Distribution and logistics, Access to specialized suppliers or materials*, and *Administrative assistance* as pressing business issues.

No firms indicated that *Human resources assistance* or *Using social media* were pressing needs.

Networking Interest

The survey concluded with the following question: *Are you interested in participating in events or functions that bring Montana optics companies together to network or address common issues?*

Ninety-one percent of the respondents answered "yes" to this question. One respondent offered a comment that bears noting here as it was often refrained in the follow-up interviews.

> *The optics community is a strong collection of individuals with various niche technologies, and it is of interest to bring them together, although it will be challenging. I am interested in being a part of a new community, but will like and need to see the common elements grow.*

Competitiveness Factor Profile

Based on the Internet survey, the nine on-site interviews with cluster members and follow-up communications, RTS constructed the below presented Montana Optic Cluster Competitiveness Factor Profile. Using a variation of the template RTS has designed over its 15 years of cluster analysis at the regional, state, national and international levels, the profile is organized around eight key cluster asset categories. The completed profile is then used to chart a future development strategy for the cluster.

1. Workforce And Human Capital

Strengths

- MSU and OpTeC are viewed as major resources for knowledgeable entry-level or near entry-level employees and, from a human capital perspective, were viewed as infusing their students and researchers with an innovation mindset.

- The high concentration of companies in the Bozeman area was also viewed as a significant workforce and talent attraction asset in and of itself. As stated by one of the optics company officials, "A concentration of companies really helps build the talent pool as people now come here with the expectation that if a job doesn't work out they can find another one in the industry right here."

- The younger, more R&D intensive companies did not view talent recruitment as a significant problem. While they often hired MSU graduates, they also recruited out-of-state for employees with specialized experience or knowledge.

Weaknesses

- Companies with more than 20 employees and/or with more of a production orientation indicated they had issues with finding specialized and experienced engineering expertise and in finding optics-qualified manufacturing technicians. In one case a company was looking out-of-state for technicians from two post-secondary training programs.

- Several company representatives mentioned that more research support is needed for OpTeC to get "more kids working in labs to get hands-on experience."

2. Innovation And R&D Assets

Strengths

- OpTeC and Spectrum Lab form the innovation infrastructure for the Montana optics industry and the Bozeman optics cluster. As such, they function as the industry's major optics research, applications development driver and talent source and have historically played an integral part in the development of Bozeman cluster.

- While the group has several older well-established companies, to a great extent it is characterized by young, small technology or applications development companies committed to innovation within the market segments they have targeted.

- On the innovation deployment side, the Montana Manufacturing Extension Center (MMEC) is regarded as a valuable technical assistance resource by those optics companies with a manufacturing orientation.

Weaknesses

- Several company respondents felt that there is a real need for innovation- and business-oriented technical assistance specifically tailored to optics companies. The general sentiment was the cluster companies and their interactions with OpTeC and Spectrum Lab together have generated a cadre of existing technical entrepreneurs and continue to produce aspiring optics entrepreneurs who need help in areas such as intellectual property management, contracts administration, access to capital, recruiting strategic partners for continued applications development or market development and so on.

- There was a sense among several respondents that the overall innovation capacity of the Bozeman optics cluster was not clearly understood and therefore, under-recognized because so many of the firms were unfamiliar with each other.

3. Entrepreneurial Energy and Financial Capital

Strengths

- There appears to be a burgeoning entrepreneurial culture within the Gallatin Valley optics cluster. A distinct majority of the firms in the cluster have been formed since 2000 so they tend to be young, small and innovation intensive. This Gallatin Valley innovation ethos is also fueled by MSU, OpTeC and Spectrum Lab, which tend to produce and support graduates and researchers with bleeding edge optics science and technology orientations.

- Capital is an issue (see weaknesses) however many of the companies are adept at obtaining SBIR Phase I and II awards as well as other federal grants. Several have also been successful applicants for Research and Commercialization Board grants.

