

Montana's photonics cluster

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Montana's photonics cluster is pushing out the frontier for the photonics and sensors industry, literally and figuratively. Globally, the photonics industry is expected to grow from \$1.5T today¹ to nearly \$2T by 2025² and is already estimated to support more than 10% of the global economy.

Home to one of the densest photonics clusters in the world³, Montana's niche in the \$150B components and sensors segment cluster includes strengths in lidar⁴ and hyperspectral imaging.⁵ The innovations coming out of the cluster will change how people and things move on the ground and through the air; how economies grow food and manage critical inputs into the economy; how countries protect themselves from man and nature; and how our global community sustains our natural assets.

- **Move.** The full lidar systems and hyperspectral imaging innovations being developed and manufactured in the region's cluster will provide the proverbial eyes and ears for what is expected to be a \$6T autonomous vehicle⁶ and \$60B unmanned aerial vehicle market⁷ by 2033.
- **Grow and manage.** Precision agriculture⁸ and forestry⁹, industries will be a combined \$45B+ market by 2033. Precision technologies rely on a bevy of photonics sensors, optics, advanced analytics, and machinery to identify man-made and natural threats, maximize crop yields, and manage long-lifecycle natural assets like timber. Similarly, the smart mining sector will grow to \$10B by 2033 and includes photonics systems capable of detecting mineral concentration levels to direct billion-dollar investments in mines.¹⁰
- **Protect.** The photonics-enabled systems defense market is expected to grow to \$415B by 2033,¹¹ including a range of technologies and innovations attached to soldiers, drones, ultra-mobile vehicles, among others. Photonics systems will also play a critical role in protecting citizens outside of the battlefield, driving what will be a \$2.5B market by 2033 for digital water technologies capable of identifying water supplies at the molecular level.¹²
- **Sustain.** Photonics sensors are expected to contribute more than 10% of the CO2 emissions savings over the next decade while also serving as a critical technology in the battling and managing the impact of wildfires on our society and economy. At a price of \$51-\$185 per ton, the savings from the CO2 emissions reductions are estimated to be \$150-\$555B.¹³ And, annualized economic losses from wildfires are estimated at \$65B to \$285B per year, so even a

¹ [McKinsey](#), "Imperatives for photonics companies in the next wave of growth", January 2023

² [Society of Photo-Optical Instrumentation Engineers \(SPIE\)](#), "Optics & Photonics Industry Report 2022", July 2022

³ Team memo. "Montana has one of the highest per-capita concentrations of photonics companies in the country"

⁴ [Grand View Research](#), "LiDAR market size", 2020

⁵ [Grand View Research](#), "Hyperspectral Imaging Systems Market Size", 2021

⁶ [Statista](#), "Size of the global autonomous vehicle market in 2021 and 2022", 2023

⁷ [Markets and Markets](#), "UAV Market"

⁸ [BIS Research](#), "Precision Agriculture Market - A Global and Regional Analysis", 2023

⁹ [McKinsey](#), "Precision forestry: A revolution in the woods", June 2018

¹⁰ [Future Market Insights](#), "Smart mining technologies market outlook (2022 to 2032)"

¹¹ [McKinsey](#), "Imperatives for photonics companies in the next wave of growth", January 2023

¹² [IDTechEx](#), "Sensors in the Water and Wastewater Industries: A \$2bn Market by 2030", June 2020

¹³ [Resources for the Future](#), "Comprehensive Evidence Implies a Higher Social Cost of CO₂", September 2022.

small reduction from better prevention and monitoring techniques can yield significant returns.^{14, 15}

Region's future share of the market

The Bozeman cluster's strengths in categories like automotive lidar (\$9B market by 2033; 66% CAGR), drone lidar (\$2B market by 2033; 28% CAGR), and hyperspectral imaging (\$30B market by 2033; 10% CAGR) are expected to outpace the overall photonics market's growth over the next 10 years (\$1.5T market in 2021 to \$2.8T overall market by 2033; 6% CAGR).

With more than 30 companies employing over 800 workers today, the Bozeman cluster represents ~0.3% of the US photonics jobs and 0.05% of the global photonics jobs. These relatively small numbers belie the true impact of the technologies on the global markets for the cluster's research, as evidenced by recent announcements from Aurora Innovation (200 jobs)¹⁶ and Hyundai's Progress for Humanity research lab (50+ jobs)¹⁷ expanding operations in the cluster. Both global players were attracted to the research and commercialization efforts in the lidar and imaging spaces.

