CAMBRIDGE SYSTEMATICS

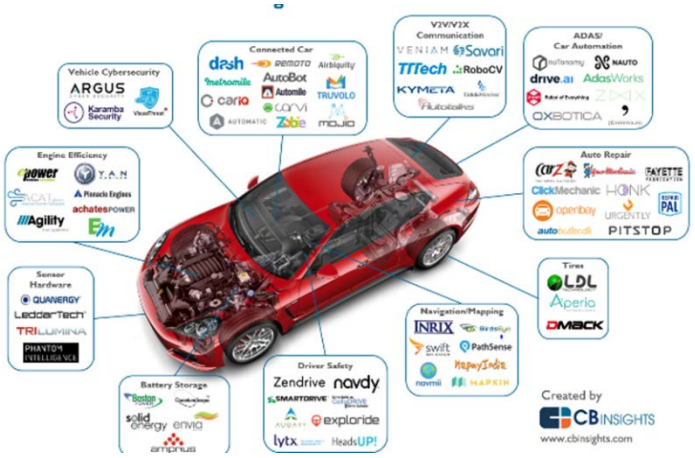
Transportation and Logistics Hub Study

Appendix C

Transportation and Logistics Hub Study – APPENDIX C

Global Automotive and Photonics Sector Overviews

Appendix C



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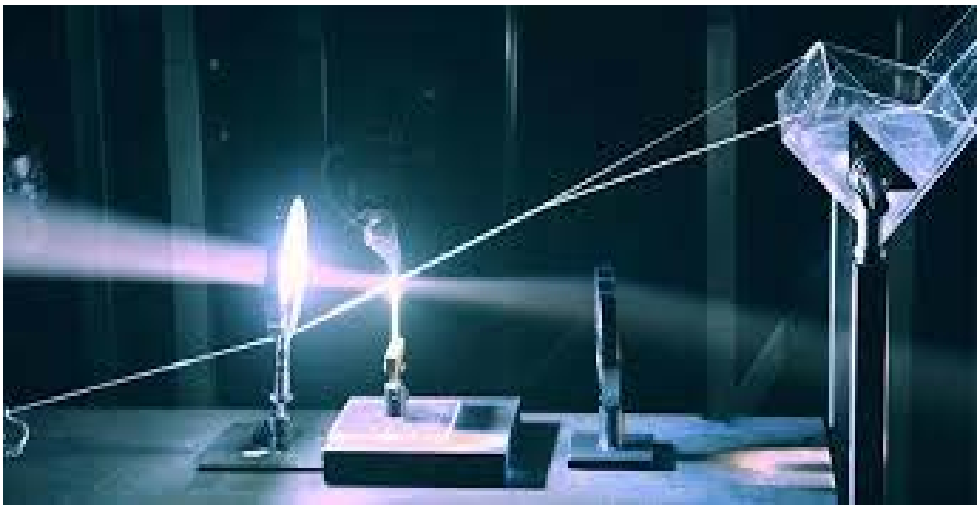
GLD Partners

and

Cambridge Systematics, Inc.



Global Automotive Sector Overview

Industry Definition and Overview

Industries in the Transportation Equipment Manufacturing subsector produce equipment for transporting people and goods. Transportation equipment is considered a type of machinery. This subsector is highly significant to the economic base in all three North American countries. Establishments in this subsector employ production processes similar to those of some other machinery manufacturing industry - bending, forming, welding, machining, and assembling metal or plastic parts into components and finished products. However, the assembly of components and subassemblies and their further assembly into finished vehicles tend to be a more common production process in this subsector than in other Machinery subsectors. There are other aspects of the automotive industry which overlap with the wider electronics industry and this is now an important if not dominating aspect of the automotive industry. The automotive industry is unique in that it is a high-volume industry that produces a product of extraordinary complexity. Because of the industry's size and breadth it is a bellwether of the national and global economies; the auto industry has historically contributed about 10% to the overall GDP in developed economies with automotive production. (Foresight 2020. Economist)

Peter Drucker described the automotive industry as "the industry of industries," because it consumes output from just about every other manufacturing industry. The automotive industry consumes a significant percentage of the world's output of rubber, malleable iron, machine tools, glass, semiconductors, and aluminum, steel, plastic and textiles. These commodities and products are sourced from all over the world via a complex array of supply chains. As the typical automobile is made up tens of thousands of parts and components coming together at assembly, the automotive industry is generally recognized by most supply chain experts as the world's most highly developed supply chain system. As mentioned above, the sector also is an important user of a growing array of electronic components and related high-technology components - and the supply chains that support this important element are in a state of rapid development at the present time.

The automotive production industry is comprised of companies that fabricate original equipment (OE) and "aftermarket" products for motor vehicles. In Europe and North America it is estimated that original equipment products account for about 75% of total automotive products manufacturing. (USITA, EAAMA) Original equipment are products that go into the manufacture of a motor vehicle (automobile, light truck, motor coach, or medium/heavy truck) or are purchased by the assembler for its service network to be used as an aftermarket part. Aftermarket products are broken into two categories:

1) Replacement products and accessories. Replacement products are automotive parts built or remanufactured to replace OE products as they become worn or damaged.
2) Accessories are products made for comfort, convenience, safety, performance, or customization and are designed for add-on after (or sometimes during), the original sale of the motor vehicle.

Overall, the automotive industry is undergoing a transformation unlike anything seen since the very early days of the industry. In the eyes of most industry experts, the very nature of vehicle transport is being redefined by technological advances that are enabling different options for producing movement (propulsion systems), guiding vehicles (autonomous controls), communicating and entertaining (connected car). Producers that design, engineer and assemble finished products are rapidly becoming coordinators of complex technologies that are typically being developed by unaffiliated small and large tech-oriented companies. The basic nature of the supplier–OEM relationship is changing as the technology has advanced in ways that are beyond the capacity of the incumbent giants in the industry. Many pundits are predicting that the well-known incumbents won't maintain the dominant role that they have enjoyed for the past 70-80 years, and instead the future automotive industry will be much less cartel-like - with more players that are fundamentally about technology and services. Though the legacy incumbents still are playing a central role in today's industry, increasingly it is appearing as though those producing the technology will play more important and perhaps dominant roles.

The industry has historically been centered in the US, Japan and Western Europe. There were and are some other national production markets (Russia, India and China) but these were not globally important and were not strong technology centers and in most cases these secondary production centers were instruments of national policy. The epicenters of the automotive industry have evolved dramatically over the last ten years and the evolution is intensifying as autotech becomes more and more important. The centers of autotech today are largely centered now in Silicon Valley, Detroit, Germany, Japan and increasingly in China.

While many of these changes are caused by pure technical innovation, government policy has played an important role in the industry's metamorphosis in requiring driving new safety systems and increasing fuel economy improvements. In Europe and in North America, the standards being imposed on industry are ratcheting-up now, in some cases some after long run-up periods. The counter-combination of increased emphasis on safety requirements (structural and tech systems) and increased fuel economy is forcing huge investments by OEMs to meet various conflicting standards. Issues like producing better safety results while also making vehicles lighter in the name of fuel economy and enhanced range are very important today, whereas even 5 or 6 years ago they were far less a focus of the OEMs. And then, there are the incorrect expectations of increasingly higher oil prices, which in North America has caused the market to desire products that are in conflict with where policy was headed.

The recent US federal election has caused the automotive industry to undertake a reevaluation of some of its most fundamental assumptions, including an array of government regulations (safety, fuel economy) and trade policy framework. For example, these issues will impact how aggressively or not the industry invests in lightweighting, in new engine management/electronic control systems, advanced materials and alternative propulsion.

Along with vast leaps in technology, this matrix of intersecting dynamics will further reshape the role for some types of suppliers and tech companies, as evidenced by companies like Nvidia, Mobileye, Google, Uber, Lyft, Baidu and a long list of pure automotive start-ups (like Tesla) becoming heavily involved. With the changing technology, market and policy parts, how all of this will look in 10 or 20 years is unclear. For now, most industry players will continue to assume that companies that produce products that are tech-

heavy applications in propulsion systems, energy storage, guidance tech, lightweighting, and applied information systems will be fundamental drivers to the vehicle of tomorrow.

From an economic development perspective, this increased growth may create new opportunities for regions that would not have been considered competitive for attracting traditional automotive commodity product suppliers. The nature of autotech/production work is becoming so highly specialized, the focus of having commodity-level suppliers located within a short distance from a particular OEM assembly plant is not necessarily the case today.

Global Production and Current Market

From a global perspective, the sector has grown substantially over the past 20 years as developing markets have matured and become wealthier. Almost doubling production during the period, the industry has underwent a dramatic metamorphosis. Following a debilitating downturn in 2007 during the recession, over the past five years the worldwide automotive industry has been enjoying a period of relatively strong growth and profitability and annual sales have reached prerecession levels in most regions. Yet given overall economic conditions, trade agreements, political shifts and the potential for revised bilateral relationships, there is considerable uncertainty and guarded optimism about the future.

Since 2005 and through the downturn, the industry has increased production by +35% and the world's total vehicle production reached over 90M units in 2015. Final 2016 numbers are expected to be approximately on par with 2015, but there are signs of softening demand. The table below illustrates the automotive sector's growth from 1997 through the last full model year.

Production Yr	Production Volume	Y-o-Y Change
1997	54,434,000	
1998	52,987,000	- 2.7%
1999	56,258,892	6.2%
2000	58,374,162	3.8%
2001	56,304,925	-3.5%
2002	58,994,318	4.8%
2003	60,663,225	2.8%
2004	64,496,220	6.3%
2005	66,482,439	3.1%
2006	69,222,975	4.1%
2007	73,266,061	5.8%
2008	70,520,493	-3.7%
2009	61,791,868	-12.4%
2010	77,857,705	26.0%
2011	79,989,155	3.1%
2012	84,141,209	5.3%
2013	87,300,115	3.7%
2014	89,747,430	2.6%
2015	90,870,583	1.1%

Global production of motor vehicles, cars and commercial vehicles (GLDPartners)

However, the sector's robustness has not been even across the world. In the current period the outlook in Europe is much weaker as the region is barely emerging from a six-year sales slump. Sales have plunged in Russia and South America, down by about 25% and 15% respectively in the latest year-over-year figures. Meanwhile, the Indian market's performance has been inconsistent but remains a focus for massive growth in the future, perhaps now the last remaining untapped market of size. Growth in China, the world's largest vehicle market, has slowed even though investments by most original equipment manufacturers (OEMs) continue to ramp-up.

Europe - Figures are still very much below the pre-crisis levels, even though a clear but modest recovery has been observed. In the last 12 months, production reached 17M units (+5%) and sales 14.9M units (+6%). Production figures are on track to reach approximately 18M vehicles next year, but much of the increase is due to export growth. Figures though are still well below the pre-crisis levels. For the rest of Europe, including Russia and Turkey, there is a marked decline both in production, 3.4M vehicles (-7%). There was clear growth after the 2008-2009 crisis, but the tendency is clearly negative for the past few years.
Asia and Middle East - Both production (47.4M +3%) now account for around 50% of global figures. China surpassed the US in 2008 as the largest market by number of vehicles sold as incomes rose and Beijing promoted the automotive sector as an engine of economic development. China is still the strongest player in this region and had a +7% increase both in production and sales last year. For 2016, some Asian markets however declined, such as Thailand (-30%) and Indonesia (with a modest decline of -2%). (Forbes)

US – The auto industry in the US has turned itself around and has become profitable after a few very challenging years. Investment in new product platforms and in next-generation technology has occurred alongside the economic recovery and has evidenced in substantial growth in the OEM and supplier business categories. Since 2009, the industry has added more than 100,000 jobs. (US House Sub-Committee on Energy and Commerce)

US auto production is typically in the 10-12M unit range and that is generally comprised of about 40% passenger cars and 60% commercial vehicles. Today, North America accounts for only 18.7% of world automotive production and this figure is expected to drop as demand and production increases in other parts of the world. In terms of US vehicle exports, there is a large flow of auto industry goods.
US Automotive Exports

- The top five US export markets for vehicles assembled in the US were Canada, Mexico, Germany, China and Saudi Arabia
- While exports to Canada increased modestly in recent years, exports to Mexico, Germany, China, and Saudi Arabia have increased by 10-15%
- About 2.1M vehicles assembled in the US were exported to over 200 countries in 2015
    - Chrysler, Ford and GM together exported more than 800,000 vehicles
    - The majority of exported US production was due to European and Asian brands exporting from assembly facilities in TX, IN, OH, IL, MS, SC, AL, GA and TN
- US exports to China have grown substantially over the past five years. Last year, 136,222 American-made vehicles were exported to China, a significant figure considering that auto exports to China were less than 1,000 as recently as 2003
- The Middle East region is the 2nd largest market for American-assembled SUV's after the US market. (Auto Alliance)

Global Automotive Production: Breakdown by Major Production Region:
1 Asia 51%
2 North America 19%
3 Europe 19%
4 South America 5%
5 Russia 3%
Source: OICA 2012

Global Sector Leaders

Globally, the auto production industry is very diverse and includes some large and small company names that are probably not all that familiar in the US. Some important names on the list of important global

manufacturers are relatively new, showing the very dynamic nature of the industry: Some of the new or high-growth global manufacturing brands today include companies like: Anhui, Avtovaz, Beijing, Brilliance, BYD, Chana, Changhe, Chery, China National, Daewoo, Daihatsu, Dongfeng, Faw, Faraday, Fisker, Fujian, Gaz, Geely/Volvo, Great Wall, Guangzhou, Harbin, Hino, Ij-Avto, Kamaz, Lucid, Mahindra, MAN, Multicar, Nanjing, Paccar, Proton, SAIC, Tata, Uaz and Vaz.

Heavy Truck and Commercial Vehicles

Companies in this industry classification manufacture truck and bus chassis and assemble trucks, buses and other special purpose heavy duty motor vehicles for highway use, such as firefighting trucks. The trucks manufactured by this industry are heavy trucks used by freight companies and do not include passenger vehicles. There are seven major manufacturers of heavy trucks in the US including Freightliner, Hino, International, Kenworth, Mac, Peterbuilt and Volvo. There are distinct markets within this category, including various classifications of heavy truck and commercial vehicles. There are many technological advances in the truck market as well, especially in propulsion systems and autonomy (vehicle platooning, etc.).

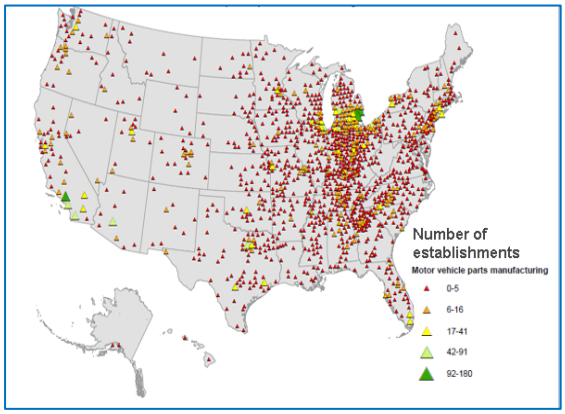
Parts and Supplies

A very large component of the auto industry is related to parts and supplies which support 1) OEM vehicle production (original equipment manufacturers), 2) after-market replacement and repair parts, and 3) maintenance repair products. Firms in the US manufactured and exported almost $80B worth of parts and components products and this figure grew by about +15% in 2015. Many of those exports goes to other NAFTA countries (73%) with lesser amounts shipped to Europe (8%), South America (5%), Japan (3%), Australia (3%) and Asia, other than Japan and China (3%) and China (2%).