- Capital requirements for companies within the optics industry tend to be relatively low when compared to other knowledge-intensive industries like bioscience. As a result, many optics companies are desirable targets for angel investors and angel networks. Although there is some angel investment in play among the Montana optics companies, angel investors as a reliable early stage capital source were not viewed as having a strong presence. This may represent an opportunity to develop a larger scale initiative tailored to the optics cluster.

Weaknesses

- Access to capital was identified as a top priority business issue.

- Several company representatives pointed out that there were very few visible and successful optic entrepreneurs to serve as role models and mentors and that mentors were badly needed for startups and early stage companies within the cluster.

- There was a perceived lack of access to startup and growth management technical assistance and experience specific to optics companies. Because the underlying science, engineering and technology is dynamic and constantly changing, applications are diverse and in a state of flux and it is so niche oriented, there is a feeling that any help here needs to be tailored to the optics sector – generic entrepreneurial assistance will be of limited value.

4. Ease of Moving Goods, People and Information

Strengths

- The companies use Fed Ex, UPS, et al to ship and receive materials and product. In general, they viewed these services as adequate for their needs.

Weaknesses

- Transportation for people was the most frequently mentioned weakness for this element – specifically, airfares and flight availability and times.

- In terms of moving information, bandwidth limitations and expense was also identified as an occasional issue.

5. Quality of Life and Amenities

Strengths

- Quality of Life and Amenities were frequently cited as major strengths for Montana optics companies. This was true both for recruiting key employees and for

business startups and location. This is a substantive marketing asset for the cluster.

The Montana outdoors lifestyle and the attractiveness of Bozeman as a college town and amenities were the key factors. A CEO from one of the very well established and older optics companies indicated they initially located in Bozeman explicitly as a lifestyle choice.

Weaknesses

- Montana's remoteness and distance from major commercial centers was the only quality of life and amenity-related disadvantage that was mentioned during the interviews.

6. Connectivity Within the Cluster

Strengths

- A number of the cluster companies, especially the "younger" ones, have strong and on-going connections to OpTeC at MSU and in some cases to Spectrum Lab. For these companies, OpTeC for all intents and purposes functions as a conduit to and window for cutting edge optics-related and often inter-disciplinary research and as a talent pipeline for the cluster companies. OpTeC and Spectrum Lab together through their missions, practices, graduates and researchers have over time fostered an entrepreneurial culture and strong innovation mindset within the cluster. In effect, they function as cluster hub for talent production and bleeding edge research and applications development.

- A subset of the cluster companies are pretty tightly networked.

- The companies as a rule do not compete in the same market spaces. Many, but not all, feature niche applications. This bodes well for any attempts to build collaborative networks, strategic alliances and other associative behavior.

- Ninety-one percent of the survey respondents answered "yes" to the question: "Are you interested in participating in events or functions that bring Montana optics companies together to network or address common issues?"

- The Montana Manufacturing Extension Center (MMEC) is a major asset here in that they provide highly valued technical assistance to those optics companies with a manufacturing orientation.

Weaknesses

- While some of the cluster companies were networked either through vendor relationships or through connections to OpTeC or Spectrum Lab, in interviews several companies indicated they "had no idea" what most of the other cluster companies did.

- One company described the connectivity environment as "a number of us are connected to OpTeC but we are not really connected to each other."

- While there are some supplier/vendor relationships and occasional business referrals among the companies, there is not a significant level of on-going business-to-business collaboration and mentoring.

7. Access to Specialized Suppliers and Services

Strengths

- There were a number of specialized supplier/vendor relationship among of the cluster companies. Seventy percent of the survey respondents reported in-state sales and, based on follow-up interviews, many of these customer relationships were with other optics companies. However, the actual sales levels reported by the respondents on average represented 6% of their total sales with 55% of sales going out-of-state in domestic markets and 39% into international markets.

- Those optics companies that engaged in manufacturing often cited MMEC as a valued technical assistance provider.

Weaknesses

- As many of these companies are developing or offering niche products or services, most (but not all) of the specialized service providers were outside the cluster.

- For the smaller and/or younger firms, a need for specialized optics business-to-business services was often mentioned in the follow-up interviews. This includes administrative, accounting, business development and intellectual property management help for established business plus startup assistance for new firms and entrepreneurs.

