



AN EXCLUSIVE RESEARCH STUDY
PERFORMED FOR THE AED FOUNDATION

A STUDY OF THE IMPACT OF **AUTONOMOUS TECHNOLOGY**

Dear AED Member,

On behalf of our Board of Directors, I encourage you to examine “A Study of the Impact of Autonomous Technology” research report that was prepared for The AED Foundation. Technology is rapidly evolving, and it is critical to maximize the opportunities that this creates. This report provides an insightful look into the future and ways that the construction equipment industry will need to adapt.

In addition to the current report, The AED Foundation funds research that backs up its claims on the importance of workforce development and shares data with legislators, educators, the media and other industry stakeholders.

To build a pipeline of qualified technicians, The AED Foundation recognizes high school and accredits college construction equipment technology programs. Currently, over 700 diesel-equipment technicians enter the workforce annually, graduating from 50 construction equipment technology programs at 39 schools across North America that are accredited or recognized by The AED Foundation. The Foundation plans to aggressively expand its number of accredited and recognized programs in 2019 and beyond.

The AED Foundation works to provide tools for dealers to recruit technicians including its Careers in Construction Equipment and Distribution brochure, technician video, and other workforce events. In addition, The AED Foundation’s Dealer Learning Center offers comprehensive management programs to give employees of member companies the tools they need to succeed. The learning center is filled with many industry-specific learning opportunities including: seminars, self-paced courses and on-demand webinars, with a variety of subjects such as parts, service, rental, HR, finance, sales and branch management.

However, without the generous support from our investors, The AED Foundation would not be able to continue to deliver research reports or the services that AED members need to improve their companies and stay up-to-date with new business trends.

I encourage you to join me in supporting The AED Foundation by visiting bit.ly/2019aedfcampaign and making a tax-deductible contribution to ensure that The AED Foundation can continue to provide this valuable information now and in the future.

Sincerely,



Whit Perryman
The AED Foundation
Chairman
Vermeer Texas-Louisiana

TABLE OF CONTENTS

Executive Summary	4
1. Introduction	6
1.1 General	6
1.2 Background	6
1.3 Research Objective	6
1.4 Study Scope	6
1.5 Report Structure	7
2. Current Status and Trends for Autonomous Systems	7
2.1 AV Ecosystem: Current Status	7
2.2 AV Ecosystem: Future Deployment	7
2.3 Types of Autonomous Systems	8
2.4 Autonomous Systems in Mining	8
2.5 Autonomous Systems in Construction	11
2.6 Autonomous Systems in Agriculture	12
2.7 Autonomous Systems in Forestry	13
2.8 Conclusions	14
3. In-Depth Analysis of an AED Member	14
3.1 Introduction	14
3.2 Berry Companies	14
3.3 Berry Tractor	16
3.4 Conclusion	16
4. Implications for AED Members and Their Workforces	17
4.1 Introduction	17
4.2 Background: Exponential Technology	17
4.3 Estimates of Technology Deployment Rates and Key Milestones	18
4.4 When and How Might AED Members Begin to Be Impacted?	19
4.5 Implications for the Workforces of AED Members	20
4.6 How Can AED Members Maximize Opportunities and Mitigate Downsides?	21
5. Action Plan and Recommendations	21

A STUDY OF THE IMPACT OF AUTONOMOUS TECHNOLOGY

Executive Summary

CAVCOE (formerly the Canadian Automated Vehicles Centre of Excellence) is pleased to submit to Associated Equipment Distributors (AED) this report on A Study of the Impact of Autonomous Technology.

There are two objectives for the research project:

- To research the impact of automated vehicles (AVs) on the business models of AED's members and their customers
- To prepare a report on the above

The AV era has already started. Fully automated shuttle buses are in use on a regular basis in many countries. Fully automated heavy haulers are already in use in mining in a number of countries, and fully automated agricultural equipment is also being developed and tested. Many car manufacturers are developing driverless cars and especially driverless taxis; these are generally expected to be commercially deployed without safety drivers in 2019-2022.