The US parts supplier industry sub-segment is made up of a large and diverse array of firms, including:

- Johnson Controls
- Goodyear
- Delphi
- TRW Automotive
- Guardian Industries
- Intl Automotive Components
- Cooper-Standard
- Flex-N-Gate Federal Mogul
- Tower Automotive
- Affinia Group
- American Tire Distributor Holdings
- CC Industries
- Interstate Battery System Intl
- Remy International
- Allison Transmission
- America Axle
- Autoliv
- Coates International
- Country Accessories
- Dana
- Dorman Products
- Douglas Dynamics
- Enova Systems
- Fuel Systems Solutions
- Gentex
- Gentherm
- Lear
- Meritor
- Miller Industries
- Modine Manufacturing,
- Monro Muffler Brake
- Motorcar Parts
- Puradyn Filter
- Quantum Fuel Systems
- Technologies Worldwide
- Shiloh Industries

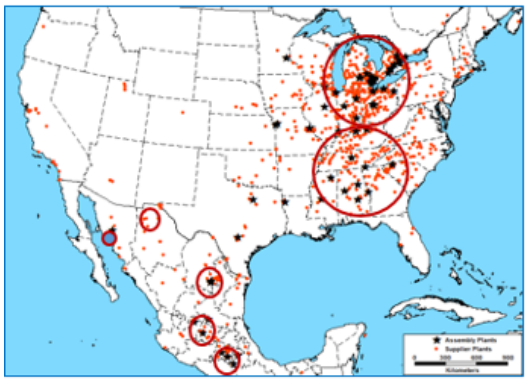
In the US, as a general rule the auto parts industry is primarily located in the Midwest, although in recent years, the industry has migrated to the south. Even with these concentrations, there are hundreds of parts manufacturers in other parts of the country and in every state. The largest of the supplier firms are mostly concentrated around assembly plants in Michigan, but also in Texas, California, Wisconsin, Georgia, Kentucky, Alabama, Missouri, South Carolina and Florida. An increasing presence of high-technology suppliers are present in both Michigan but also in a range of other states including Massachusetts, California, Washington, New York and Texas. Other states also have a small base of tech suppliers including Arizona, New Mexico, North Carolina and Virginia.



North American Geographic Concentrations

Bureau of Labor Statistics

From a wider North American perspective, the automotive parts manufacturing and assembly industry is generally clustered in five major geographic zones, with the traditional automotive regional center in Michigan, Ohio, Indiana and Ontario. Though still quite a center for manufacturing, this region's almost exclusive dominance has diminished as OEM cost pressures mount in the name of increased competition and as automotive assembly locations have migrated to the Southern US and to Mexico. Due to lower operating costs and incentives, the Southeast US has been a fast growing region for auto assembly plants and parts and component manufacturing. The center of gravity for the industry in the US has increasingly moved south as foreign manufacturers have built assembly plants in Alabama, Tennessee, Mississippi, Texas and Georgia.



Auto Supplier Concentration in US and Mexico

Source: Chicago Federal Reserve Bank

Mexico has emerged as a globally significant automotive industry player, now the 6th largest automotive producer and 4th largest exporting country in the world. Mexico has three major concentrations of manufacturing activity: 1) Saltillo/Monterrey, 2) Guanajuato/Silao and 3) the Mexico City/Puebla combined region. There is also some automotive investment in the Northwest part of the country, primarily in Hermosillo (near Ford) and Chihuahua, especially in Cuidad Juarez near the international border.

The medium and heavy truck manufacturing industry in the US is largely concentrated in the eastern half of the country in Ohio and in the Southeast (Virginia, the Carolinas, Oklahoma and Texas). There is also manufacturing presence in Mexico with Volvo, Kenworth, Chrysler, Isuzu, Mercedes, Freightliner and Blue Diamond with plants throughout the country.

The 21st Century Automobile Manufacturer - Ford Motor Company Snapshot

Ford is a public company that has undergone significant transformation in the last 20 years with the majority of that change taking place in the last 10 years. During this time, they have fully shed a near fully integrated production philosophy that was adopted during the 1950's building boom. Ford operates as distinct business operating units in North America, South America, Europe and Asia Pacific & Africa.

> Inexpensive energy led to the SUV production surge in the 1990's and Ford and its counterparts thrived financially on these high margin vehicles. With the end of inexpensive energy and due to increasing federal fuel economy standards, Ford along with other domestic manufacturers were compelled to adjust their product mix toward smaller, more efficient vehicles. Along with a raft of new global vehicle platforms and powertrains, Ford adopted a global production strategy similar to that of its Asian counterparts. It became more focused on its core mission and worked hard to shed non-core business activities.
>
> The Company divested its vertically integrated parts manufacturing into a spinoff company known as Visteon. The Visteon divesture was completed in 2000 with it operating as a standalone public company. The Company's goal was to develop a lean supply chain system where it could encourage and mandate delivery efficiency and product innovation, but from the perspective of a client. This has allowed Ford to be more fleet-footed and focus on what it felt were its core competencies, vehicle design, integrated systems engineering, assembly and marketing.

Incumbents vs. Newcomers

Within a more complex and diversified mobility-industry landscape, incumbent players are being forced to compete simultaneously on multiple fronts and cooperate with competitors. Other industries such as telecommunications or mobile phones/handsets have already been disrupted, the automotive industry has seen very little change and consolidation so far prior to the last 3-5 years.

- For example, only two new players have appeared on the list of the top-15 automotive original-equipment manufacturers (OEMs) in the last 15 years, compared with ten new players in the handset industry.

Software is the new sector engineering - In another game-changing development, software competence is increasingly becoming one of the most important differentiating factors for the industry, for various domain areas, including ADAS/active safety, connectivity, and infotainment. Further on, as cars are increasingly integrated into the connected world, automakers will have no choice but to participate in the new mobility ecosystems that emerge as a result of technological and consumer trends.

New Market Entrants

Many more new players are likely to enter the market, especially from cash-rich high-tech companies and start-ups. These new entrants from outside the industry are also wielding more influence with consumers and regulators (that is, generating interest around new mobility forms and lobbying for favorable regulation of new technologies). Automotive incumbents cannot predict the future of the industry with certainty. They can, however, make strategic moves now to shape the industry's evolution. To get ahead of the inevitable disruption, incumbent players need to implement a four-pronged strategic approach:

1. **Prepare for uncertainty**. Success in 2030 will require automotive players to shift to a continuous process of anticipating new market trends, exploring alternatives and complements to the traditional business model, and exploring new mobility business models and their economic and consumer viability. This will require a sophisticated degree of scenario planning and agility to identify and scale new attractive business models.
2. **Leverage partnerships**. The industry is transforming from competition among peers toward new competitive interactions, but also partnerships and open, scalable ecosystems. To succeed, automotive manufacturers, suppliers, and service providers need to form alliances or participate in ecosystems—for example, around infrastructure for autonomous and electrified vehicles.
3. **Drive transformational change**. With innovation and product value increasingly defined by software, OEMs need to align their skills and processes to address new challenges like software-enabled consumer value definition, cybersecurity, data privacy, and continuous product updates.
4. **Reshape the value proposition**. Car manufacturers must further differentiate their products/services and change their value proposition from traditional car sales and maintenance

to integrated mobility services. This will put them in a stronger position to retain a share of the globally growing automotive revenue and profit pool, including new business models such as online sales and mobility services, and cross-fertilizing the opportunities between the core automotive-business and new mobility-business models.

Sector Direction and Trends

Overall, the structure of the industry looks very different than at the beginning of 2007 when the industry was headed for the depths of the recession. This evolved structure can be traced to XX major factors and these factors are defining today's global industry and its direction:

1. Sector Recovery and Restructuring - The recession had a dramatic effect on the industry and some long-lasting changes as many suppliers went out of business, were forced to seek bankruptcy protection or were merged into larger better positioned partners. This has streamlined the automotive supplier structure and created larger Tier 1 player with more capacity.
2. China (and Asia) – China ascended to be the largest global auto market and its enormity is re-centering the global epicenter of the industry. Investment patterns of global brands are showing China to be the premier market. China exported more than 1M vehicles for the first time in 2012. The emergence of South Korea and specifically Hyundai as a global power has been dramatic. Hyundai is now the 4th largest automotive group in the world after Toyota, GM and Volkswagen.
3. Public Policy - Due to the (overall historic) rising cost of fuel, higher fuel taxes in other parts of the world and increasing government fuel economy and safety standards, carmakers and their suppliers have been wrestling with these challenges by committing to levels of engineering innovation that has never been witnesses before.
4. Technology – Reacting to market demand and new technological capability, with an increasingly wide range of technology partners, automakers are defining vehicles as rolling technology phenomena by vastly enhancing productivity and communications, increasing safety, environmentally friendly propulsion, and also edging toward a state of driverlessness.
5. Market Shifts - There is a close correlation to Asia's growth (China and South Korea) and the relative decline in dominance of Japanese producers. While still quite large an important, the major Japanese brands do not enjoy the dominance that they had for about 30 or so years. The continued rise of Volkswagen and Fiat as a global volume leaders has been an important factor. Using their large and dominant share of the large European market, both have grown their markets quiet substantially as global brands. The increase in demand for premium products and premium brands has moved the entire industry forward and has created a much larger luxury segment than any historical norm.

Overview of the Automotive Supply Chain System

The typical automobile is made up of approximately 20,000 detailed parts with about 1,000 key component systems. This complexity creates a quite substantial set of supply chain management challenges, especially as markets become more global. A key consideration for the automobile industry today is to manage supply chain and sourcing decisions based on total-landed cost, not limited to labor costs or piece-part costs which has been the historical model.

Supply chain methodology varies significantly across the automotive industry but all manufacturing process is supported by manufacturing layers or as referred to in the industry, "tiers". From the manufacturing and purchasing perspective, the term Tier 1 (T1) refers to a company that directly supplies to the final manufacturer, while Tier 2 (T2) firms supply Tier 1 firm. Some suppliers are both T1 and T2 suppliers if they directly supply an OEM as well as another supplier that directly supplies an OEM. A multi-tiered supply chain (T1 and T2) takes raw materials and basic component products and adds value which results in key components that are ultimately assembled into finished vehicles. There are four typical value-add

manufacturing processes which, though separate, are systemized to together create the final product: 1) small components from T2 manufacturers through to T1 manufactures and sub-assembly process, 2) powertrain manufacturing, 3) stamping facility making (typically) steel vehicle bodies and 4) final assembly. Typical order-to-delivery lead times are 30-40 days for regional markets and 60-80 days for global markets.

New vehicle assembly supply chains in North America are very well-honed so that much of the needed part and commodity (meaning low-value) component content is sourced from the vicinity of the assembly plant. Beyond that, there is considerable content movement between the suppliers and assembly plants in the US, Mexico and Canada, but lesser content movement from overseas sources. For lower value product, it simply costs too much to transport community products over long distances.

New AutoTech Cluster Locations - Unlike low-value commodity products which have decentralized manufacturing sites adjacent to automotive assembly plant, high-specification/high-value products are developing around global centers of excellence for research and product development and testing. It is highly likely that ramped-up autotech manufacturing that will occur in the coming years will be near or somehow connected to these global centers.

We foresee such cluster hubs developing in Asia, North America and Europe. This means that it would be likely that in the US, places like Michigan with its large concentration of automotive engineering talent and in Silicon Valley with its software engineering and creative tech/tech finance presence, would be likely hubs for significant autotech investment. Beyond that, it's our belief that the range of unique requirements of autotech will cause investments in non-traditional settings, where there is strong university connections and skilled tech workforces.

GLDPartners sees that Michigan will further develop as a global center for autotech manufacturing where the enormity of the automotive apparatus is so large. In California, we see some manufacturing occurring at or near to Silicon Valley, especially for testing and development, and for some very high-spec manufacturing. Though proximate to Silicon Valley, for the remainder of California we see some other manufacturing taking place, but frankly with the State's lack of business and competitive focus, we believe there are real constraints. For nearby states that can prove readiness and competitiveness, we see a window of opportunity to be function as an extended arm of the Silicon Valley high-tech apparatus. And beyond that, we believe that there can be other nodes with development and product manufacturing activity, again around an existing base of specialty production and/or university collaboration. There will be some similar product development and manufacturing in Asia and Europe (and in Israel which has become a formidable player in this space).

Supply Chain Structure

Today, supporting more models and ever more sophisticated products, OEM supply chains have over time become significantly complex structures. OEMs have worked to simplify their accountable supplier base by increasing the use of larger systems componentry, resulting in a decrease in T1 suppliers by almost 80% over the past decade. The goal for most OEMs has been to further reduce the number of suppliers. This reduction of direct supplies brings efficiencies but also introduces business risks as poor performers can create very serious problems.

Today's automotive sector is an ever-changing matrix of global suppliers working together on supply chain integration and sub-assembly processes. An example from Ford Illustrates:

> The Lincoln MKZ is assembled in Hermosillo, Mexico for sale in the US market. The plant began operation in 1986 as a stamping plant with assembly soon following. Parts content for this vehicle is 60% North American, 30% Asian and 10% European. The electronics in the vehicle are 70% Asian, 22% North American and 8% European. The vehicle is assembled with a combination of sheet metal stamped on site with steel sourced in Mexico and the US. Interior and drive trains are assembled from parts and finished components made in other parts of the US, Asia and Europe. The instrument cluster is assembled in Visteon's plant in Michigan and is made of parts sourced globally with the center LCD screen coming from a supplier in South Korea. As technology is evolving quickly, sometimes on a year to year basis, Ford continues to refine its suppliers to keep up with critical product innovations and this requires that management have flexible supply chain systems to accommodate changes in sourcing location, volume, speed from production to assembly, etc.

Domestically, most component logistics movements are moved via truck. Air cargo is an accepted method for small, lightweight and high-value products where freight can be easily absorbed into its overall cost structure. Frequently coming from T2 suppliers who can operate with less cash flow and where warehousing is not typically part of the operating model, the T1 purchaser usually will absorb the freight costs to reduce inventory carrying costs. The development of cheap but acceptable labor for the products in countries such as Mexico is driving an increase in airfreight where many parts are made then sent to another country or continent for final assembly into another product.

From an auto manufacturing company perspective, the methodology in which the company handles the movement of parts, components and finished products and manages inventory has changed substantially over the past 20 years. Auto manufacturers began forming partner relationships with third-party logistics companies (3PLs) around 1990. As OEMs were re-engineering their business processes, they realized their logistics management practices also required change, which gave birth to the outsourced logistics relationships of today.

Automobile manufacturers that have outsourced their logistics services have generally found a reduction in operational costs by 15-20%. In these instances, the 3PL manages the storage, distribution, inventory level, sometimes procurement, processing, warehousing, marketing and distribution. Importantly, the 3PL typically makes many critical decisions for the automaker concerning transport mode and carrier, inventory facility use and location, and even sometimes sourcing.

From a North American perspective, over the past 30 years there has been an increasing effort to source from low-cost countries. To an extent, this trend has reversed as manufacturers are requiring suppliers to be nimble to meet rapidly changing production and technology evolution and as transport costs and transit time has become a drag on operational efficiency. Therefore, the lowest production price has proven to be one important factor but in some instances not the most important or dominant factor. Manufacturers/suppliers are increasingly cognizant that the total cost of sourcing, includes logistics costs, quality of work and operational efficiency allowing for streamlined production adjustments, etc. In terms of cost, this approach is referred to as "best-cost-country" sourcing, and for supply chain management providers represents another opportunity to encourage, enable, manage and optimize sourcing.

Mexico Solution - Mexico's automotive sector is expanding rapidly with a recent influx of recent European and Asian automakers establishing assembly plants. Automakers have announced $7.8B in Mexican investments in the past 24months and production is projected to increase by 30-40% over the next 5-10 years as 8 of the 10 leading automotive OEMs and over 300 T1 suppliers now have plants in Mexico.

(Automotive News) Some current projects include: Honda is presently building its 1st large assembly plant, Toyota has just built a new plant with a joint-venture with Mazda and Audi recently started-up.

Mexico has more free trade agreements than the US and they have a free trade agreement with the EU that saves a 10% tariff that's applied to US-built vehicles. For automakers that are building "world cars" that are meant for global consumption, Mexico is promoted as an ideal spot as it is offers high-productivity, proximity to the large US consumption and extensive supplier markets, and with good global logistics assets. The Port of Veracruz for example was the busiest vehicle port in North America last year large than Los Angeles, handling 753,685 units for such companies as Ford, Nissan and Volkswagen.

Mexico's Rise and Potential Impact to Western US - That the North American center of gravity for the automotive industry has edged toward Mexico is meaningful for suppliers and for supplying high technology parts investment. With the growing status to the sector of Silicon Valley, this could have meaning to Western US states that fundamentally compete well on location and for quick-ship timing, especially to Northern and Central Mexico, with their strong tech credentials and good transport connectivity between markets.