8. Government Regulations

Strengths

- No one mentioned local, state or federal government regulations as being of specific benefit to their company or the optics industry.

Weaknesses

- International Traffic in Arms Regulations (ITAR) export compliance regulations were cited and characterized by defense contractors selling lasers and laser system components as a major, unfair and irrational trade restriction burden in that they were developed years ago when lasers "were new." The regulations have not been updated and as a result US companies cannot sell lasers and components in international markets when their competitors in other countries can.

- Montana's business equipment tax was also mentioned as a government generated business cost – especially for small companies using very high value equipment.

Findings

An International and National Context

- As a ubiquitous enabling technology domain, optics is already established with a wide and deep technology platform that encompasses a group of technologies with a multitude of existing applications as well as the promise of an untold number of future technologies and applications.

- Defining optics or photonics as an industry is problematic as it is still emerging. Its existing base of technologies and applications are continuing to evolve while new technologies and applications are constantly and rapidly being created. The US has adopted no definition for this industry. At this point US optics companies can be found in numerous NAICS codes.

- The European Commission has sponsored the development of its own industry definition through Photonics 21, a European Technology Platform formed in 2005 to unite Europe's photonics industry and research institutions. The group has over 1800 members and drives the European optics agenda. This activity has produced several developments that should be noted for the purposes of this Montana optics industry strategy development effort.

    - The total world market for photonics products in 2008 was estimated at €277bn or about $370bn in 2008 US dollars at current exchange rate.

    - The annual real global photonic market growth rate was 10% for the 2005-08 period. By way of comparison, for this same time period, worldwide gross national income grew at 4.4%.

    - Photonics21 released a statement of its vision for photonics as a key enabling technology of Europe *(Photonics – Our Vision for a Key Enabling Technology of Europe,* European Technology Platform Photonics21, May 2011).

    - In September of 2011 Photonics21 issued a press release to announce its commitment to a proposed public-private photonics partnership with the European Commission. According to Photonics21, the proposal targets a 7 billion euros investment level by 2020 with 5.6 billion euros contributed by the photonics industry and 1.4 billion euros provided by the European Commission.

    - At present the US has no photonics or optics industry innovation strategy or development policy at the national level nor is it regarded a trackable category from an industrial activity standpoint.

- A domestic and international inventory of optics/photonics clusters and/or cluster support organizations identifies nine clusters or cluster support organizations in the US and 50 organizations in Asia/Pacific Rim, Canada and Europe.

Pinning Down the Optics Industry in Montana

- In the US there is no standard definition yet for optics or photonics as an industrial sector or subsector. As a result of this NAICS-based definition dilemma, analysts may use NAICS codes for guidance, but for the most part they then build up their particular industry or cluster description organically by identifying firms, one-by-one that appear to engaged in optics or photonics-related commerce.

- The working definition for this assessment combines two approaches. First, it populates the cluster with known establishments that have self-selected as optics firms and then identifies their NAICS codes. It then triangulates among several analyses that identified NAICS codes in which optics firms resided (Connecticut, Arizona, Florida) and compiles this list and then merges with the NAICS codes for known Montana optics firms. The resulting NAICS-based template is then used to identify the names of Montana firms in each of these NAICS subsectors. The firms are then vetted one-by-one to determine if they are a "fit" that should be included in the Montana optics industry or cluster definition.

- Because our focus is on the optics industry's core value-creating companies, we chose not to include ophthalmology and optometry offices, service labs and product distributors though they are included in some industry and especially cluster definitions as they are part of some of the marketing, distribution and end-user chains. This narrowly defined approach identified 38 companies that form the basis for the optics industry in Montana.

- Twenty-eight of the 38 optics companies in Montana were located in or around Bozeman. From 1981 to 1995 nine optics companies were established in the Bozeman area. From 1996 to 2012 18 optics companies were established in the Bozeman area.

- A sizeable majority of the firms in the cluster were formed since 2000 and they tend to be young, small and innovation intensive.