To take the autonomous vehicle market as an example, lidar-based driving systems will serve as the critical eyes and ears for autonomous vehicles produced by Aurora Innovation and many others. The \$6-12T market¹⁸ for these vehicles is dependent on the \$300-400B lidar-based driver assistance sub-market¹⁹, which is itself reliant on the \$100-130B automotive-focused photonics market.²⁰ Aurora, Hyundai, and many more have recognized that the lidar technologies upon which the entire industry will be built on have its roots in many of the innovations cultivated in our cluster.

Another example of Montana's criticality to the future of the photonics market is in the defense space, which takes on both economic and national security dimensions. In short, the photonics sensors and lidar technologies being developed in Montana are being used in everyday life as well as frontier spaces. No other photonics hub in the world has access to the types of innovations and frontier space to develop the types of edge case applications that are required to produce systems that can operate from battlefields to Mars. The Headwaters Hub will leverage Montana's leading photonics sector to develop globally competitive sensor/lidar/hyperspectral imaging-based technologies for enabling autonomous vehicles and systems operating in critical environments from forests to farms and the battlefield to Mars.

The Economist recently published a special report on the future of war (July 8, 2023) in which multiple articles highlighted how warfare between Ukraine and Russia have become driven by sensors, many of whom have its roots in technologies in which Montana has distinct expertise: "For years, the West's

¹⁴ [Nicholas Loris](#), Presentation to the Committee on the Budget for the United States Senate, "A Burning Issue: The Economic Costs of Wildfires", March 2023

¹⁵ [National Institute of Standards and Technology](#), "The Costs and Losses of Wildfires A Literature Review", November 2017

¹⁶ [Pittsburgh Inno](#), "First look: Aurora to build lidar research and development facility in Bozeman, Montana", June 2022

¹⁷ [Hyundai](#), "Hyundai New Horizons Studio to Design and Build Ultimate Mobility Vehicles in Bozeman, Montana", May 2022

¹⁸ [Statista](#), "Size of the global autonomous vehicle market in 2021 and 2022", 2023

¹⁹ [McKinsey](#), "Autonomous driving's future: Convenient and connected", January 2023

²⁰ [McKinsey](#), "Imperatives for photonics companies in the next wave of growth", January 2023

armies have aspired to a way of war in which a cornucopia of “sensors” (video cameras, thermal imagers, radio antennae and so on) would detect targets, pass data to the best-placed “shooter”, whether a howitzer, missile or warship, and create a “kill chain”—or, to use a newer buzzword, a “kill web”—of unprecedented speed and efficiency.”²¹

By building on these recent announcements to attract additional medium- and large-projects over the next decade, and continuing its pace of startup creation and innovation, the cluster could grow its employment base from 800 direct jobs in 2023 to more than 6,150 jobs over the next decade. This figure would represent 1.2% of US photonics jobs and 0.2% of global jobs (5x today’s share).

Number and earning potential of related jobs

With nearly 30 companies employing ~800 workers at an average salary of more than \$72,000²², Montana’s photonics industry is researching, testing, and developing the technologies that will impact every industry in the future. The average salary for photonics workers is more than a third higher than Montana’s overall average, providing a needed boost to the broader economy.²³

Given the high employment multipliers for manufacturing in general and for the photonics industry in particular, the photonics industry in Montana today is estimated to support up to 5,000 direct, indirect, and induced jobs throughout the state, contributing more than \$300M in total wages to the economy.²⁴ Ten years from now, the photonics industry could grow to 6,100 direct jobs, which would total nearly 25K direct, indirect, and induced jobs throughout the cluster.

Conclusion

Montana’s photonics cluster will continue developing the critical innovations that will affect how people around the world interact with each other and the natural environment. Montana’s cluster of world-class talent and research assets (both education and corporate centers), combined with its frontier environment that enables edge-case testing for these advanced technologies, create a competitive advantage that is near-impossible to replicate anywhere else in the world.

²¹ [The Economist](#), “The war in Ukraine shows how technology is changing the battlefield”, July 2023.

²² [Montana State University](#), “Becoming a world leader: Efforts MSU began decades ago have helped transform Bozeman into a thriving center of the photonics industry”, April 2023

²³ [Statista](#), Average annual pay of employees in Montana in the United States from 2001 to 2022”, June 2023

²⁴ Internal calculations based on University of Montana, “[2022 Montana Manufacturing Report](#)”, September 2022.