Summary: Key Market and Supply Chain Issues

There are a series of major factors drivers that are influencing the inherent shape of the automotive supply chain. Here is a summary to the underlying influencing factors in the auto sector:

- *Global growth will be centered in Asia and this is where the major automotive producers and suppliers are focused.* This dynamic is new and is fundamentally altering the balance of the global automotive industry.
- China has become a globally significant automotive producer and will soon be the largest manufacturer in the world, Chinese-sourced cars will soon begin to gain significant global market share, requiring new supply chain systems.
- New production centers in North America, China, South Korea and Southeast Asia have matured into world-class automotive industrial complexes.
- Assembly operations and parts manufacturing of scale have emerged in smaller measures in such counties as, India and Thailand and will grow through the next decade.
- South Korea has emerged as a global auto powerhouse and is as Japan was in the early-mid 1970s.
- Europe and the US are important places to the industry but their indigenous markets are essentially mature. Key competition for both will be the ability to effectively sell to Asia.
- In North America, there has been rapid industry migration to the US South and to Mexico.
- Mexico has emerged as a global production center for US manufacturers and Asian and European makers, much of which is exported to the US but increasingly to other parts of the world.
- Continued expansion of foreign carmakers in the US; and some are supplying virtually all of their components from the US, and others still have a reliance on higher-levels of global sourcing. There will be increased pressures for local/regional sourcing.
- Alternative power systems including electric and hydrogen propulsion are redefining the very nature of the vehicle that has existing for about a century.
- The parts and component supplier industrial structure has fundamentally changed over the past 10-15 years as the supplier base restructured following the deep recession and due to the requirements of global assemblers
- There has been massive consolidation as weak suppliers were either let to vanish or were acquired by larger (in some cases global) supplier companies.

- Manufacturers have increased their demands on suppliers for lower costs and simplified processes. This has meant larger Tier One suppliers which are responsible for increasingly large componentry elements.
- High-cost electronics have necessitated new inventory management practices.

Product Advancements and the Central Role for New Technologies

The development of vehicle technology mainly falls into two categories: 1) auto manufacturers and traditional suppliers, and 2) companies that are technology innovators. Some companies, such as Tesla in the US and Baidu from China, arguably fall into both categories. This phenomenon of a far expanded role for a range of technology companies is dramatically altering the industry. Though never the case in years past, OEMs are by necessity working more closely with technology innovators on joint projects.

Though they are desperately trying, OEMs have found it very difficult to transform themselves to become tech leaders and some are instead relying on partner and outsource relationships and joint applications with small and large tech companies. An example of this is Microsoft's involvement and now Blackberry QNX in developing Ford Sync infotainment system. In a sign that OEMs are relinquishing to the pure providers for some tech applications, the new Apple CarPlay and Android Auto systems are being installed by most. Some OEMs are still trying to play the role of a tech company – and a good example of this is Toyota's development of an in-house competitor to Sync called Entune.

Cars and trucks bear little resemblance to their ancestor products even 6 or 7 years ago. This phenomenon is interesting but also critical to understand how the industry manages a far more complex research-to-supply chain management system. In engines, in product materials, in safety systems and entertainment, technology applications are literally changing the very core of the modern vehicle. The cost of electronics and software content in vehicles was less than 20% of the total cost a decade ago and today it is approximately 35% (Technical University, Munich).

Traditional suppliers are also remaking themselves, for example Delphi Automotive's deep commitment and Continental's recent investments to become leaders in autonomous vehicle management systems. So there are a wide range of companies that are legacy supplier to the industry that are in some cases redefining there future growth around next-generation technologies.

And well-beyond the highly visible announcements, there are a large number of companies vying to play important roles in the next-generation automobile like Nvidia, Qualcomm, Harman (now Samsung) and Intel. These firms are examples of large successful technology firms that have reshaped their business strategy around autotech and then there are literally thousands of tech start-ups like Codha, Mobileye and Autotalks which are all involved in wireless systems and C2C interactivity.

Via intense competition, OEMs and their T1 suppliers have been driven to quickly develop and integrate various technologies. It is important to note that the OEMs are finding ways to "upcharge" for new product advances and have developed rather substantial profit centers around safety-tech, infotainment tech, etc. Not all technology though is visible and therefore paying for itself via optional charges. In terms of materials science advances, composites and other structural next-gen products, these have lagged behind other technologies because OEMs don't feel the market is willing to pay extra for the technology.

These dynamics will evolve further and with now increasing commercial awareness of both the OEM world of environmental values, heightened public expectations, desire for increasingly high-performance and new CAFÉ (fuel economy) rules, various factors will support increasing business opportunity across a range of technologies.

Carmakers and their technology suppliers are now competing directly with Silicon Valley for talent. This has largely not been a significant factor for the industry in past years, but as technology is becoming far more central to the industry, the challenges for a new generation of programming and product development talent has now developed. Similar to computers and smartphones, electronic parts like sensors and microprocessors comprise the "backbone" of today's cars. Automakers are hiring thousands of software programmers – or "codites", who play an important role in vehicle design and operation. The impetus to hire codites is increasingly pitting Detroit against its technology partners in Silicon Valley. It should not be surprising that the state of California – long considered the nation's high-tech and R&D capital – has the largest number of engineers employed in the US with 62,000. Michigan, however, with a workforce one-quarter the size of the Golden State's, has nearly 60,000 engineers in its labor force. Due to tech skills shortages in Silicon Valley and Michigan, there will be increasing opportunities for some other areas which can supply talent.

A new generation of smarter, smaller and faster robots is poised to transform automotive manufacturing, vastly improving quality and speed. Collaborative robots, or "cobots," are now populating factory floors working in tandem with humans to make operations run more smoothly. Cobots are a newer trend, able to assist in a myriad of ways, from moving parts and improving safety to taking on wearisome tasks to improve the health of workers.

Mobility and Sharing

The underlying foundation of the consumer automotive industry is expected to change quite dramatically and the impact on the legacy OEMs is expected to be extensive. This foundation has been historically structured around an OEM selling to a retail user. Looking ahead, there are expectations that this fundamental model will change in that more and more people will share vehicles and that vehicles will be seen simply as an instrument of pure mobility. The impact will reshape the manufacturer-buyer relationship and might in-fact reduce the number of vehicles sold. OEMs are beginning to adjust their business strategies accordingly.

Consumer mobility preferences and behavior are predicted to change radically, leading to 10% of cars sold in 2030 being a shared vehicle and the subsequent rise of a market for fit-for-purpose mobility solutions. The trends beyond 2030 aren't well-understood but many experts suspect that shared mobility will become more the rule than the exception.

Consumers today use their cars as all-purpose vehicles, whether they are commuting alone to work or taking the whole family on vacation. In the future, it is anticipated that many people will want the flexibility to choose the best solution for a specific purpose, on demand and via their smartphones. We already see early signs that the importance of private-car ownership is declining: in the US for example, the share of young people (16 to 24 years) who hold a driver's license dropped from 76% in 2000 to 71% in 2015. In this same period, there has been over 35% annual growth in car-sharing members in North America and Germany.

Consumers' new use of tailored solutions by purpose will lead to specialized vehicles designed for very specific needs. For example, the market for a car specifically built for e-hailing services—that is, a car designed for high utilization, robustness, additional mileage, and passenger comfort—would already be millions of units today.

Mobility as a Service (MaaS), which provides aggregated, single account, on-demand multimodal transportation services in a seamless and convenient way is quickly gaining momentum. ABI Research forecasts global MaaS revenues will

exceed $1T by 2030. The MaaS ecosystem will breed a competitive environment full of dynamic transportation marketplaces, public private partnerships and aggregators moderating and managing supply and demand according to government policies and frameworks.

Betting on this direction, automakers are attempting to secure footholds in ride-hailing and vehicle sharing. Nearly all of the major players have made investments in MaaS, some examples:

- GM has been the most active to date, investing in or purchasing more than 15 companies since 2011, either directly or its venture arm, GM Ventures. GM was the first major OEM to commit heavily to ride-hailing and automation, investing $500M in a corporate minority round to Lyft, buying SideCar's assets and acquiring Cruise Automation for almost $1B.
- Toyota and Volkswagen have taken corporate minority stakes in Uber and Gett, and Volvo has also secured a separate partnership with Uber.

Autonomy – Industry experts see vehicle autonomy as a progressive process where early stages include a range of technologies to provide advanced driver assistance systems like automatic lane braking and parking, and as the technology allows and as consumers adapt, progresses to full self-driving. Seeing the path toward autonomy as a process, in 2016 the USDoT's National Highway Traffic Safety Administration (NHTSA) defined the progressive process in terms of five levels of vehicle autonomy.

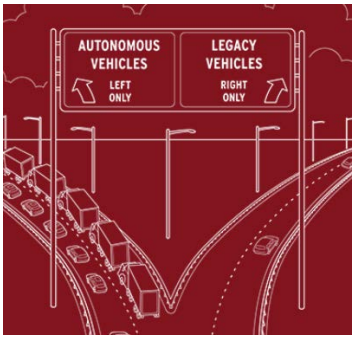
As defined by NHTSA, the five levels of autonomous vehicle technology are meant to define stages of increasing vehicle operation independence.

Level 0 The driver controls all input systems: steering, brakes, throttle and power.

Level 1 Most functions are still driver-controlled, but a specific function (steering or accelerating) is done automatically by the car. Even the earliest cruise control systems would qualify.

Level 2 At least one driver assistance system of both steering and acceleration/deceleration is automated, (i.e. cruise control and lane-centering). The driver is disengaged from physically operating the vehicle by having their hands off the steering wheel AND foot off pedal at the same time. The driver must remain ready to take control of the vehicle.

Level 3 Drivers are necessary, but completely shift "safety-critical functions" to the vehicle under certain conditions. The driver is still present and is required to intervene if necessary, but is not required to monitor as closely. Issues are raised concerning transferring control from car to human.



Level 4 This level achieves full autonomy. Vehicle design performs all safety-critical driving functions & monitor roadway conditions for an entire trip. Technology is limited to the operational design of the vehicle (does not cover every driving scenario).

Level 5 Refers to a fully-autonomous system that expects the vehicle's performance to equal that of a human driver in every driving scenario.

The levels are important because they serve as common general guidelines for technological advancement. The development of various advanced driver-assistance systems (ADAS) becomes the most crucial factor as together these systems become the autonomous vehicle. Though there is still quite a way to go in some areas, in many ways the technology in these ADAS systems are fairly well-developed.

Though the new US Administration may have different policy and budget priorities, it's important to note that the Obama Administration has a plan to invest almost $4B in autonomous vehicle research over the next 10 years in its quest to support the US automotive industry, while encouraging the infrastructure, safety and pollution objectives associated with vehicle autonomy.

From interviews with executives this fall with the top 20 OEMs there was a highly optimistic view of the technology and market advancing. Building on technology that is already available in a few luxury vehicles, self-driving vehicles will be able to navigate city streets by 2022 and may represent 25% of worldwide auto sales by 2035. It was also the view that Japan and Western Europe will probably adopt the technology most quickly, with the US, Korea and China following. By 2035 about 18M vehicles may be partially autonomous and 12M could be full autonomous, with China the largest market by that time. The manufacturing price premium for this additional technology will range from $2-10,000 and is expected to decline 4-10% per year in the first decade as adoption spreads.

With rapidly growing urban area that are increasingly facing traffic gridlock, automakers are keen to create technologies that ease traffic. In many areas, local and regional (State) governments are desperate for solutions as there is little new road capacity possible in many areas, and most governments would like to avoid the massive costs of developing new road capacity. Full autonomy is expected to increase traffic throughput by up to 250%, which would alleviate many current traffic issues and reduce the need for some traditional road infrastructure investments. There would be a corresponding improvement in air pollution as cars would not be sitting in traffic or at stoplights as often.

The rise of driverless vehicles is going to have a major impact on businesses and professionals. Automated vehicles could replace corporate fleets for deliveries or transporting employees, for example. Cars will become safer as they move toward fully-autonomous driving. KPMG predicts that the number of accidents are predicted to go down 80% by 2040. The market introduction of ADAS has shown that the primary challenges impeding faster market penetration are pricing, consumer understanding and safety/security issues.

OEM and Tier 1 Supplier Progress

- Ford Chief Executive Officer Mark Fields said at the Consumer Electronics Show in 2016 that an automaker probably will introduce a self-driving vehicle within half a decade, but it won't be Ford which is focusing on less expensive features that assist in driving.
- GM said in September, 2016 it will introduce hands-free highway driving technology on a Cadillac in two years.
- Mercedes unveiled its self-driving concept car has four seats that can face each other, rather than the road. Screens will let passengers monitor information about the vehicle and the outside world, using technology that responds to eye movements and gestures. They expect a production version of this vehicle will be on the market within 15 years.
    - Mercedes already sells a system that can pilot a car on the freeway, as long as the driver keeps a hand on the steering wheel, and this year introduced a hands-free system.
- Tesla currently offers a hands-free highway driving system in its Model S and has announced that every car in production will now have the capability for full autonomy by 2018.
- Magna is a manufacturer of a range of semi-autonomous products, and also owns a vehicle-assembly subsidiary. Magna could be a potential outsource player in the autonomous vehicle category, where it might function similar to how Foxconn supports Apple. This role could manifest as joint ventures with tech companies whose technologies are key but are not automotive assembly business (Google, Uber, Baidu and a growing list of global tech companies)
- Continental projects that it will earn $1.3B in revenue from systems that build autonomy into brakes, acceleration and steering, this is now the fastest growing part of the company by far.

CEO Brian Krzanich said Intel Capital intended to invest more than $250M over the next two years to develop technology for autonomous vehicles. Krzanich said the company would use its expertise to handle vision processing, 5G connectivity, cloud computing, machine learning and security. Intel has traditionally has not been a major automotive supplier. Over the past 12 months, the company says it has booked contracts with a variety of automakers worth $1B. Customers include BMW, Daimler, Hyundai, Infiniti, Jaguar, Kia, Lexus, Mini, Rolls-Royce, Toyota and Tesla. In July Intel announced that it was teaming with BMW and Mobileye to develop self-driving system for the iNext, which will replace the 7-series sedan as BMW's flagship. The three companies will make their technology available to other carmaker and project that fully automated vehicles would be commercially available by 2021.

Intel plans $250 million investment in self-driving tech
Automotive News
November 15, 2016 @ 3:20 pm

Intel's announcement portends an expanding battle among chipmakers in the market for autonomous vehicles. Last month, Qualcomm announced the acquisition of NXP Semiconductors, the auto industry's largest chipmaker for $38.5B.

Alternative Propulsion Technology

Propulsion systems are undergoing dramatic change as OEMs are searching to satisfy customer demands for increased power, while also addressing increased fuel economy standards and an increasing green environment awareness. Legacy OEMs have taken quite different strategic paths in this regard, some have invested heavily in electric power systems, while others have straddled the line and have produced hybrid technologies using smaller batteries with traditional internal combustion engines (ICE). Still others like Mazda have chosen to remain ICE focused, while still others are investing in hydrogen and diesel technology.

48-Volt Electrical Systems: Electric Accessory Drives

The practical realities of global manufacturing and refueling infrastructure investment mean that the internal-combustion engine (ICE) will probably be the dominant powerplant for several more decades. One of the key technologies that will help ICEs become more efficient is the 48-volt electrical system. Most of today's engines drive alternators, coolant pumps, oil pumps, and air-conditioning compressors mechanically via a belt or directly and they generally run continuously. The common automotive 12-volt electrical systems have electrical power limitations and are overwhelmed by today's widespread use of electronic features. As ever more features are added more electrical power will be needed. Stepping up to the 10-kW output enabled by 48-volt generators will allow those new features and today's mechanical accessory drives to go electric. That will reduce the parasitic loads on engines and potentially boost fuel economy by about 10%. Newly introduced Bentley and Audi models have 48-volt electrical subsystems today, and it's expected that this will spread to the mainstream in the coming years.

Advanced Cylinder Deactivation

In 1981, Cadillac introduced an innovative new V8 engine variant that could automatically switch off two or four cylinders. Paired with fuel injection and relatively crude electronics, the experiment was a market failure. Today, cylinder deactivation is commonplace and generally imperceptible to the driver. In the coming years, additional sensors and sophisticated control algorithms will increasingly enable engines to run more of the time on less than their full complement of cylinders. By the end of this decade, GM and Delphi, licensing technology from the startup Tula Technology, expect to have advanced variable cylinder deactivation which would allow as few as two cylinders active in light-load conditions. According to GM, this could reduce fuel consumption by as much as 15%. Johnson Controls is also making large market investments in related technology.