- Though in absolute terms the Montana cluster is not the scale of perhaps the most well-known cluster {in southern Arizona, at least three of the critical ingredients are present: a geographically dense (in this case, very dense) concentration of optics companies, a burgeoning infrastructure that includes a third ingredient, talent production, and innovation hub}.

- The companies' efforts span a wide range of activities and applications and for the most part are distributed across four, occasionally overlapping, industry segments though there is also some activity in other areas including Medical Technology and IT/Consumer Electronics areas.

1. Optics Production Technology
2. Optical Measurement and Machine Vision
3. Defense Photonics
4. Optical Systems and Components.

- The group of companies that comprise the Bozeman/Gallatin Valley concentration engage in a rich mix of production manufacturing, custom design and manufacturing, R&D, and product and process development activities.

- Many of the companies have a strong connection to Montana State University's Optical Technology Center (OpTeC) and its associated non-profit Spectrum Lab.

- Though there is always competition for talent from the labor pool for any cluster, in spite of their numbers the Bozeman area optics firms tend not to compete in the same market segments for the same customers.

Infrastructure

- Industry associations, alliances, networking organizations and center are also important cluster infrastructure elements. These entities often end up functioning as robust hubs that connect and leverage talent and innovation resources, transmit and relay technical and business information, and advance the overall interests of the cluster. As presented below, to a great extent the elements to form a strong hub are already in place within Montana's optics clusters.

- OpTeC plays a prominent role within the optics cluster as its networking center for research and talent production. Many of the companies, especially those formed since 2000, are staffed and led by scientists and engineers from MSU that were, and in many cases still are, active OpTeC participants. A number of these companies also have on-going research, intellectual property creation and licensing relationships with MSU and its faculty through the OpTeC conduit.

- Spectrum Lab was "spun out" of OpTeC in 1999 to further develop technologies from Montana State University's research laboratories, to move those technologies into private companies and to provide educational opportunities for MSU students. To this end, Spectrum Lab serves as a kind of optics "applications incubator" for faculty and industry and as a bridge between MSU labs and the private sector.

- While MMEC works throughout Montana and services all manufacturing sectors, it has played an on-going role as a highly valued technical assistance resource for those optics companies with a production and manufacturing focus. MMEC engineers have specialized optics-related manufacturing expertise and the center itself has developed into an integral part of the optics cluster infrastructure.

Optics Company Survey Responses

- Information was gathered from 12 of the 28 (43%) Bozeman optics cluster companies (this response level also represents 32% of the Montana optics industry total). Face-to-face interviews were also conducted with seven of these respondents as well as the two previously described major optics infrastructure elements that connect.

- Most pressing business needs and issues - *Experienced/specialized employee recruitment* and *Business/market development* tied for first, each with 64%. Next was *Access to capital*, which was selected by 45% of the respondents followed by *Strategic partnering,* selected by 36% of the responding firms.

- The survey concluded with the following question: *Are you interested in participating in events or functions that bring Montana optics companies together to network or address common issues?* Ninety-one percent of the respondents answered "yes" to this question.

Competitiveness Assessment Summary

The emergence of the Montana optics cluster is not really a recent phenomenon. Although it has certainly become more visible over the last few years as a presence in Bozeman and as a significant economic development asset for the state, it is a thirty-year story that unfolds in fits and starts beginning in 1981. Hindsight allows us to spot a cluster development path that begins with a small group of production oriented optics companies in the 80's and then expands in the 90's with another group of companies along with the establishment of OpTeC and then Spectrum Lab. The path continues to expand and extend itself over the next 15 years as the pace quickens as more optics companies and connections develop.