The research results show that there are multiple initiatives leading to automation and electrification in the heavy equipment space. The overall impact will not be the sudden arrival of automated heavy equipment in all sectors of the market. Instead, there will likely be incremental advances, such as driver assistance systems, and certain applications within each market will be automated first simply because they are easier to automate.

This approach is consistent with the way in which autonomous technology is being deployed for cars, trucks and buses: there are easier-use cases which will see automation first:

- Small, low-speed automated shuttle buses
- Cars for driverless taxi applications in well-mapped urban areas
- Autonomous tractors for moving trailers at low speeds in ports and logistics-handling areas

These low-hanging fruit applications will be followed by more challenging use cases.

We recommend that AED members do the following:

1. Actively monitor technology developments both within their sectors and outside, looking for potential disruptive trends that may well come from autonomous system technologies being developed by major tech companies.
2. Develop business model flexibility to accommodate changes in equipment automation and electrification.
3. Network with manufacturers, dealers, service operations and end clients to develop a greater understanding of needs and concerns as automation is introduced into the various business sectors.
4. Be aware of commercial pressures toward a more service-based (as opposed to sales-based) business model and prepare a business strategy for that.
5. Expand technician training to accommodate as much experience as possible relevant to automation and electrification.



COMPILATION OF THE IMPACT STATEMENTS HIGHLIGHTED IN THIS REPORT

Business models: from sales to service

Heavy equipment manufacturers are already developing autonomous systems and are looking at providing services to their clients, as opposed to traditional equipment sales. If this transition from a sales-based to a service-based business model gains momentum over the next 5-10 years, it could have major ramifications for the entire AED ecosystem.

Technology

Technology has never been developing at a faster rate than it is today, and tomorrow it will be even faster. A major prediction about exponential technology development is that a computer will have human-level intelligence by 2029. All AED members developing business strategies beyond the next 10 years should consider the profound impacts that artificial intelligence, in particular, could have on their business and operational models.

In the next five years we can expect the trend toward automation and electrification to accelerate from low levels to noticeable levels. In the next 10 years we can expect most heavy equipment to become partially, if not fully, autonomous. In the next 15 years we can expect humanoid robots to be capable of operating any legacy human-driven equipment.

A few heavy equipment end users have already expressed a desire for fully autonomous work sites and electric equipment, as this helps them to lower overall costs and to meet efficiency and environmental targets. The indications are that it is a no-brainer for heavy equipment operations to transition to fully autonomous and electric operations at the earliest commercially viable opportunity.

Technicians: transition from diesel engines and powertrains to electric motors and batteries

Within the next 10 to 15 years, based on exponential trends, we estimate that more than 80 percent of heavy equipment machinery will be powered by electric powertrains and have systems centric to autonomous operation. These technology disruptors will require the heavy equipment industry to develop a new type of technician. They will require the industry and AED-accredited schools to produce a skilled technician who has a blend of the standard mechanical skill sets with a much more extensive background in electronic and automated systems. Not only is the current technician shortage at a record high, but the industry must now begin developing the technician of the future, today.

A STUDY OF THE IMPACT OF AUTONOMOUS TECHNOLOGY

1. Introduction

1.1 General

CAVCOE (formerly the Canadian Automated Vehicles Centre of Excellence) is pleased to submit to Associated Equipment Distributors (AED) this report on A Study of the Impact of Autonomous Technology.

1.2 Background

AED is an international trade association representing companies involved in the distribution, rental and support of equipment used in construction, mining, forestry, power generation, agriculture and industrial applications.

Their more than 400 distributor member companies account for more than \$51 billion in annual sales revenue of construction equipment and related supplies and services in the U.S. and Canada. The average distributor member achieves more than \$111 million per year in revenues, employs 280 people, and has eight branch locations.