Alternative Fuel Technology

An alternative-fuel vehicle (AFV) uses a flexible-fuel system (one with a common fuel tank designed to run on blends of unleaded gasoline with ethanol or methanol) or a dual-fuel vehicle (designed to run on a combination of an alternative fuel and a conventional fuel) operating on at least one alternative fuel. It is estimated that more than a million alternative-fuel vehicles were in use in the US in 2014; 50% of these operate on liquefied petroleum gas (LPG, or propane) and almost 25% use compressed natural gas (CNG).

Many believe that the ideal alternative-fuel engine would burn fuel much more cleanly than conventional gasoline-powered internal-combustion engines and yet still be able to use the existing fuel infrastructure (gas stations). CNG, propane, hydrogen, and alcohol-based substances (gasohol, ethanol and methanol) all have proponents. However, although these fuels burn somewhat cleaner than gasoline, the use of all of them involves trade-offs. For example, because they take up more space per mile driven, these alternatives require larger fuel capacities or shorter distances between refueling stops. In addition, conventional automobiles have required modifications to use alternative fuels, however, many US automobiles have been manufactured with equipment that enables them to run on E85, a mixture of 85% ethanol and 15% gasoline. Fuels derived from plant materials, such as ethanol, are a popular concept because they do not deplete the world's oil reserves; in various locations, "biodiesel" test cars have run on fuel similar to sunflower-seed oil.

Hydrogen Power

Hydrogen Fuel Cell Vehicles (FCV) operate on hydrogen instead of the typical gasoline or diesel. A FCV utilizes a fuel cell, which create a hydrogen and oxygen chemical reaction to convert to energy. The electricity, which is produced from this process, is then used to run the vehicle’s motor and produce the driving power for the car. When using hydrogen fuel cell technology, a bank of fuel cells is sufficient to power a car for hundreds of miles and can be refueled considerably quicker than an electric car. Not only do hydrogen fuel cells burn clean, but their only by-product is water.

Hydrogen is continually being researched as a clean energy replacement for other sources of power. In the automotive industry, hydrogen fuel cell technology is gaining more traction to become the forefront of potential clean technology. Some Japanese companies are investing large amounts in hydrogen technology. Japan’s Ministry of Economy, Trade and Industry set a target of 40,000 hydrogen fuel-cell vehicles on its roads by 2020 supported by 160 fueling stations. Toyota released the Mirai in the last 18 months which is the company’s first commercial fuel-cell-powered car. Though hydrogen has its proponents, there are serious challenges to its widespread use. Low-cost sources of hydrogen are required and the system requires pipelines and shipping methods to transport hydrogen and then fueling stations to distribute it to end users like cars, households and industries. Driving the costs of this infrastructure down far enough to compete with fossil fuels would depend on a global economy of scale, and many countries would have to buy in.

The cost of developing advanced zero-emission powertrains for future vehicles is substantial. Especially in hydrogen fuel-cell research, some legacy OEMs are doubling and tripling-up to share costs.

- Responding to the Japanese government's strong push to create a "Hydrogen Economy", Honda and GM agreed to share their fuel-cell development efforts and the two companies are taking a further step. The partnership will set-up a factory to manufacture fuel-cells with a goal of starting production by 2025. The plan is for each company to manufacture its own vehicles using the shared technology. Honda has proceeded a bit faster and recently launched its Clarity model. GM had the world's largest test fleet of hydrogen-powered vehicles but after its 2009 bankruptcy the company shut down its fuel-cell R&D efforts, so this has meant that GM had to begin anew.
- Toyota partnered with BMW to share costs on hydrogen fuel cell tech. BMW’s objective is to take advantage of the costly technology Toyota developed for its Mirai in exchange for cooperation on

sports-car projects. The retail price of the Mirai is high due to the limited production and sales are constrained by a still limited fuel distribution system. Christopher San Marchi, manager of the hydrogen program at Sandia National Laboratories notes "if manufacturers were able to sell 1M vehicles, the price would come way down, we have not started reaching economies of scale yet."

- Mercedes-Benz has joined with both Ford and Nissan to pool hydrogen development efforts and are expected to launch a new FCV in the very near future, though volumes will be low.
- Anticipating substantial new demand in Japan, Kawasaki Heavy Industries and Iwatani Corp. partnered with Kobe City to build a Y10B ($84M) liquefied hydrogen import hub. The project, due to be completed in 2020, will import hydrogen made from lignite coal in Australia.

Besides the cost of the fuel-cell stack and the lack of a refueling infrastructure, the other major issue is storing the hydrogen. Until now, FCVs have stored hydrogen gas in bulky carbon-fiber-wrapped cylinders at pressures up to 10,000 psi. For several years the US DoE's Advanced Research Projects Agency–Energy (ARPA-E) has been funding a variety of research projects to develop conformable storage systems for compressed natural gas. The "intestinal" storage system developed by San Francisco startup Volute consists of a series of what are essentially small gas cylinders linked together in series and wrapped back and forth on top of one another. An arrangement like this provides much greater packaging flexibility than one or two large cylinders, making it practical in smaller cars and in irregularly shaped areas

Turbine Plug-In Hybrids

Batteries are showing tremendous promise for electrification of cars and smaller light trucks, yet when payload is important, batteries are too bulky to be practical. For bigger cargo haulers ranging from package delivery to trash collection and long-haul trucking, batteries consume too much of the payload capacity and take too long to charge to be used alone. A company called Wrightspeed, has devised a plug-in-hybrid powertrain for big haulers that contains enough battery for nearly 30 miles per charge and a turbine powering a range-extending generator. Recent startup Nikola Motors has a similar system for big rigs, designed to run on compressed natural gas. Theses turbines can run on pretty much anything that will burn.

Battery/ICE Hybrid Technology

Hybrid electric vehicles (HEVs) are powered by two or more energy sources, one of which is electricity to produce high efficiency, low-emission results. There are two types of HEVs, series and parallel. In a series hybrid, all of the vehicle power is provided from one source. For example, an electric motor drives the vehicle from the battery pack and the internal combustion engine powers a generator that charges the battery. In a parallel hybrid, power is delivered through both paths, both the electric motor and the internal combustion engine powering the vehicle. Thus, the electric motor may help power the vehicle while idling and during acceleration. The internal combustion engine takes over while cruising, powering the drive train and recharging the electric motor's battery.

Electric-Vehicles and Energy Storage

Stricter emission regulations, lower battery costs, more widely available charging infrastructure and increasing consumer acceptance will create new and strong momentum for penetration of electrified vehicles (hybrid, plug-in, battery electric, and fuel cell) in the coming years. As evidenced by the extremely fast model introduction pace expected over the next 3-5 years, in 2030 the share of electrified vehicles is expected to be a much more significant share of new-vehicle sales. Through continuous improvements in battery technology and cost, it is expected that adoption rates will further increase. As battery production costs decrease to $150 to $200/kilowatt-hour over the next decade, electrified vehicles will achieve cost competitiveness with conventional vehicles, creating the most significant catalyst for market penetration.

BYD was the first to deliver a truly zero-emissions ecosystem to the world in 2011 and the firm is now the World's leader in battery-electric vehicle production. BYD gained the leading position in the last year as the Chinese EV market has grown due to government incentives. Globally, the largest EV-producers were:

Ranking	Manufacturer	Sales*	Country
1	BYD	43,073	China
2	Nissan	42,012	Japan
3	Mitsubishi	36,623	Japan
4	Tesla	36,312	USA
5	VW	27,755	Germany
6	BMW	25,470	Germany
7	Renault	20,136	France
8	Kandi	17,201	China
9	Ford	17,117	USA
10	Gotye	15,384	China

* last 12 months

**Notable manufacturers not making this year's leader list: GM with Volt US sales at 11,399 units, Toyota with 4100 Prius PHV sales, Fiat and Kia all below 5000 units.

BYD also dominates in the electric bus market where there is limited competition at present. Globally, BYD will deliver nearly 6000 electric buses in 2016, with about 300 zero-emission electric buses scheduled to be built in 2016 from BYD's factory in Lancaster, CA.

Together, LG Chem and Samsung control 34% of the world's automotive battery market. Other important players include SK Innovation and Panasonic. Samsung is one of the largest lithium ion battery manufacturers in the world and it wants to move from the small electronics market into electric vehicles and energy storage. Samsung bought Magna's battery business last year and recently opened its own gigafactory in China (40,000 vehicles) and is expected to be a major player in the large Chinese market.

Manufacturer	Major Automotive OEM Customers
LG Chem	20 global EV makers: GM, Audi, Ford, Hyundai, Volvo, SAIC, Chery
Samsung	Zhengzhou Yutong Bus and Beiqi Foton Motor
Panasonic	Tesla
Samsung SDI	JAC
Johnson Controls	Jaguar Land Rover, Mercedes

The GM Bolt demonstrates how far LG Chem has advanced creating batteries for the mass market. The car is going on sale now at a cost of around $37,000 and comes with a Tesla-like range of 238 miles. LG Chem is able to produce these cells for $145/kWh, which is now allowing for affordable long range. There are some very promising technologies on the horizon, including silicon anodes in the battery. Silicon can absorb more electrons for a greater energy density than current chemistries that consist mostly of nickel, manganese and cobalt. Companies including Nissan are developing blends of silicon that could boost capacity by a claimed 10-40% within the next five to 10 years

Though Johnson Controls produces some EV/hybrid vehicle batteries, but the company is mainly investing in technologies to enhance far more efficient including advanced start-stop vehicles, hybrid electric vehicles (HEVs), micro hybrid vehicles, and plug-in hybrid vehicles (PHEVs).

There are dozens of other smaller players working on niche innovations in this area, an example:

Arotech – A Michigan-based firm with a battery and power systems division that manufactures lithium and zinc-air batteries and smart chargers for the military and to the private defense industry in the Middle East, Europe and Asia.

Connected Car Technologies

Connected cars are those that have access to a communications network and that able to send and receive signals read through sensors that interpret the physical environment around them and interact with other vehicles or entities. McKinsey estimates that connected car market revenues will grow to $192B by 2020. To date, most of the technology development emphasis is on vehicle adaptations for web-applications.

In general terms, connected car technology can be divided into vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems. In V2V systems, technology allows vehicle to interact with each other, and in the case of V2I, the vehicle interacts with the local and regional road infrastructure system.

Vehicle-to-Vehicle Technology - Vehicle-to-vehicle communications involves the use of various technologies that enable interactions between vehicles. This occurs by the use of sensors, computer processors and data transfer systems connected to the cloud which exchange data about position and speed. The overall objective for V2V system design is largely about preventing accidents and producing efficient traffic flows.

While much of this technology is expected to be put into common use in the near-term and mid-term, there have already been noteworthy technological advancements in improving driving safety through V2V communication technology. Currently, in some products V2V communications alert the driver in advance of a dangerous situation or potential accident for manual driver reaction. In the future, these alerts will become an integral part of autonomous vehicle functionality as there will be automated reactions with no driver involvement required.

Many government organizations are noting substantial value in the advanced use of this capability. The National Highway Safety Administration (NHSTA) is evaluating how to mandate V2V in the future, predicting that it could prevent 592,000 crashes per year. There are high expectations for accident prevention with V2V technology. BCC Research estimates that 78% of crashes could be avoided in vehicles equipped with V2V communication.

Some OEMs such as Toyota and Volvo are beginning to think beyond V2V and are exploring the value of V2X, which includes developing technology that will allow cars to communicate with pedestrians via their smartphones. This could ensure the safety of hard-to-see pedestrians in blind spots or at night.

The ability to process and transfer data is at the heart of V2V systems and vehicles will generate a tremendous amount of data. As we proceed toward autonomy, this will become an extraordinarily important issue. For example, Google's self-driving car generates one gigabyte of data per second. And there are estimates that autonomous cars will generate two petabytes of data every year. The demand for constant monitoring of large amounts of data has led to partnerships with high tech companies such as Qualcomm who has partnered with Mercedes to integrate 5G wifi communications to seamlessly send the large amounts of data from hundreds of sensors. This relatively new innovation allows engineers to track aerodynamics, tire temperatures and suspension load.

V2V rollout hits critical stage
Technology is 'at the 1-yard line' but faces political obstacles

Vehicle-to-Infrastructure Technology - Vehicles that can communicate with road infrastructure systems (V2I) allow for an active interface with traffic signals and system beacons so that drivers are made aware of road conditions and route adjustments can be made by the car itself or the driver.

With V2I technologies, there is a significant opportunity to improve traffic flow and reduce congestion. Vehicles will communicate with each other and their immediate surroundings. Computer-derived algorithms then determine speed, route and road lane choice and instruct drivers accordingly. Improved traffic flow would not only affect travel times, but it would also reduce fuel consumption and have a substantial impact on the environment with lower emissions from reduced idling times and frequent stops and starts. Further, as has been pointed out already, road planners estimate that there will be a much lower road capacity requirement as free-flowing roadway require few lanes.

Revenue Significance to OEMs – It is estimated that OEMs could increase revenues by 10-15% if they were to dominate the connected car market. From the OEM's perspective, the ideal scenario is for integration of connectivity and digital features to bring new opportunities for revenue and profit. OEMs are hoping that connectivity will significantly improve the user experience so that it will become a differentiating factor from one OEM to another, providing opportunity for price premiums.

Technology Obsolescence – With technology proceeding at such as rapid pace, it is certain that products will be become obsolete over very short periods. This will inhibit product sales as customers will always be concerned about buying a product that may be improved within a short period of time. As well, from a technology obsolescence will impact the smooth running system of both V2V and V2I, causing weaknesses in system operation, or safety challenges. Automakers and their technology system supplier/partners are anticipating this and working on seamless methods to provide updates to vehicles.
Much of this will occur via over the air (OTA) systems, and this itself will become a major business element of the automotive business. As an early example, Tesla's over the air technology can improve over time. Tesla has been able to lead the way in overcoming vehicular technology obsolescence by implementing over-the-air updates, Tesla is able to update the cars that are already on the road. Other more traditional OEMs are trying to catch up. IHS predicts that over-the-air software updates will actually save automakers $2.7B in 2016, and $35B by 2022.

Service and Maintenance - Traditionally, vehicle servicing has been offered by dealerships and third-party service shops. With the emergence of higher quality sensors and more data collection, drivers can know exactly what is wrong with their vehicle, without the need to visit a repair shop. Additionally with OTA software updates, many issues typically handled at physical service locations will be remotely corrected.

In-Car Networks - Having an in-car ethernet system will be an important and disruptive technology. Its importance will be seen in infotainment audio and video, impacting content available in the car which is rather limited still today. Ultimately though, the real significance is in the future when vehicles operated autonomously allowing for passengers the ability to consume more content. Over last year or so, every major OEM has been working on in-car ethernet architectures. This technology will start showing up in 2018 vehicles and will soon become the standard vehicle architecture.

Leading connected car technologies companies:

- Alpine Electronics
- Continental AG
- Denso Corp
- Harman - Samsung

- Panasonic
- Pioneer
- Bose
- Blaupunkt
- Delphi
- Fujitsu
- Garmin
- Kenwood

Semiconductors

The modern automobile requires a substantial amount of data processing power and as vehicles move toward increased connected and autonomous technology, high performance semiconductors will be at the very heart of the automobile. This means that semiconductor manufacturers will play a far larger role in the development of technology integration than ever before. Though they have not paid a lot of attention in the past, firms like Qualcomm, Samsung and Infineon are now making the automotive sector high priority for specialized products to power graphical interfaces behind the advanced vision systems and a myriad of other technologies.

A smaller firm that is making significant impact on the segment now is Nvidia, which has primarily been known for producing video game chips. It has shifted its attention to cars, starting in 2007 when its systems powered the integration of Google Earth inside an Audi. Several luxury carmakers use its super-processors, which can simultaneously process reams of data coming from multiple cameras, Lidar and ultrasonic sensors.

In the most recent quarter Nvidia's automotive revenues increased 61% on a year-over-year basis. The main factor driving this growth is demand for the firm's DRIVE PX 2/autonomous car platform. Nvidia is successfully integrating its deep learning expertise in processing data and functionality. Nvidia has been working on building its automotive computing platform for over a decade and believes that the key to self-driving cars is through computer vision realized by neural networks. The key feature behind the growing adoption of the DRIVE PX 2 platform is that it is capable of understanding in real time what's happening around the vehicle, by constantly processing the data coming in from the vehicle cameras and sensors to produce complex images of objects around the vehicle.