Table 7: Cluster Competitiveness Factors

Asset Category	Comments
Workforce & Human Capital	OpTeC is a major contributor to the talent pool. High concentration of companies in Bozeman is a talent attraction asset. Some issue with finding specialized engineering expertise and qualified manufacturing technicians.
Innovation & R&D Assets	OpTeC and Spectrum Lab function as research and applications driver and talent source and promote a strong innovation mindset. MMEC is a valuable technical assistance resource for firms with manufacturing orientation. However, there is a need for entrepreneurship and business assistance tailored to optics.
Entrepreneurial Energy & Financial Capital	There is a burgeoning entrepreneurial culture within the Gallatin Valley optics cluster. Access to capital is a major issue. Optics company capital requirements are relatively low so should be an attractive angel investor target. Need for entrepreneurial assistance tailored to optics companies.
Ease of Moving People, Goods & Information	No major issues shipping and receiving product due to FedEx, UPS, et al but some concerns with air fare and flight availability and schedules for people.
Quality of Life and Amenities	Montana outdoors lifestyle and beauty frequently cited as a major strength for recruiting talent and for business location decisions.
Connectivity with the Cluster	A number of the younger companies are connected – often through relationships with OpTeC. Older, more established companies not as well connected within the cluster. 91% of optics company survey respondents indicated interest in participating in networking functions.
Access to Specialized Suppliers and Services	Most specialized supplier sources were outside Montana. Many of the companies had traded relationships with each but on average only represented 6% of sales (94% outsides the state). MMEC often mentioned as major specialized assistance source for manufacturers. For younger firms, need for optics specialized business assistance often mentioned.
Government Regulation	Obsolete and irrational ITAR export compliance regulations a major obstacle for optics defense contractors.

Clearing the Development Path: The Optics Cluster Strategy

To a great extent the goal of this strategy is to help clear the development path this cluster is already in the act of charting. As stated earlier in this document, clusters do not need a public sector strategy in order to exist but the right strategies can help the businesses in them become more successful and competitive. To this end, then, this strategy needs to accomplish five things.

1. By this analysis' count, at least 28 of Montana's 38 optics companies are located in Gallatin County, in or around Bozeman. The strategy should focus on Bozeman cluster power as the differentiating organizing asset. However, it is important to note there are other optics companies scattered around the state including four in the Missoula area plus three more north of Missoula up Highway 93 in Ronan, Polson and Kalispell as well as two companies in Butte. While the focus should be on the geographically bounded Bozeman concentration of optics companies, the cluster development strategy should be implemented in a way that facilitates and connects and the flow of benefits and information to Montana optics industry companies outside of Bozeman.

2. The strategy should respond directly to the most pressing needs expressed by the companies.

   The companies say they need help with:

   - Specialized employee recruitment
   - Business development
   - Getting access to capital
   - Identifying and developing strategic partnering relationships

   The companies surveyed indicated a strong interest in networking, getting better connected to each other and improving business and technical information flows within their group.

3. The strategy should feature a mechanism that responds to the above listed needs.

4. The strategy should protect and feed the cluster's key infrastructure elements and fill in important infrastructure gaps.

   The key elements are the OpTeC – Spectrum Lab tandem that perform and advance multi-disciplinary bleeding edge research, drive into applications development, and generate talent and MMEC that provides valued technical assistance to optics companies with manufacturing operations.

5. The strategy should position the cluster as an economic development marketing asset for Montana.

Actions

The below presented action recommendations define a cluster development strategy designed to both respond to optics companies' most pressing business needs, as expressed by those companies, while pressing the advantage on the cluster's most distinctive and powerful development assets. To this end, these actions are designed to enrich the entrepreneurial culture and very strong innovation orientation that define the cluster and its companies – a culture and orientation that is fueled by an innovation infrastructure that generates multi-disciplinary science and engineering talent, bleeding edge research and a strong flow of application possibilities for this ubiquitous industry with diverse international market segments and niches.

Action 1

Working with a steering committee of key optics cluster companies and stakeholders, design and establish the Big Sky Optics Alliance to oversee the implementation of the strategy and to function as a hub for the cluster.

The steering committee would be charged with managing the development of the initial business plan for the Alliance including mission, structure, operating priorities and funding sources and with recruiting the first board of directors.

Two early and key decision points here are 1) whether the Alliance should be "incubated" within another organization during its formative stages and 2) whether the Alliance should be designed as a stand-alone entity or as a working entity under the umbrella of another entity such as Innovate Montana or the Governor's Office of Economic Development.

Action 2

Assuming they are amenable, factor in roles for OpTeC, Spectrum Lab, and MMEC within the strategy implementation effort as key innovation infrastructure elements.