Some customers of AED's members are already deploying early-stage automated systems in various sectors – especially mining and agriculture. Developments in autonomous systems point toward rapid growth in the use of these technologies over the next few years.

In addition, the wider societal adoption of autonomous systems could have significant direct and indirect impacts on the work performed by customers of AED members. For example, the widespread deployment of autonomous vehicles as mobility-as-a-service could reduce the need to build new infrastructure such as parking garages and roads, and could also reduce the need to widen existing roads.

1.3 Research Objective

There are two objectives for the research project:

- To research the impact of AVs on the business models of AED's members and their customers
- To prepare a report on the above

1.4 Study Scope

The scope is defined by the following questions regarding AED's members, their customers, and the deployment of autonomous systems:

- Given the rate of technology development, what are the optimistic, most likely, and conservative timelines for autonomous system deployment?
- What are the milestones that will indicate key advancements with autonomous systems?
- When will autonomous systems be deployed and when might this affect the business plans of AED's members and their customers?
- What forms might these autonomous systems take and what services might they perform?
- What are the opportunities and threats that autonomous systems present to the end-user ecosystem? For example, there are various ground and drone-based concepts for the detection and repair of cracks and potholes. Some of these may be feasible and some may not.
- What are the impacts on the workforce and the future skill set requirements for technicians employed by AED members for support, maintenance, etc.?
- What are the pros and cons of a "watch and wait" approach while autonomous systems are deployed?
- How can AED's members best position themselves to maximize the opportunities and mitigate the threats presented by autonomous systems?

1.5 Report Structure

After this Introduction, there are four chapters:

1. **Current Status and Trends in Autonomous Systems:** providing a broad overview of the current status and deployment trends in the overall AV ecosystem as well as more specific details related to heavy equipment
 2. **In-Depth Analysis of an AED Member:** focusing on one AED member and the forecast impact of AVs
 3. **Implications for AED Members and Their Workforces:** providing a broader and more detailed examination of the impact of AVs on AED's members
 4. **Action Plan and Recommendations:** integrating the earlier conclusions and providing a road map
-

2. Current Status and Trends for Autonomous Systems

2.1 AV Ecosystem: Current Status

This section of the report describes the current status of the overall AV ecosystem, of which heavy equipment is one part.

The AV era has already started. Fully automated shuttle buses are in use on a regular basis in many countries. Fully automated heavy haulers are already in use in mining in a number of countries. And fully automated agricultural equipment is also being developed and tested. Many car manufacturers are developing driverless cars and especially driverless taxis; these are generally expected to be deployed in 2019-2022.

These early AVs are designed for use in geographically constrained applications, such as on private land or in a downtown area.

The key benefits are that they will be safer, will likely be electric and therefore reduce emissions, and will free up time that would otherwise be lost to the driving task. In a report that CAVCOE co-authored, we predicted that with full deployment of autonomous and connected vehicles, 80 percent of traffic collisions, fatalities and injuries could be eliminated. Another key benefit is the cost savings. The same report predicted that a typical Canadian family could save \$3,000 per year by selling one car and using driverless taxis.


It is important to document that there are ongoing challenges in the development, testing and deployment of AVs. These include cyber-security, extreme weather, pedestrian prediction, hand gestures, etc.

2.2 AV Ecosystem: Future Deployment

The deployment trends are that, during the 2020s, the number of AVs in use on public roads and the total vehicle miles traveled (VMT) will increase steadily. In the 2030s, we will see the introduction of more advanced driverless vehicles that can go almost anywhere almost all of the time, even on lanes that have not been mapped. The AI technology will be equivalent to – or may be superior to – human drivers under almost all conditions. There will likely still be a very small number of situations that AVs will not be able to handle in the 2030s, but these situations would be taxing to even the most experienced human driver and would in no way limit the general usefulness of AVs in over 99 percent of use cases on public roads.