Nvidia's Automotive Revenues Surge, Driven By Autonomous Vehicles

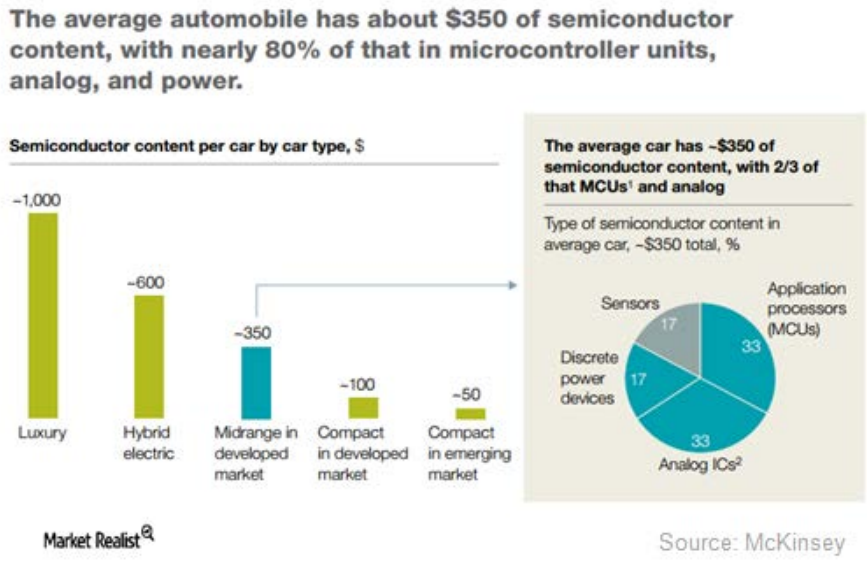
The automotive semiconductor market has witnessed consolidation in 2015 and 2016. NXP Semiconductors acquired Freescale and ON Semiconductors acquired Fairchild Semiconductors. Qualcomm and Nvidia also entered this space with new products. The top automotive semiconductor suppliers control about 80% of this submarket. With an increasing number of new cars being equipped with internet connectivity as well as advanced driver assistance systems, this is a market that is set for significant growth over the next few years.

2017 Automotive Semiconductor Revenue Projections

Manufacturer	2017 Revenues
1. NXP (incl Freescale acquisition & Qualcomm acquisition)	$3.8B
2. Renesas	$3.0B
3. Infineon	$2.7B
4. STMicroelectronics	$2.1B
5. Freescale	$2.0B
6. Bosch	$1.6B
7. Texas Instruments	$1.6B
8. ON Semiconductor	$1.1B
9. Toshiba	$729M
10. Micron	$706M
11. Nvidia	$594M

Sources: IHS Markit, Semicast Research. GLDPartners

Semiconductor content in vehicles is increasing with mid-range cars containing $350 worth of semiconductor content. The automotive semiconductor's product development life cycle is lengthy and complex, making automakers reluctant to switch semiconductor suppliers as it entails high switching costs. Moreover, the supply agreements are for longer terms, thus reducing the risk of losing customers to competitors. Qualcomm is already one of the leading suppliers of chips for smartphones, perhaps becoming the main beneficiary of Intel's absence in the market to date. Now, with the NXP purchase Qualcomm is set to develop wholly new markets with the main prize being automotive semiconductors. Steve Mollenkopf, CEO of Qualcomm, has said the NXP acquisition accelerates their strategy to extend their leading mobile technology into robust new opportunities. By joining Qualcomm's capabilities and technology roadmap with NXP's leading industry sales channels and positions in automotive, security and IoT, they will be better positioned to empower customers and consumers to realize all the benefits of the intelligently connected world.



Beyond the automotive subsector, Intel still dominates as the largest semiconductor company in the world by market share. Intel's 2015 market share to be more than 14%, whereas Qualcomm now has a 7% market share with the NXP acquisition. Though the global semiconductor sector us huge, the overall market is entering a slow growth period. According to the World Semiconductor Trade Statistics, the global semiconductor market is expected to grow at only 1.4% to $341B in 2016. The overall semiconductor industry's growth will be driven by the industrial and automotive segments, which are expected to grow at CAGRs of 9.7% and 8.2%, respectively, between 2014 and 2019.

Sensors

Sensors are essential components of automotive electronic control systems. Sensors are defined as devices that transform physical quantities such as pressure or acceleration into output signals that serve as inputs for control systems. Starting in the late 1970s, microprocessor-based automotive engine control modules were phased-in largely to satisfy federal emissions regulations. These systems required new sensors such as manifold pressure, air temperature and exhaust-gas air-fuel-ratio operating point sensors. Micro electro-mechanical sensors (MEMS) are a key technology for the connected car world. MEMS sensors produce high performance and are small, sturdy and extremely cost-effective.
By rapid technological developments in recent years, the scope of automotive applications has widened. The number of sensors per vehicle has increased from approximately ten in 1995, to more than fifty in 2017. Governments around the world are implementing safety legislations to increase the safety of the passenger. People in developing countries have also become more aware of the requirement of safety features such as air bags, antilock braking, crash avoidance and are opting for the safety systems which is likely to drive the market. The automotive sensors market was valued at $19.7B in 2014 and is expected to grow to $30.9B by 2020.

The major application areas of sensors in automotive includes: powertrain, body electronics, vehicle security system, safety and control, telematics and others. Temperature sensors, pressure sensors, speed sensors, level sensors, nox sensors, oxygen sensors and MEMS sensors are some of the important types of sensors used in the automotive industry. It has been estimated that the powertrain application would hold a large share of the automotive sensors market. However, the market in the telematics followed by safety and control application is expected to grow at the fastest pace over the next ten years.

Self-driving cars use a combination of sensors, cameras, and GPS to detect what's around them and safely navigate city streets and highways. A number of companies developing self-driving vehicles also rely on light-sensitive radar, known as LiDAR. LiDAR emits short pulses of laser light so that software in the self-driving vehicle can create a real-time, high-definition 3D image of what's around it. These sensors shoot out millions of laser pulses a second to detect nearby objects and determine the best driving path.

Some common sensor applications:
Airbag systems - MEMS sensors detect abrupt vehicle deceleration. This information is the essential decision criterion for triggering the release of the vehicle's airbags. The sensor data is processed by a central airbag ECU, which activates restraint systems relative to the nature and severity of the accident.
Driver information systems - Vehicle comfort features like navigation, tilt or inclination measurement, telematics, car key modules, car alarm or eCall systems are a rapidly growing field of application for MEMS sensors. Typically, the required performance level for these MEMS sensors is lower compared to sensors for sophisticated safety applications like airbag or vehicle stability systems.
Engine management systems - Barometric pressure sensors are a key component in engine management for diesel and gasoline engines. They are designed to measure the current ambient pressure accurately and with low drift. Atmospheric pressure is a function of height above sea level and weather conditions.
Transmission control systems - MEMS sensors for automatic transmission detect oil pressure in the hydraulic actuators of the gearbox, with a very precise response time of less than a millisecond. This action is crucial for fast and ultra-smooth shifting of gears.
Vehicle dynamics systems - In vehicle dynamics systems, MEMS sensors measure vehicle rotation around the vertical axis and lateral acceleration to determine the dynamic state of the vehicle.
Active suspension systems - Active suspension systems have an important impact on driving comfort and safety. They are based on low-g acceleration sensors that precisely record the dynamics of chassis and body and regulate suspension damping and body movement to make driving safer and more comfortable.
The global automotive sensors market consists of many big market players which have expertise in this particular segment.

Leading Automotive Sensor Manufacturers

Company	Country
Analog Devices	US
Avago Technologies	CA
Bosch Sensortec	Germany
Bourns	CA
CTS Corp	US
Denso	Japan
Gill Sensors	UK
Delphi	UK
STMicroelectronics	Switzerland
Infineon Technologies	Germany
TE Connectivity	US
Sensata Technologies	US
Asahi Kasei Corporation	Japan

In the global automotive sensor market continuous technological advancements, supportive government and environment regulations, increasing vehicle production and customer preferences for more safety and comfort are some of the major driving factors responsible for the surge of the automotive sensor demand. Infineon Technologies and Sensata Technologies are among other leaders in this market who are expected to retain an impressive market share in the near future. A truly global subsector, headquartered in German, Infineon has a global presence and operates subsidiaries in: California, Singapore and Japan.

Globally, companies are also investing huge amount of money into R&D in order to differentiate their product from the competitors.. For automotive sensors suppliers, Asia-Pacific markets such as China and India are the next big opportunity and many companies are setting up manufacturing plants in these developing and emerging economies.

LiDAR can be particularly useful on roads with faded on non-existent lane markings. Google and Ford both use LiDAR on their self-driving test vehicles. But LiDAR sensors are very expensive. For instance, some of the first LiDAR systems developed by Velodyne cost $80,000. That price has fallen to about $8,000 today for Velodyne's latest prototype, which is used in the testing of autonomous vehicles. The high price has created an obvious opportunity for companies that figure out how to make inexpensive, reliable LiDAR sensor. Recently, Ford and Chinese search engine firm Baidu invested $150M in Velodyne, a leading supplier of LiDAR sensor technology. The money will be used to help Velodyne lower the cost of its LiDAR to a target price by 2018.

Sensor Start-Up Example: Quanergy Systems, a Silicon Valley startup that makes light detection and ranging sensors used in self-driving cars, has raised $90 million from investors, illustrating their growing interest in autonomous vehicle technology. The funding round, led by Sensata Technologies, also included investments from auto parts manufacturer Delphi Automotive, Samsung Ventures, Motus Ventures, and GP Capital. Quanergy's post-funding valuation is $1.59B. This investment brings the company's total funds raised to about $150 million. Quanergy's LiDAR sensors are being used by five automakers that are developing automated vehicles. The LiDAR could be deployed sooner on non-passenger vehicles used mining and agriculture industries.

Advanced Driver Assistance Systems - Safety Technologies

Safety technologies have begun to transform the driving experience and manufacturers and their supplier partners have made extraordinary advances including radar-based technology for vehicle alerts, smart braking technology, camera-based view systems, pedestrian warning technologies and next-generation airbags. Regulators in the US, Canada, Europe, Japan, South Korea and China are mandating that more safety-related features such as backup cameras be included as standard equipment on new models. Unlike some other technologies that are seen as discretionary purchases, the expense of government-mandated safety equipment has proven difficult for OEMs to pass on to the customer, especially in the lower-priced segment of the market where the profit margins are thinner. The US DoT's requirement that all new vehicles have a backup camera will increase vehicle costs by between $100 and $200. In higher-priced product segments of the market, the ability to price-in government mandated technology is somewhat easier for OEM's.

NHTSA in the US has documented three distinct but related streams of technological innovation that reduce traffic accidents: 1) in-vehicle crash avoidance systems, 2) V2V communications, and 3) self-driving/autonomous vehicles. Already taking hold with consumers, further market penetration and next-generation advancements in technology will create tremendous growth for companies that have established themselves as category leaders such as Valeo, Continental and Bosch.

There is room for additional growth as certain technologies move to another level of sophistication, where new entrants will likely succeed in winning market share. In terms of collision avoidance sensors, lane departure sensors, auto cruise control, panoramic cameras and blind spot monitors, these technologies have a 35% market penetration rate in the US today but that is expected to grow to 70-80% by 2021. In other global markets the figure will vary quite significantly, but there will be growth in all markets.

A range of passive technologies have been developed that are designed to alert drivers of impending danger. These technologies have largely relied on human intervention to prevent accidents, but in some instances there have been new active technology features added that allow for semi-autonomous vehicle function. Some of these technologies like blind spot detection struggled for acceptance in the early days (ten years ago or so) after introduction as a standalone application as they were perceived to some as a feature for less-competent drivers. This has evolved as new safety technologies are more widely accepted as part of premium option bundles. Growing in importance is the fact that automotive insurers now can rely on historic safety data and have adjusted premium structures to reflect lower risks for vehicles equipped with various safety features.

Exterior View Cameras **-** Automakers are advanced in meeting the recent US mandate for rearview cameras, which calls for cameras in every new vehicle starting with 2018 production. The biggest beneficiary of the new federal mandate is Magna, which currently has 40% of the North American market. Magna began selling rearview cameras in 2004 and this year, Magna they will produce 5M units globally, with production expected to exceed 8M in 2018. Other suppliers such as Delphi, Gentex, Panasonic and Valeo will also benefit.

Blind Spot Detection (BSD) – Are systems that first began to appear in top-of-the-line consumer vehicles in 2005, with Volvo as pioneer. Today such systems are available on high-volume models. In 2016, annual BSD installations are forecast by ABI Research to reach 20M (just over 25% of the predicted world vehicle market), with a worldwide market value of over $12B. The emergence of cross traffic alert is the most widely accepted tech. Previous ultrasonic sensor systems have been improved with radar-based systems. There is still substantial growth in this segment as enhanced technologies are now allowing sensors to check for

approaching vehicles over longer distances and can provide extra warnings when other vehicles are approaching at a high rate of speed.

Lane Departure Warning Systems or Lane Keeping Assist (LKA) - Lane departure warning systems use a variety of sensors to make sure that a vehicle doesn't leave its lane accidentally. If the system determines that the vehicle is drifting, it will sound an alarm so that the driver can take a corrective action in time to avoid hitting another car or running off the road. More modern lane keeping assistance systems go a step further and are actually capable of taking small corrective actions without any driver input. BSD can also be linked to lane-keeping systems, by bundling the two systems together drivers get machine vision to help them stay in lane and be safer when deciding to move out of the current lane.

Adaptive Cruise Control - This advanced driver assistance technology is especially useful on the highway, where drivers otherwise have to constantly monitor their cruise control systems for safety reasons. With advanced cruise control, a vehicle will automatically slow down or speed up in response to the actions of the car or truck in front of it. Most of these systems automatically disconnect below a certain speed threshold, but other more advanced system can be used in stop and go traffic.

Driver Drowsiness Detection - Driver drowsiness or awareness detection systems use a number of different means to determine if a driver is losing attention. Some of these systems look for the driver's head to nod in a telltale motion that indicates sleepiness, and others use technology similar to lane detection warning systems.

Automatic Braking - Automatic braking is a pre-crash technology that is designed to reduce the severity of high speed collisions in the event of a lapse of driver attention. While some automatic braking systems can actually prevent collisions, they're typically meant to slow the vehicle to the point where less damage is caused and fatalities are unlikely. Within a few years, most AB systems will have the capability to bring the vehicle to a complete stop, avoiding an accident completely.

Adaptive Light Control - Adaptive light control systems are designed to help drivers see better and further in the darkness. This advanced driver assistance technology allows the headlights to swivel and rotate to better illuminate the roadway through corners and in other circumstances.

Automatic Parking - Automatic parking systems vary by OEM, but most of them are designed to help a driver parallel park. Some of these systems can actually perform the entire job automatically, others simply provide advice so that the driver knows when to turn the steering wheel and when to stop.

Hill Descent Control - Hill descent control is an advanced driver assistance technology that makes it easier to descend steep inclines. These systems typically work by activating the brakes to automatically slow the vehicle, which works through the same basic mechanism that allows ABS, TCS, and other technologies to function. Some hill descent control systems allow the speed to be modified via the cruise control system, and they can typically be overridden by pressing either the brake or the accelerator.

Intelligent Speed Adaptation - This advanced driver assistance system depends on a variety of information to help a driver maintain a legal speed. Since these systems monitor the current speed and compare it with the local speed limit, they only function in certain areas.

Automotive Night Vision - Night vision systems allow drivers to see things that would otherwise be difficult or impossible to make out at night. There are a number of different technologies, all of which can be broken down into the categories of active and passive. Active night vision systems project infrared light, and passive systems rely on the thermal energy that emanate from cars, animals and other objects.

Tire Pressure Monitoring (TPMS) - Tire pressure monitoring systems provide the driver with information about the inflation level of each tire.

The technology that allows these safety products to be possible are derivations of some kind of sensor technology. There are various sensor-types in use today, including: camera-based, radar-based, and sound-based ultrasonic technology. More sophisticated technologies use light detection and ranging (LIDAR) which employs light pulses and laser technology.