The Alliance should focus on responding to optics company business needs and on helping them grow and prosper. In view of its mission, its board should be private sector dominated. However, a well developed innovation and technical assistance infrastructure here imbues the optics industry with competitive advantage – it helps the firms and the cluster continuously create new value. These three organizations together are to a large extent what make this a cluster rather than just a collection of companies. Because they produce talent, research, commercialization paths, applications and technical assistance for the manufacturing dimension, they create an advantage for the companies.

Action 3

Establish very focused initiatives to address the optics company-specific entrepreneurship training and technical assistance gap.

While OpTeC, Spectrum Lab, and MMEC help define a well-developed infrastructure for this cluster, there is still a notable gap. A number of companies expressed a need for business-

oriented technical assistance specifically tailored to optics companies. The general sentiment was that cluster companies and their interactions with OpTeC and Spectrum Lab together have generated a cadre of technical entrepreneurs within the cluster and that they will continue to produce aspiring optics entrepreneurs who need help in areas such as intellectual property management, contracts administration, access to capital, recruiting strategic partners for continued applications development or market development and so on.

To this end, two initiatives are recommended – one directed at university students and researchers so they are better prepared for the business of optics company development and one aimed at providing assistance to existing entrepreneurship and companies.

1. *Either through GOED or under the auspices of the Big Sky Optics Alliance, working with and through MSU and OpTeC, design and find funding for an initiative to infuse entrepreneurship courses and experiences into optics-related curriculum.*

2. *Either through GOED or under the auspices of the Big Sky Optics Alliance, establish a program to provide optics companies access to entrepreneurship and business assistance providers that work with technology companies and are viewed as credible by the optics companies.*

At the moment, the demand for these services is acute but limited. Put more simply, due to the size of the cluster, for the near future only a handful of companies will need this kind of help at a moment in time. But, those that do need it really need it. As the cluster continues to develop and expand the demand for this type of assistance will also expand. These services could be delivered by putting a qualified individual or organization on retainer, by providing the optics firm with a voucher to be used for the purchases of technical assistance help, or by working with an existing technology entrepreneurship entity to develop more in-depth optics industry specific business knowledge.

Action 4

Design and launch an initiative to promote and encourage angel investment in Montana optics companies.

Capital requirements for companies within the optics industry tend to be relatively low when compared to other knowledge-intensive industries like bioscience. As a result, many optics companies are desirable targets for angel investors and angel networks. Although there is some angel investment in play among the Montana optics companies, angel investors as a reliable early stage capital source were not viewed as having a strong presence though cluster companies as a group regard access to capital as one of their highest priority needs.

As a starting point, two actions are recommended here.

1. *GOED could encourage the formation of a small optics angel investment network by paying for the development of the group's business plan and/or helping to defray the*

network's organizing costs. In the past these types of modest efforts have been effective in fomenting the formation of business and manufacturing networks. The GOED role here is that of a catalyst and not a sustainer.

2. *Enact financial incentives for angel investment in qualified companies. This could be accomplished by providing a tax credit for early-stage investment in qualifying companies and/or by deferring taxation of capital gains from investment in qualifying early-stage companies that are reinvested in qualifying early stage companies.*

Action 5

Continue to build the talent base – talent trumps everything. Establish a robust optics internship program.

Spearheaded by GOED or under the auspices of the Big Sky Optics Alliance, this internship program would work with and through OpTeC to place promising students in cluster companies. An effective approach here might fund these positions at some prescribed, competitive rate, say $15/hour, and the state could reimburse the company for half the hourly wage. This would be an "everybody wins scenario" where the student receives an attractive wage and obtains in-the-trenches experience, the company gets a good deal and the cluster and state build talent with a very modest fiscal impact.

Action 6

Connect to the Globe: Establish a formal initiative to connect Montana optics companies and the Montana optics cluster to firms and clusters in other places – especially in other countries.

Montana optics company survey respondents indicated almost 40% of their sales were outside the US. This report identifies at least 50 optics/photonics alliances and associations in other countries. These organizations are now participating in numerous international optics alliances and collaborations covering North America, Europe, the Pacific Rim and Australia. Their activities include information exchange among researchers, rotating summer schools, employee exchange, and internship programs.