The trend toward mobility-as-a-service, also known as micro-transit, means that people will buy rides rather than cars. This will have an impact on infrastructure projects. For example, we expect to see fewer transit mega-projects, fewer parking garages, and homes with fewer garages. This in turn will impact the type and number of construction projects that AED members will engage in.

In addition, thought leaders predict that as the world moves toward electric vehicles of all kinds, the need for car dealerships and gas stations will decline. Some people predict that by 2030, oil prices will collapse, and the oil and pipeline industry as we have known it for the last 100 years will be on life support. All this will impact construction opportunities for AED members.



There will be increased infrastructure projects in some areas. For example, Texas A&M University has determined that when the majority of vehicles are automated and communicating with each other, traffic flow will be improved if traffic signals are replaced with European-style mini-roundabouts.

The conclusion is that the AV era will not only introduce new technologies for all vehicles, including heavy equipment, but it will also change the market for transportation and transit construction projects.

2.3 Types of Autonomous Systems

In this section of the report, we move from the general AV ecosystem to some more specific aspects of AV technology in heavy equipment.

For the purpose of this report, an autonomous system is defined as software programming and hardware sensors and controls that can be applied to heavy mechanical equipment that gives the equipment the capability to do all of the work for a specific task without any human input or guidance.

Autonomous systems in the context of AED clients generally perform one of two functions, or can be combined to carry out both:

- Autonomous Driving System (ADS)
- Autonomous Work System (AWS)

There are a number of different technical solutions that can give ADS capability. The main variations arise from the method used to position the equipment within a work zone and the ability of the ADS system to recognize and respond to unplanned and/or unexpected objects and occurrences.

For a highly controlled work zone, a simple ADS can rely on wireless transponders on vehicles and transponders acting as fixed way-points within the confines of the work site to provide accurate positioning information. In some current systems, the vehicle or infrastructure does not always have sensors to detect unexpected obstacles, but due to the tightly controlled nature of the site, the chances of such obstacles occurring are minimal. As the costs of sensors fall and software control systems improve, we expect that safety sensors will become standard even in highly controlled work zones.

In highly controlled work zones, the primary decision-making software and algorithms will reside in a centralized control facility and will probably include real-time human monitoring and oversight of site operations.

Examples of this type of system are provided later.

More capable ADS systems, such as those being developed for autonomous vehicles for use on public roads, use very accurate maps of the geo-fenced area of operations, and have highly developed sensors on board with very complex artificial intelligence software that makes safe decisions for operation based on identification of all of the moving obstacles, etc., in the vicinity of the vehicle.

The most advanced example of this type of system, now commercially released with safety drivers on the roads of Phoenix, Arizona, is the Waymo (formerly Google self-driving car project) system. In December 2018 there was a soft commercial launch of the Waymo service in Phoenix using a few hundred riders, but as yet there are still safety drivers in the vehicles.

2.4 Autonomous Systems in Mining

Autonomous systems in mining have been under development for several decades, and due to the nature of the working environment, the current systems are relatively advanced compared with other sectors.

Underground Mining

In restricted enclosed spaces, automated machinery offers many advantages over machinery that requires a human operator to be present. Safety is the most obvious advantage, with remote hard-wired operation moving the human operator away from work faces and hazardous areas of the mine. Operation via wireless relay allows operators to be housed farther away, possibly even in a control room in a remote location.

An example of a specialist automated (AWS) hard rock mining machine is one from Atlas Copco, which has been designed to do less damage to surrounding rock than its competitors and to reduce the risk of fall of ground (**see Figure 1**). <http://www.miningne.ws/2017/07/10/atlas-copco-introduces-the-future-of-hard-rock-mining/#>



Fig. 1: Atlas Copco automated hard rock mining equipment. Credit: Atlas Copco

Atlas Copco is also a provider of automated drilling technology; the 11 automatic drilling system drills at the West Angeles mine have now drilled more than 5,000 km. Automated drills are claimed to be safer, more accurate and more consistent. The autonomous drill system used by Rio Tinto enables an operator using a single console at a remote location to control four autonomous drill rigs from multiple manufacturers simultaneously, improving precision and equipment utilization.