Lower-cost alternatives to LIDAR are high-tech cameras. Cameras are not only cheaper, but they often have better resolution, and can see certain elements on the roadways — lane markers, traffic lights — that Lidar misses. A few startups, like Nauto and Cruise, are deploying cameras coupled with smart computer-vision algorithms to retrofit cars with driver-assistance technology that set the stage for full autonomy. Mobileye, an Israeli company is emerging as the dominant supplier with a majority of global carmakers using its technology. Tesla's cameras have been combined with Mobileye's advanced software and chips. Recently GM said it was working with Mobileye to test self-driving features on the hybrid Chevy Volt.

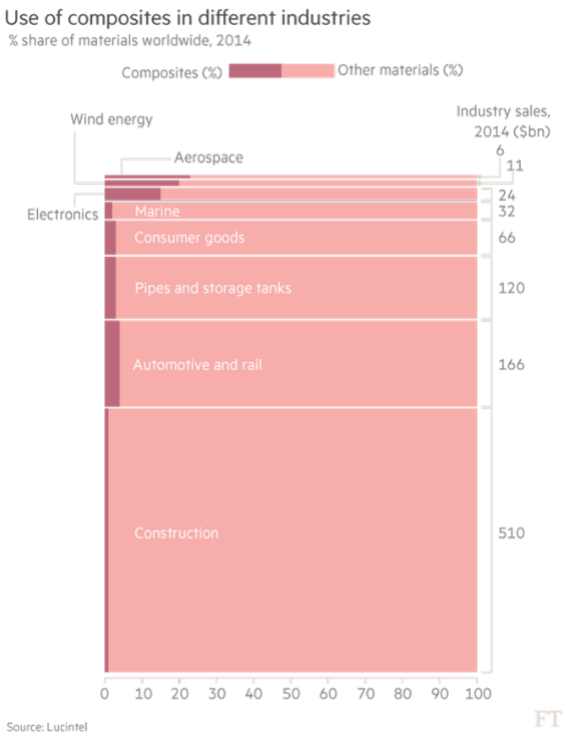
The main technology company players in developing these technologies are companies such as:

- Aisin Seiki (Japan)
- Autoliv (Sweden)
- Bosch (Germany)
- Continental (Germany)
- Delphi (UK)
- Ficosa (Spain)
- Hella (Germany)
- Knorr-Bremse (Germany)
- SMR (India)
- TRW (US)
- Valeo (France)
- Visteon (US)
- Mobileye (Israel)

Materials Science Advancements

The use of composites has been quite robust in some manufacturing sectors such as aerospace and wind energy. In aerospace, for some commercial aircraft and to reduce weight, Boeing employs almost 50% composite parts. In other manufacturing sectors, the use of composites materials has been far lower. In the automotive sector the use of composite alternative materials has been modest to date and this was largely due to the use of other less expensive materials such as lightweight high-tech steel. The cost of composites has been very high but is reducing to a level that makes it far more realistic for use in everyday vehicles.

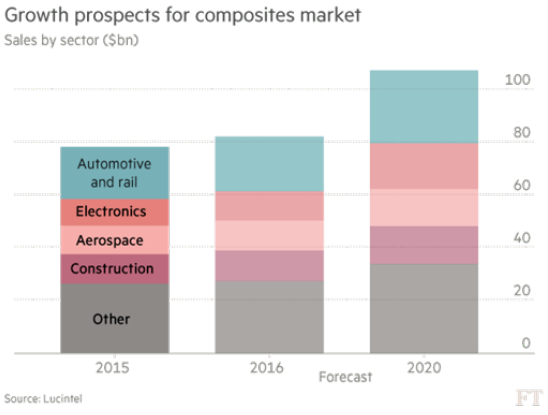
Due to a combination of government safety requirements and consumer preferences, cars have been getting heavier, on average, since they were invented. But with government's push to reduce emissions and the move from combustion engines to electric vehicles powered by heavy batteries has propelled a need for lightweight materials. If you put batteries and sensors into the cars, you have to counteract to compensate the additional weight, the additional target is to overcompensate, to improve emissions and the agility of the car.



In the name of energy efficiency and maximizing performance, manufacturers and their supply partners have made huge investments in next-generation materials which have created weight savings and added structural rigidity. Other advances have been made in interior materials quality and durability but automakers recognize that there is far more to accomplish. Analysts predict that by 2020 plastics will represent 18% of the average vehicle's weight, up from 14% in 2000. Since 2008 the average vehicle weight has dropped 20%, which has translated into a similar reduction in per-

vehicle emissions. In Europe, analysts project that by 2020, the average vehicle weight will shrink to the 1970 level, after peaking at nearly 1.5 tons in 2010.

Mass-volume plastics, acrylonitrile butadiene styrene (ABS), PP, PUR, and nylon account for 70% of the plastics used in a car, while composites and higher-end plastics account for the rest. Importantly, plastic consumption patterns vary by region, sometimes even from one automotive original equipment manufacturer to another. European manufacturers use more plastics than those in North America and Japan. As automakers are challenged to build vehicles that are more environmentally friendly, the use of plastics is rising. This presents a significant opportunity for chemical companies, composites manufacturers and the feedstock middlemen. Taking full advantage of this opportunity, however requires dealing with a new set of challenges. Among the most daunting of these are the following: Steel is still cheaper than high-grade plastics and has benefitted from its own innovations. In both product and process (for example, laser-welding), steel has improved performance, while reducing weight. As plastics category prices are influenced by oil costs, they can change quickly. At the present and for the near and mid-term, with oil prices at a current seven year low mark, this pricing trend dynamic presents increased competitiveness to the plastics and composites opportunity. (AT Kearney)

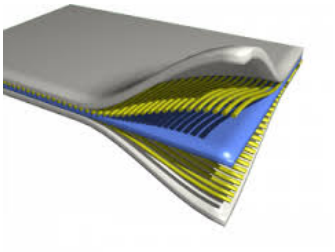


An important lifecycle issue is recyclability. In the case, steel has an advantage largely because the numerous different types and grades of plastics are more complex to recycle. To meet this challenge, chemical companies have had to develop ways to reduce plastic's environmental footprint with bio-sourced and recyclable materials. A concern for bioplastics makers is that in Europe, new regulations require a large proportion of vehicle materials to be recyclable. A European Union directive requires 95% of an end-of-life vehicle to be valorized and 85% of that to be recycled. This means 60% of a vehicle's plastics must be recycled. It is expected that similar legislation will be introduced in other regions of the world in the foreseeable future. The problem is that while recycled plastics are environmentally friendlier and less costly than non-recyclable ones, they are less pure and do not perform as well.

In attempting to resolve this dilemma, there is another option: composites that combine the advantage of steel and plastics. These fiber-reinforced plastics represent a credible alternative to steel both in terms of material characteristics and in some cases, cost competitiveness. Fiber-reinforced plastics are now being used to make structural and non-structural components such as seat structures, bumpers, hoods, and fuel tanks. Joining forces in becoming more plastics-oriented, the automotive industry and the chemical industry are increasingly collaborating to create a value chain that includes peripheral companies such as plastic-injection companies and automotive suppliers. This integrated supply chain eco-system will have two goals: 1) improving plastic's performance standards to better meet commercial needs and

comply with government regulations; and 2) developing innovative ways to provide solutions for contradictory objectives of sustainability, safety regulation and improving performance.

While standard engines account for about 12% of a car's total weight, electric powertrains account for 20% due to the weight of the battery pack. To preserve optimum fuel efficiency, automakers are using materials that are more lightweight, plastics and polymer-based components and high strength but lighter weight metals. More than a hundred types and grades of plastic, categorized by performance requirements such as appearance, rigidity, resistance, weight, and cost, are used in the average vehicle. OEMs are increasingly shifting material considerations upstream in the overall design process, especially to overlay safety criteria and energy-efficiency objectives. Collaborative research and development are more focused on material properties than ever before and if integrated early enough in the design and specification process, composite products will be used to substitute parts like-for-like and deliver an advantage by improving aesthetics, and reducing costs and vehicle weight. Reducing vehicle weight is typically accomplished by compression various materials; for example, thinner seats are the result of merging foam, fabric and structure. However, such breakthrough innovations require re-engineering of system architecture and will need to be initiated well in advance of a program's design phase. (Plastics Magazine)



Some of the leaders in supplying high-end composites products to the automotive industry are companies such as:

- Adherent Tech
- Ashland Performance
- Celanese Intl
- Convergent Tech
- Cytec Engineered
- Dow Aksa
- DuPont
- ESI North America
- Faurecia US
- Honda R&D Americas
- Huntsman
- Manville
- Materials Tech
- Milacron
- Owens Corning
- PolyOne
- PPG Industries
- SABIC Plastics
- Strongwell
- Xperion

Industry Collaborations

The automotive industry has traditionally been fairly risk adverse but with today's new pressures from government regulation, new waves of competition, ever increasing consumer expectations and environmental awareness the multidimensional burdens are relatively overwhelming to the monolithic OEM that's been doing business largely in the same manner for decades.

In the automotive industry, because of its history there is a layer of inertia that can make it hard for new solutions to take-hold. New product technologies have traditionally been the result of slow processes, and the fact is that in the past the OEMs didn't need to work hard at technological evolution in the same way that they do today. This is changing very quickly because of the previously articulated pressures. The reality is that the industry is in a decade of massive upheaval and tech-led product companies will be the beneficiaries. There is also an expanded opportunity for research/academic institutions and their nearby communities to establish themselves in ways that might have previously been impossible.

New model partnerships between OEMs, composite product manufacturers, applied research centers and government are becoming more important to help to boost investment and research, facilitating cost-efficient mass production. An important example is a significant composites industry effort was recently announced in the US by the federal government, in conjunction with a wide consortium of academic organizations and business. The *Institute for Advanced Composites Manufacturing Innovation* was unveiled

and includes 122 companies, non-profits, universities and research laboratories in partnership with the Department of Energy. IACMI is a $250M manufacturing innovation institute focused on US leadership in next-generation composite materials.

The focus of the effort is around advanced fiber-reinforced polymer composites, to bring these materials down the cost curve can enable their use for a broader range of products including lightweight vehicles with record-breaking fuel economy; lighter and longer wind turbine blades; high pressure tanks for natural gas-fueled cars; and lighter, more efficient industrial equipment. There is a focus on wind energy industry, advances in low-cost composite materials will help manufacturers build longer, lighter and stronger blades to create more energy. In automotive applications, advanced composites could reduce the weight of a passenger car by 50% and improve its fuel efficiency by roughly 35% without compromising performance or safety.

The Institute will focus on lowering the overall manufacturing costs of advanced composites by 50%, reducing the energy used to make composites by 75% and increasing the recyclability of composites to over 95% within the next decade. The new hub will also unite these manufacturers with top-flight research universities, such as the University of Tennessee with its pioneering 3D printed carbon fibre research, and the University of Kentucky with the largest US open-access carbon-fibre chemistry laboratory. IACMI includes the following key partners:

Business

- Adherent Technologies
- Ashland Performance
- Assembly Guidance
- BASF Company
- Boeing Company
- Celanese International
- Convergent Technologies
- Cytec Engineered
- Dassault Systemes
- Dow Chemical
- Dow Aksa
- DuPont
- ESI North America
- Faurecia US Holdings
- Ford Motor Company
- GE Water & Power
- Graco
- Honda R&D Americas
- Huntsman Polyurethanes
- Manville
- Lockheed Martin
- Materials Technologies
- Milacron Technologies
- Owens Corning
- PolyOne Corporation
- PPG Industries
- SABIC Plastics
- Strongwell
- Toray Composites
- TPI Composites
- Vestas Americas
- Volkswagen
- Wolf Robotics
- Xperion

Universities and Laboratories

- University of Tennessee
- Colorado School of Mines
- Colorado State University
- Iowa State University
- Michigan State University
- Mississippi State University
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- Purdue University
- The Ohio State University
- University of Colorado-Boulder
- University of Dayton Research Institute
- University of Kentucky
- University of Michigan
- Vanderbilt University

Trade Associations

AutoAlliance - http://www.autoalliance.org/
The Alliance of Automobile Manufacturers (Auto Alliance) is an important representative for a united auto industry. They are involved in developing and implementing solutions to public policy challenges that promote sustainable mobility and benefit society in the areas of environment, energy and motor vehicle safety. The Alliance represents 77% of all car and light truck sales in the US.

American Composites Manufacturing Association - http://www.acmanet.org/
ACMA provides a forum for members of the composites industry to come together to produce shared market opportunities and address common challenges. ACMA advocates for the interests of the composites community, proactively and positively affecting regulatory and legislative outcomes on a wide range of policy issues, including energy and environment, worker health/safety, trade policy and job creation. ACMA works to develop and expand markets for composite products in the U.S. and around the globe.

Automotive Industry Action Group - http://www.aiag.org/
Supports a diverse group of stakeholders including retailers, suppliers of all sizes, automakers, manufacturers, service providers, academia, and government to work collaboratively to streamline industry processes via global standards development & harmonized business practices.

Center for Automotive Research - http://www.cargroup.org/?module=Home
CAR is involved in the research of significant issues that relate to the future direction of the global automotive industry. They are focused on a wide variety of trends and changes related to the automobile industry and society at the international, federal, state and local levels. To fulfill its mission as an impartial voice of the industry, CAR maintains strong relationships with industry, government agencies, universities, research institutes, labor organizations, media, and other major participants in the international automotive community.

Original Equipment Suppliers Association – www.oesa.com
OESA provides a forum for automotive suppliers by addressing issues of common concern through peer group councils, serving as a reliable source of information and analysis, providing an industry voice on issues of interest. With 450 member companies having global automotive sales exceeding $300B, OESA represents more than 70% of North American automotive supplier sales.

Society for the Advancement of Material and Process Engineering - http://www.sampe.org/
SAMPE provides information on new materials and processing technology either via conferences, exhibitions, technical forums, publications, or books in which professionals in this field can exchange ideas. As the only technical society encompassing all fields of endeavor in materials and processes, SAMPE provides a unique and valuable forum for scientists, engineers, and academicians

Thoughts About Plausible Investment and New Mexico Opportunity

As the automotive business is increasingly incorporating a range of very high-value technology products, manufacturers at the part and component level and assembly manufacturers will require increasingly speedy, sophisticated and integrated supply chain solutions. There will increasingly be a focus to diversify suppliers and supply chain points so as to reduce risk. Many of these supply chains are essentially new to the automotive industry and are somewhat immature at the current time because of quickly changing technology, supplier relationships and the integration into the auto assembly process. This situation will likely evolve substantially over the next 3-5 years before settling into a state of maturity.

This period of sector evolution will create churn and provides opportunities for business settings that provide:

1) A fundamentally competitive business environment
2) Some distinct advantage to T1 suppliers and OEM's (perhaps especially to newer OEMs) in terms of pure transport/supply chain factors; time, cost and reliability
3) A tech foundation including a historic labor force (electronics technicians)
4) Notable and strong university and research relationships
5) A State government that is outwardly friendly to the needs of the automotive sector, certainly in the area of testing, liability/insurance
6) Ready facilities; buildings, business parks, planned areas for testing

Given the tremendous strength of the autotech business in California, it is certainly plausible that New Mexico could establish itself as an extension of that West Coast base. In reviewing the opportunity, while further analytics must be undertaken we think reasonable objectives could include:

Logistics and Distribution

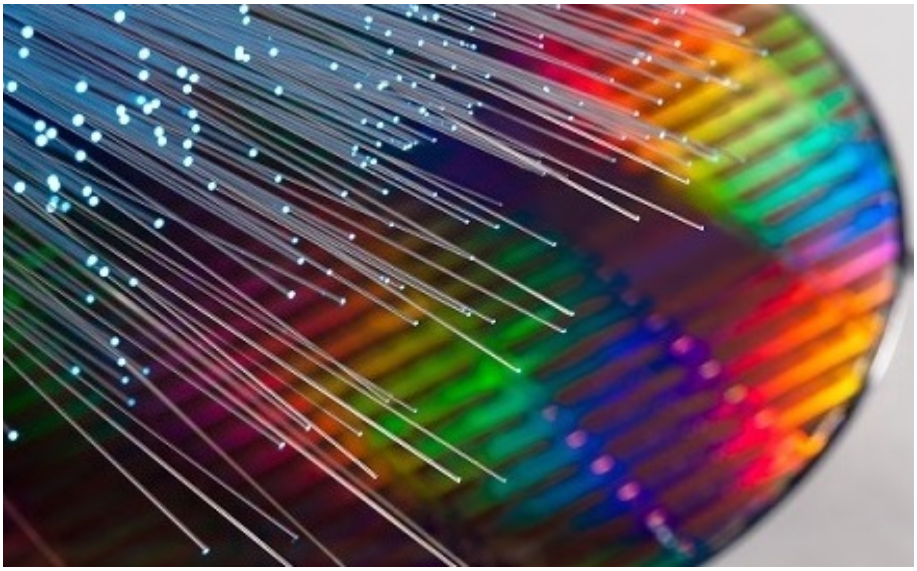
Due to New Mexico's relative proximity to California, various supply chain situations could potentially benefit from a forward deployment warehousing operation on the ground. Some of these situations would be the manufacturer, T1 or T2, who own the goods, as smaller suppliers cannot typically warehouse supply for financial capacity reasons. NM could act as a central base for moving goods to both Southern California, Arizona and Southern Nevada – and the Silao/Guanajuato, Mexico auto assembly hub. For inbound product from Mexico to US assembly, a NM location could support a facility that combines projects for component assembly, or where final or last minute product customization occurs.