The most logical entity to undertake this initiative is the Big Sky Optics Alliance once it is up and running. OpTeC should also be regarded as a valuable participant, especially on education-related and research connections and exchanges.

Action 7

Consider larger optics firms outside of Montana as a strategic recruitment target to anchor the cluster.

The Montana optics cluster is comprised of small firms and very small firms. There are some circumstances in which recruiting a larger firm to anchor the cluster makes business sense for the cluster and economic development sense for the state. The strategic

recruitment target would need to meet two criteria: 1) it could not be a direct competitor of existing firms and 2) it would need to have the capacity to be a substantive customer for a subset of the existing cluster firms.

If the recruitment target meets these criteria then the remaining issue is the labor market and workforce availability impact associated with adding a larger firm into the cluster mix. An argument can be made that while this may indeed be an issue, it is a good issue to have. You address this by producing more talent and importing more talent – both important capacities for dynamic clusters.

Marketing Considerations For the Governor's Office of Economic Development And The Economic Development Community

As a final note, based on the foregoing analysis and recommendations, the Montana optics cluster can boast at least five characteristics that can serve as distinctive assets from an economic development marketing standpoint.

1. Company density can be a talent recruitment magnet. The large number of companies in the Bozeman area portends employment mobility. A talented engineer or scientist considering a move to Bozeman can anticipate other employment and career advancement opportunities if the one in question does not work out.

2. Bozeman (Big Sky Country) as a place and lifestyle is one of the most desirable locations in the country.

3. Through OpTeC (and Montana State University) and Spectrum Lab, optics companies and optics talent have access to bleeding edge science, engineering and applications.

4. Youth and Energy. Young entrepreneurs, engineers, and scientists drive the companies and environment.

5. Big Sky Optics Alliance (assuming it is established). The cluster has its own activity and information hub that supports a wide range of company business needs and promote peer-to-peer networking and collaboration.

Appendix A: Montana Optics Company Survey Instrument

Montana Optics

Montana's optics industry is one of the state's best-kept economic development secrets. We'd like to change that. We are contacting you because your company has been flagged as member or potential member of our state's optics industry.

The Governor's Office of Economic Development wants to know what it can do to help Montana optics companies continue to start and to grow. We also want to shine a national spotlight on what you and your peers have already accomplished. To do this we need to know who you are, what you do, and what business issues are on your mind when you are driving to work in the morning. Please take a few minutes to complete this very short on-line survey. Once we assemble this information we will act on it.

Please note this survey guarantees respondent confidentiality. Findings are only reported at an aggregate level, not on an individual basis.

1. Company Information

Name:

Company:

City/Town:

State:

Email Address:

Phone Number:

2. Do you have offices other than the location listed above?

- Yes
- No

3. If yes, where are your other locations?

4. Approximately how many employees do you have?

- 1-5
- 6-20
- 21-50
- 50-100
- Over 100

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Montana Optics

5. What are your products or services OR planned products and services?

6. Where are your markets (approximate % local, national, international)?

Local

National

International

7. What are your most pressing business issues at the moment? You can select more than one answer.

- ☐ Experienced/specialized employee recruitment
- ☐ Worker training
- ☐ Access to capital
- ☐ Strategic partners
- ☐ Business/market development
- ☐ Distribution and logistics
- ☐ Access to specialized suppliers or materials
- ☐ Intellectual property management
- ☐ Manufacturing or process issues
- ☐ Access to specialized scientific or engineering expertise
- ☐ Administrative assistance
- ☐ Human resources assistance
- ☐ Using/maximizing impact of social media

Other (please specify)

8. Have you ever received an SBIR grant?

- ○ Yes
- ○ No

Montana Optics

9. If so, what phase(s) and what is the title? What is the status?

10. Are you interested in participating in events or functions that bring Montana optics companies together to network or address common issues?

- Yes
- No

Comment

Thank you for participating in this survey! We truly hope this project benefits companies like yours.