Tech Assembly and Product Manufacturing

It is likely that projects would probably be primarily a medium-to-highly sophisticated, high-spec products. It is certain that Mexico will be an increasingly important factor in the global automotive industry. Understanding how the supply chain interface between Mexico and Asia (and US) will develop is an important key for a potential NM business proposition. We foresee this to be an extremely important issue and one that may require some time to mature. If there were an NM opportunity, it would likely be in the areas including and related to sensor development. A NM location could offer one day ground transport shipment time to a growing number of assembly plants in Southern California, Arizona and Southern Nevada, while also allowing two-day shipping to the Silao/Guanajuato, Mexico auto assembly hub. Given NM's location within the one day dray limit, component assembly operations can also promise efficient support for inbound mixing with products arriving via vessel or air from China, Korea and Japan.

It is critical to note that if NM were to intend to become deeply involved in the autotech space, it would need to produce a serious strategy that would include a shared use testing and prototype development facility, to include on and off-road testing, cold and warm weather testing, etc. Policy to support the needs of a rapidly growing sector is tremendously important, addressing issues associated with liability. Lastly, over time increased dimension to ABQ's air cargo connectivity will be critical, but this will come with heightened demand.

Photonics Sector Overview



Advanced optics and photonics are enabling technologies for applications in communications, computing, manufacturing, healthcare, energy, defense, and numerous other areas. Just as electronic circuits perfected the use of electrons to develop faster, more powerful computers and cellular phones, it is anticipated that doing the same with photons will lead to even greater, more efficient processing power. Success will revolutionize the internet, expand national defense capabilities when it comes to imaging and will lead to dramatic increases in health care delivery. Progress in the field of optics and photonics has the potential to generate new knowledge, promote economic growth, create new industries and new high-skilled jobs, and provide technologies for new applications.

Executive Summary

- Photonics is a broad technology; it is not an industry
- The global photonics market size is expected to reach $979.90 billion annually by 2024
- The core photonics producer-sector in the United States is made up of small and medium companies, plus start-ups with revenues in the $1-10 million range and employment of up to 50 people.
- The photonics ecosystem is global in nature with market share very evenly divided between Taiwan, Korea, Japan, Europe and the U.S.
- The U.S. government has lagged behind the rest of the world in funding and supporting photonics and has not recognized it as an industrial sector.
- Historically, U.S. photonics companies with their strong base in fundamental research and basic photonics technologies, were most successful when their market size was small and low volumes of production were needed. They have not been as successful when efficient mass production is required.
- Additive manufacturing which is an enabling technology based in photonics has the potential to fundamentally change manufacturing and may be the key to enabling the United States to once again mass produce the photonics enabled products that moved offshore to Asia many years ago.
- New Mexico and Albuquerque have reached a tipping point: they can continue the status quo of approaching photonics as an industry and continue to incubate and encourage a strong base in

fundamental research and basic photonics technologies, or they can expand their outreach by focusing time and investment on the few key industry sectors that use photonics as an enabling technology and are judged to be of global significance during the next ten years.

Photonics Overview

Photonics is the science of using and controlling photons—the smallest unit of light—to convey information and images and is one of the fastest growing high-tech technologies in the world today. Electricity is the lifeblood of modern society and underlies most of our present technology. But with demand increasing, electronics has nearly reached its speed limit and as the demand for faster speed increases, the need for systems based on photons or light will grow.

Photonic devices are used for generating, modulating, guiding and detecting optical radiation across the electromagnetic spectrum and have broad implications for industrial growth and productivity across the U.S. economy including advanced manufacturing, information and communications technology (ICT), defense and national security, energy, and health and medicine. The global photonics market size is expected to reach $979.90 billion annually by 2024, according to a new report by Grand View Research, Inc., but is still very much a market in its infancy. The prospects for market growth can be attributed to rapid innovations in the industry for the development of technologically-enhanced products and related services, as well as growing opportunities for the new market development.

The photonics ecosystem is global and in terms of 2015 revenue The Optical Society (OAS), which is the leading professional association in optics and photonics, is reporting the following market share:

China 12%

Taiwan 16%

Europe 17%

Korea 17%

U.S. 17%

Japan 18%

Others 3%

In the US National Research Council's report, **Optics and Photonics, Essential Technologies for our Nation,** photonics is regarded as one of the Key Enabling Technologies (KETs) which represents what are expected to be the most important building blocks for future technological innovation across all industrial sectors. These technologies are expected to play critical roles in the evolution and sustainability of leading-edge economies. Others include:

- Advanced Materials
- Micro-and Nano-Electronics
- Nanotechnology
- Industrial Biotechnology
- Advanced Manufacturing

Although the photonics sector in the United States includes a small number of larger companies or divisions, the country's core photonics producer-sector is made up of small and medium companies, plus start-ups with revenues in the $1-10 million range and employ up to 50 people.

While there are numerous accepted definitions of optics and photonics, there are no single standard definitions yet in the U.S. Examples include:

- The National Bureau of Standards – "a class of enabling infrastructure technologies that promise broad economic benefits by bringing together technical advances from optics and electronics to develop high-performance manufacturing processes, ultra-high-sensitivity metrologies, and new products. "
- Optics Society of America – "Optics and photonics technologies use the emission, processing, and detection of light, or the information carried by light. This includes the spectrum ranging from the far infrared to x-rays".
- Photonics Directory (www.photonics.com) – "the technology of generating and harnessing light and other radiant energy whose quantum unit is the proton"
- U.S. National Research Council – "the field of science and engineering encompassing the physical phenomena and technologies associated with the generation, transmission, manipulation, detection, and utilization of light"
- Making Light Work for Canada, 2008 – "Photonics is the science of light – how to produce it, detect it, manipulate it, employ it and analyze it. Photons (particles of light) have properties such as color, polarization, and directionality that multiply their uses by an order of magnitude compared to electrons in microelectronic circuits. In fact photons provide our most precise link to the matter around us with an invaluable opportunity for probing and energizing materials with extraordinary finesse. The technological world is just beginning to tap into this."

Because photonics is a broad technology rather than an industry, attempting to actually define all of this as an industry comprised of discrete NAICS codes is a very difficult task. 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. Within the current industry, the terms optics, photonics, optoelectronics, and electro-optics are most often used simultaneously and it is an interdisciplinary field crossing Physics, Physical Chemistry, and Electrical Engineering.

Products in the industry include:

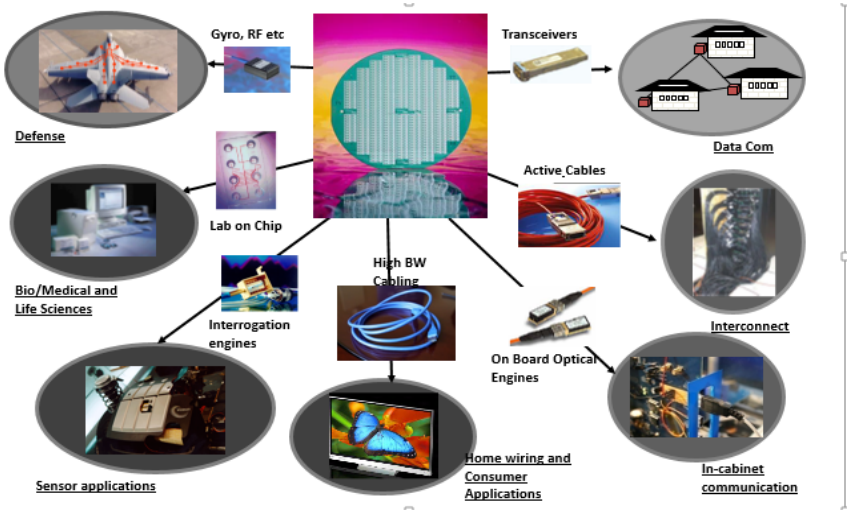
- optical communications (e.g., fiber optics, lasers, and infrared links),
- optical imaging (e.g., spy and weather satellites, night vision, holography, flat screen display, and CCD video cameras),
- optical data storage and optical computing (e.g., CD's and DVD's),
- optical detectors (e.g., supermarket scanners, medical optics, and nondestructive evaluation of materials),
- lasers (e.g., welding lasers, laser surgery, laser shows, and laser rangefinders)
- spectroscopy (e.g., chemical and biological detection, anti-terror detection) and
- quantum optics (e.g., quantum teleportation, quantum cryptography, and single-photon optics)

The National Research Council in **Optics and Photonics, Essential Technologies for our Nation** cites several examples that clearly illustrate the role of optics and photonics in our everyday life:

- Low-cost light-emitting diodes and liquid crystal displays have revolutionized smart phones and computing devices
- Optic fiber that carries information on the internet
- Technologies that enable the manufacture and inspection of all integrated circuits in all electronic devices
- Reduced size of microelectronic components that have significantly increased computer capabilities and hardware memory components
- High powered lasers that are used for cutting and welding in advanced manufacturing
- Medical diagnostics tools
- Military applications for laser-guided munitions.

None of these applications would have been possible without the significant technical advances that have made high-performance photonic components widely available. Ironically, despite its presence in so many consumer products, most consumers are totally unfamiliar with the word, photonics. The consumer goods market is a perfect example of how the photonics technology has powered a revolution, but the general population is totally unaware.

Photonics Touches Many Industry Sectors



Jean Louis Mainge

When attempting to gauge the economic impact of photonics on the U.S. economy, there are no North American Industry Classification System (NAICS) codes that enable the tracking of revenue, employment, and R&D spending. The absence of such information reduces the visibility of photonics and makes it much more difficult to garner support from both the public and private sectors for investment in these technologies

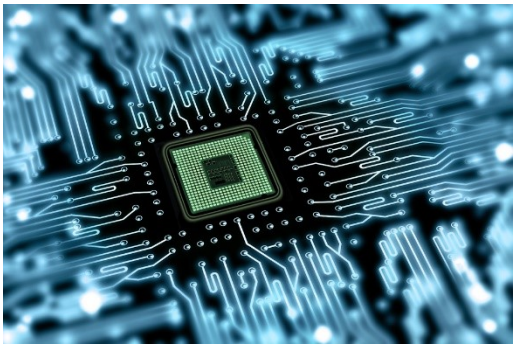
Unfortunately, the U.S. has not kept pace in recent years with other countries (for example, Germany and China) regarding photonics research and development. There has been strong investment from the European Commission; in fact for the period 2002-2006 there were 50 photonics research projects funded by the EU valued at over $165,000,000. Total investment by the EU through 2015 is valued at over $580,000,000.

In Japan there has been $300,000,000 invested in the last 10 years compared to $44,000,000 in funding in the U.S. which has been sponsored by the Department of Defense.

To improve U.S. competitiveness, in 2012 the National Photonics Initiative was created, which supports increased collaboration among private-sector companies, universities, and government on photonics research and commercialization. The NPI is a collaborative alliance among industry, academia and government seeking to raise awareness of photonics and drive US funding in areas critical to maintaining US economic competitiveness and national security. The initiative is led by a coalition of scientific societies, including the American Physical Society (APS), the IEEE Photonics Society (IPS), the Laser Institute of America (LIA), the Optical Society (OSA) and SPIE, the International Society for Optics and Photonics (SPIE).

To further advance U.S. competitiveness in photonics, in July of 2015, The Department of Defense awarded the new Manufacturing Innovation Institute for Integrated Photonics to a consortium of 124 companies, nonprofits, and universities led by RF SUNY. The Institute is headquartered in Rochester, NY, the long-time home of optical technology pioneer Eastman Kodak. The new Department of Defense led manufacturing institute was created to spark new growth in the manufacturing of optical and photonics technology capabilities—and position the United States for continued leadership in this critical technology area.

International Photonics Associations



European Photonic Industry Association (EPIC) EPIC is the industry association that promotes the sustainable development of organizations working in the field of photonics in Europe. EPIC fosters a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC is the industry association with the largest network and maintains the European photonics database.

International Optoelectronic Association (IOA) The IOA is an informal coalition of international optoelectronic/photonic associations. It represents the interests of the industry to national governments, collects information on optoelectronics markets and produces technology roadmaps. The member countries meet each year to discuss optoelectronic markets and trends **OSA Industry**

Development Associates (OIDA) OIDA, the former Optoelectronics Industry Development Association, was originally set up in the United States — in part by the Defense Advanced Research Projects Agency (DARPA) — following the 1988 report Photonics: Maintaining Competitiveness in an Information Age. In 2014, OIDA merged with the Optical Society of America to become the OSA Industry Development Associates. OIDA plays an important role as the voice of the industry by providing market analysis, road mapping, and government lobbying. The Optical Society's (OSA) mission is to promote the generation, application and archiving of knowledge in optics and photonics and to disseminate this knowledge worldwide.

SPIE SPIE is an international society advancing an interdisciplinary approach to the science and application of light. The not-for-profit society advances emerging technologies through interdisciplinary information exchange, continuing education, publications, patent precedent, and career and professional growth. SPIE organizes numerous conferences, courses and workshops covering every application of optics and photonics.

The New Mexico Photonics Industry

In 2014, a study, **Photonics in New Mexico**, was undertaken by the New Mexico Optics Industry Association (**nmOptics)** in collaboration with the City of Albuquerque, the Manufacturing Extension Partnership (MEP) and the International Society for Optics and Photonics (SPIE) to study the photonics industry in New Mexico. The primary purpose of the study was to quantify the economic impact of photonics activity in New Mexico.

An extensive research effort was undertaken which started with an initial dataset of 9000 companies and ultimately culminated in information on 96 firms in New Mexico which have a percentage of photonics in their product offerings. The research effort was made much more difficult because there is no NAICS classification for photonics and in fact most companies do not even associate themselves with photonics because it is an enabling component of a larger system.

The study reported that New Mexico employs more than 6,234 people who are somehow engaged in the photonics enabled industry and they account for 8% of the state's manufacturing revenues. Some of the firms focus on research and development while others are in manufacturing and include entrepreneurs, manufacturers, technicians, finance, sales and marketing people. The study concluded that New Mexico's firms were "well positioned to make significant advances in solar cell manufacturing and optimization, test and measurement systems, semiconductor processing and biomedical devices."

Industry Trends that will Spur Photonics Enabled Technologies and Products

Photonics as an enabling technology has solutions that touch the entire spectrum of industry sectors. With expectations high for accelerating growth in the photonics market sector, it is instructive to review the trends in different industry sectors and identify those trends that photonics will enable through products and solutions. Each of the following trends specific to their industry portend substantial opportunities for growth in photonics enabled technologies and products over the next decade.

Trends in the aerospace sector

- Wider use of robotic technologies----demand will grow as the technology improves
- Use of lasers for welding, cutting, surface treatment
- Laser-additive manufacturing and 3D printing
- Electro-optic systems simulations----military will use immersion tools for simulation and training
- Photo darkening windows
- Replacement of electrical wiring by optical fibers----will reduce weight
- More efficient lighting
- High resolution displays----will be used for virtual maintenance and in manufacturing
- New technology for energy storage

Trends in the automotive sector

- Secure, connected vehicles for navigation and car-to-car communications----will require photonics based connectivity, wireless links, human-machine interface and navigation data
- Real-time environmental monitoring
- Intelligent vision systems----will collect and react to the data that is generated by the sensors
- Dynamic lighting with nano/micro technology, novel materials and optical elements
- More efficient technology to make automotive components
- Collision-avoidance and rear-view systems
- Laser welding for efficiency and faster production----lasers are becoming the main manufacturing tool in the automotive industry

Trends in the Communications and Microelectronics Sectors

- Dramatic increased requirement for bandwidth with Datacom, HD video and the Internet of Things
- Short-reach interconnects for data centers
- Security for data communications

Trends in the Defense and Security Sectors

- Cyber security solutions
- New products to deal with Information overload and data integration
- Soldier health monitoring systems
- Remote sensing
- Miniaturization of equipment and intelligent integration of sensors

Trends in the Health and Medical Sectors

- Miniaturization and portable devices
- Technology for minimally invasive approaches
- Greater precision of tools
- Regenerative medicine (replacing, engineering, or regenerating human cells, tissues or organs
- Safe imaging technology to replace X-rays
- Increased use off wearable systems and telemedicine

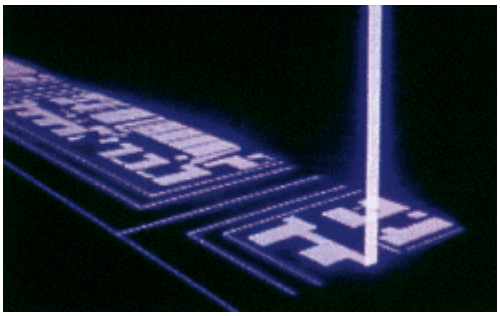
- Distributed healthcare delivery

Trends in the Pharmaceutical Sectors

- Targeted drug delivery
- Combining therapeutics with diagnostics
- Rapid point-of-care diagnostics----important to improve and reduce healthcare costs

Each of these trends will be impacted in very specific ways by photonics technologies and clearly illustrate the great potential that photonics has to be a significant engine for national economic growth. Some of these opportunities are unique and the solutions created could be leveraged to create companies with global opportunities. However until photonics is recognized as an industrial sector, its visibility will be limited.

Photonics and the Future of Manufacturing in the United States



Photonics is similar to other high technology sectors in the United States as an example of cutting edge innovation that has occurred in the U.S. but when the products have gone into production, the U.S. share of the manufacturing has declined dramatically and moved offshore to the emerging economies in South East Asia.

There are three specific examples of photonics enabled products that demonstrate the current relationship between innovation and manufacturing in photonics. All three deal with optic and photonic applications based upon semiconductor technologies that originated in numerous corporate laboratories in the U.S.

The Display Industry

The display industry was developed in the U.S. in the 1960's but the industry's production operations quickly migrated to Japan and ultimately to Korea and Taiwan. Thin-film transistors (TFT) and liquid crystal displays (LCD) became the dominant technology and in fact still remain so today. The advances in technology were made by RCA, Westinghouse, Exxon, Xerox, IBM, and AT&T.

But what critically hurt the industry was that only one of the firms, IBM, invested in high-volume manufacturing and that was actually a joint venture with Toshiba. In contrast, all the Japanese manufacturers invested in high volume manufacturing facilities. Strategically the U.S. companies felt as though they had to choose between manufacturing and investing in the construction of an expensive fabrication facility or spend those dollars in R&D for the next generation of substrates. They chose to invest in R&D, so very early the die was cast for manufacturing to be done offshore.

In 1996 more than 96% of all the displays were produced in Japan but less than 10 years later, fewer than 11% were made in Japan with the top two production locations having moved to Korea and Taiwan. The main reasons for the shift in production were the lower engineering and labor costs in Taiwan and Korea and the ability of these countries to raise the capital needed for investing in state-of-the-art fabrications facilities. The successful integration of each generation of production equipment is dependent upon investment in high-volume production facilities.

Today, the U.S. continues to participate in the display industry through the introduction of new materials, technology and equipment and by working collaboratively with manufacturers outside the U.S. But, unfortunately the U.S. has lost the production of displays and the economic impact of new jobs and capital investment.

Solar Cells

The innovation and manufacturing of solar photovoltaics (PVs) have their roots in the U.S. when in 1954 the first silicon photovoltaic device was invented at the Bell Labs and was used in space satellites which made the U.S. government the primary customer. Until 1980 the U.S. was the world leader but by the mid-1980s the United States, Japan and Germany competed for the lead in solar cell production. By the mid-1990s the United States and Germany surpassed Japan in PV shipments. However, since 1995 the U.S. share of PV production has fallen and by 2015 only 2 of the 10 solar manufacturing companies in the world are U.S. companies. And, unfortunately the largest U.S. manufacturer, First Solar, has just announced a massive layoff in their Toledo, Ohio facility which is their only manufacturing facility in the United States. Solar panel manufacturing is now dominated by Chinese firms.

Although the United States no longer dominates the global production of solar modules, it has maintained its lead in the patenting of solar technologies. There is tremendous innovation in the materials that underpin the solar technologies that are used for energy generation. There are presently four PV technologies that are being used in the manufacturing process and it is very difficult to assess which design technologies may be dominant in the future. But as of 2016 it is likely that the basic materials underpinning solar technologies will continue to undergo considerable change and it is very possible that once again U.S. based innovation can lead to expanded production in the United States if we learn from the mistakes that were made 50 years ago.

Optoelectronics Components for Communication Systems

Optoelectronic components which include lasers, modulators, amplifiers, photodetectors and waveguides produced on semiconductors are the components which are necessary to send and receive information in light-based communication systems. This technology originated in the Bell Labs and was followed by addition research at Bell that produced the fabrication methods that allowed all these optoelectronic components to be produced economically. Corning was the next company to introduce a revolutionary product, low-loss optical fiber that has proven to be the critical element in the development of optoelectronics. And, by 1986 several other giant corporations including DuPont, ITT, Allied Signal, Eastman Kodak, IBM, and Celanese, had begun the production of fiber optics and other related components.

The development of optoelectronics was dramatically affected in 1984 by a federal antitrust suit against AT&T which changed the structure of R&D and manufacturing in the U.S. communications industry forever. AT&T spun off Bell Laboratories into a new company, Lucent, which ultimately merged with Alcatel. During all this turmoil, many small and medium sized optoelectronic component manufacturers were started in the United States as they were reacting to the void left in the market after the antitrust action as well as the tremendous growth in the market.

However in 2000 the telecommunications market collapsed and the industry was thrown into turmoil. In order to survive, producers of fiber and components had to reduce production costs. Between 2000 and 2006, the National Academy of Sciences reported that the majority of optoelectronic companies moved manufacturing from the United States to developing countries in East Asia. These firms did not use

contract manufacturers but rather were formed as wholly owned foreign subsidiaries. Only a few U.S. companies that were mainly start-ups that were relying on public funding sources or venture capitalists chose to keep their manufacturing in the U.S. However as in the two previous cases the U.S. has maintained a dominant lead in issuance of patents.

Although many of the key photonics innovations have occurred in the United States including display and communications technologies, the multibillion dollar display industry has moved mostly to Southeast Asia, with a very small amount of the display production occurring in the U.S. Even though the United States led in the manufacture of telecommunication equipment for decades, China went from having no companies in the top communications companies in the world in 1998 to dominating the list in 2015. And a similar situation exists for Chinese optoelectronic companies that specialize in selling optical components and subsystems----they are dominating the world market.

The drive for competitiveness and shareholder value has caused corporations in nearly every area of photonics to search for alternative manufacturing locations. The exception may be defense-related markets and applications that are subject to export controls. The effects of this offshore movement of manufacturing however seems to have had little or no effect on innovation in photonics. The U.S. remains the leading source of patents in two of the key sectors of photonics, solar and communication components, and is the leader in potential next generation technologies such as flexible displays, thin-film solar cells and monolithically integrated optoelectronic devices.

It is apparent that for reasons such as sensitivity to labor and capital costs differentials the United States has been unable to compete successfully in high volume, low-cost manufacturing of products based on photonics technologies. The global photonics ecosystem depends on low- cost production and advance manufacturing. The question that remains to be answered is can the U.S. find a way to be a strong competitor in the lower volume, high-value-added manufacturing of products based on the next generation technologies where they are the leading source of innovation.

Low Volume Products

Low volume products are generally high precision and very complex or they are products that are related to national security concerns. Very often they are products that are in the early stage of development and they require a prototype or they are products in the medical industry.

As an example, The United States has excelled in the production of low-volume, high precision medical instruments that are based upon high precision optical components. Although cost is an important element in these products, the need for reliability and precision far outweighs the cost considerations. It is markets of this type that present the best opportunities for the United States to regain manufacturing leadership

Additive Manufacturing

While there are issues concerning the ability of the U.S. to compete successfully in high-volume, low-cost photonics manufacturing, it is likely that the United States can be a strong competitor in custom, precision and high value-added photonics manufacturing. Recent advances in several manufacturing capabilities such as different methods of additive manufacturing hold out considerable promise for the development of low-cost machines capable of providing precision results. Additive manufacturing has the

potential to change how future products are designed, sold, and delivered to customers, making mass customization and easy design changes possible. Additive manufacturing has the potential to allow the production of parts near the end user no matter where the design is done.

Additive manufacturing describes multiple techniques in use since the mid-1980's to build solid parts by adding materials in layers. In contrast to the traditional "subtractive processes" that remove material from solid blocks to manufacture goods, additive manufacturing reduces waste because it only uses the materials needed to produce a product. The process also reduces the need to maintain large inventories of component parts because they can be produces using just-in-time processes.

Additive manufacturing is a small but rapidly growing industry and is in fact used today as an effective shop floor tool. It is an enabling technology that is based in photonics and has the potential to fundamentally change manufacturing. An additive manufacturing machine can produce multiple types of products without retooling which has the potential to benefit defense industries such as aerospace, which demands a continual light weighting of components. Additive manufacturing companies are already working with the large defense contractors such as Lockheed Martin, Northrop Grumman, and Boeing.

At this time additive manufacturing is not a complete replacement for conventional machining or the fabrication processes, but it does have several advantages:

- A short time from a CAD file to a complete part
- Cost effective low volume production
- Process eliminates high cost custom tools and fixtures

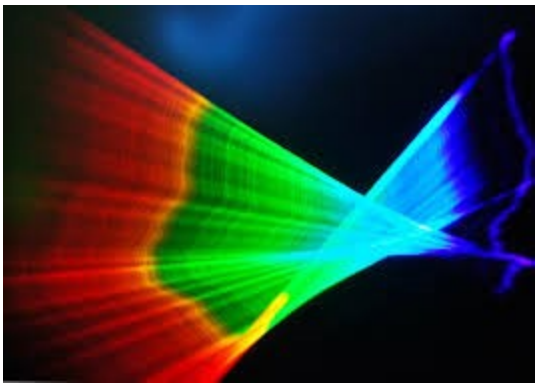
Historically the technology was used to produce simple parts for experimental purposes, but today very precise parts are produced. And with the advantages just discussed additive manufacturing can be a good fit for prototypes, which are products with a high degree of customization and complexity and are products that are produced in low volume as well as low-to mid-priced machine manufacture.

Trends in Additive Manufacturing

Over the next 5-10 years, we will see consumer machines continue to drop in price and industrial machines continue to get better but stay expensive. Early application areas will be consumer products, medical implants and tools, dental implants, and aerospace. On the industrial side, additive manufacturing will focus on producing high value components and products along with those requiring complex internal geometries that cannot be made using traditional manufacturing techniques. Industrial machines will continue to improve, building more types of materials, parts, and eventually whole products with increased speed and precision. To advance, industrial machines will rely on process improvements, quality control, and development of new materials.

Additive manufacturing when fully scalable will lead to economies-of-scale calculations so that mass customization and easy changes in design will become possible. The expectation is that by 2030, machines will have improved to the point that they can build whole volumes at once, creating multiple products quickly and at relatively high precision, directly competing with traditional manufacturing

approaches. Additive manufacturing may be the key to enabling the United States to once again manufacture the photonics enabled products that have moved offshore to Asia.



Importance of Education

To enable the United States to be productive in manufacturing photonic goods, a capable and fully trained workforce will have to be in place at all levels including skilled operators and craftsmen as well as technicians and engineers. But there is some concern that in the U.S. holders of advanced degrees from university programs in photonics and related degrees tend to pursue careers in academia and R&D rather than opportunities in design or manufacturing. The private sector must develop some attractive career paths for holders of advanced degrees to pursue in order to encourage them to go into photonics manufacturing and/or applications of photonics technologies throughout manufacturing.

In the **Photonics in New Mexico** study, the outstanding educational environment for photonics was acknowledged but it was pointed out that the major problem for New Mexico in terms of workforce is the lack of good jobs for trailing spouses and the reputation of the K-12 public school system.

The Future of Photonics Manufacturing

The future for photonics enabled manufacturing lies in part to the activities and success of the American Institute for Manufacturing Integrated Photonics, (AIM Photonics). As evidenced earlier in this report, the United States has not been successful in manufacturing low-cost high-volume products even though they were first developed and commercialized by U.S. firms. The production of these products is now dominated by international companies.

The creation of this institute is focused on developing an end-to-end integrated photonics ecosystem in the U.S., including domestic foundry access, integrated design tools, automated packaging, assembly and test, and workforce development. The winning consortium partners have stated that “AIM Photonics intends to apply key lessons from the electronics industry to the photonics integrated circuit (PIC) industry, which is currently low-volume, non-scalable, and uses expensive manufacturing methods and under-developed equipment. We aim to create a national infrastructure that is widely accessible and flexible enough to meet the challenges of the marketplace with practical, innovative solutions.”

The Institute will develop and demonstrate innovative manufacturing technologies for:

- Ultra-high-speed transmission of signals for the internet and telecommunications
- New high-performance information-processing systems and computing
- Compact sensor applications enabling dramatic medical advances in diagnostics and treatment
- Multi-sensor applications including urban navigation, free space optical communications and quantum information sciences
- Other diverse military applications including electronic warfare, analog RF sensing, communications, and chemical/biological detection

All of these developments will require cross-cutting disciplines of design, manufacturing, packaging, reliability and testing. The Institute brings government, industry and academia together with the goals of

organizing the current fragmented domestic capabilities in integrated photonic technology and better positioning the U.S. relative to global competition. Activities under the Institute will enable universities and small-to-medium enterprises to participate in the integrated photonics movement. They are currently completing a roadmap for photonics.

If the AIM Photonics Institute can achieve success, The Optical Society foresees a bright future where a concerted effort among government, industry, and academic stakeholders might bring:

- Electronic imaging devices implantable in the eye that can restore sight to the blind
- Genome sequencing for every baby upon birth
- Cost-effective, laser-based, 3-D desktop printing of many different types of goods
- The generation, detection, and manipulation of single photons in the same way as is done with single electrons, and doing it all on a photonic integrated circuit
- The use of optics as interconnects between integrated circuit chips, with dramatic increases in power efficiency and speed
- The development of a flexible display on a Smartphone
- The availability of holographic images at home
- The ability of mobile lasers to neutralize threats from afar with high accuracy and speed

Without this national coordinated effort, it will be very difficult for individual organizations and companies to ensure the growth of the photonics industry and to accelerate the use of photonics by companies in the many industrial sectors that are key to our economy.

Implications for New Mexico

New Mexico and Albuquerque have historically played a role in the national photonics community and have made a number of important contributions to photonics technology. They are the home of several national laboratories, a cluster of photonics companies as well as research institutions located across the state. But New Mexico and Albuquerque have reached a tipping point: they can continue the status quo of trying to approaching photonics as an industry and continue to incubate and encourage a strong base in fundamental research and basic photonics technologies, or they can expand their outreach by focusing time and investment on a few key industry sectors that use photonics as an enabling technology and are judged to be of global significance during the next ten years. These activities are not mutually exclusive and can be most effective when done in tandem.

Photonics is an enabling technology, it is not an industry. There needs to be a strategy to develop a critical mass in high value industry sectors and aggressively pursue these sectors. In **Photonics in New Mexico** the study concluded that New Mexico's existing firms were "well positioned to make significant advances in solar cell manufacturing and optimization, test and measurement systems, semiconductor processing and biomedical devices." If indeed the indigenous industry base is strong in those sectors, they could be the building blocks to begin to create the critical mass for the creation of strong clusters built upon the existing companies as well as attracting new participants.