<https://www.mining-technology.com/features/mining-robots-rio-tinto-doubles-autonomous-drilling/>

Another technological trend in mining is the move to electric propulsion systems and battery electric vehicles (BEVs). Caterpillar is developing a proof-of-concept BEV version of the 1300G LHD (load, haul, dump) machine (see Figure 2).

Fig. 2: Caterpillar 1300G – a proof-of-concept battery electric version is currently in development. Credit: Caterpillar

https://www.cat.com/en_US/by-industry/mining/articles/ug-battery-electric-concept-lhd.html

<https://www.australianmining.com.au/news/caterpillar-develops-battery-electric-lhd/>



Over-ground Mining

A leading example of an advanced version of autonomous systems for over-ground mining is the Komatsu Autonomous Haulage System (AHS), where “each autonomous dump truck is equipped with vehicle controllers, a high precision GPS system, an obstacle detection system and a wireless network system” (see **Figure 3**).

Before the end of 2019, if testing and development go according to plan, Volvo’s self-driving trucks will haul limestone from a mine to a port approximately five kilometers away. Volvo appears to be planning to offer this as a service, as opposed to selling the equipment. <https://www.engadget.com/2018/11/26/volvo-self-driving-truck-mine-hauling/>

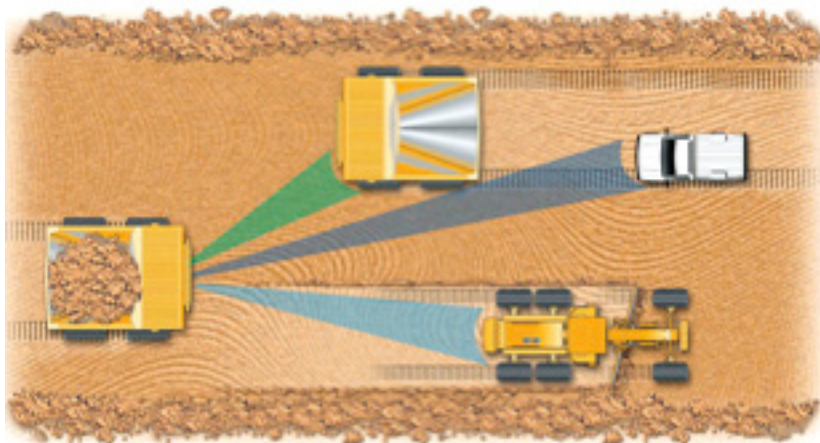


Fig. 3: Komatsu AHS. Credit: Komatsu

<http://www.komatsu.com.au/AboutKomatsu/Technology/Pages/AHS.aspx>

Rio Tinto has been working with companies like Komatsu at mines in the Western Australia Pilbara area since approximately 2008-2009 and has had workers controlling driverless trucks from an operations center in Perth, some 1,200 kilometers away. <https://www.abc.net.au/news/2015-10-18/rio-tinto-opens-worlds-first-automated-mine/6863814>

In late November 2018, Rio Tinto announced it would invest billions of dollars in its first “intelligent” mine in the Pilbara. An article in the Business Times states: “It will use systems that connect driverless trucks, trains and drills for the first time, using data analytics to optimise production, improve safety and cut downtime, using just a fraction of its Pilbara workforce.” <https://www.businesstimes.com.sg/energy-commodities/rio-tinto-backs-us26b-smart-mine-in-australia>

At a special media event in October 2018, Komatsu showcased their technology at their Arizona Proving Grounds. Komatsu now has over 130 fully autonomous trucks operating at seven sites (six sites are fully autonomous) from the Alberta oil sands to Chile and the Pilbara area. To date, their fleet has a perfect safety record with no incidents. Although haul trucks can be fully autonomous, the loading units are not yet automated. The benefits of autonomous trucks described at the media event included the following:

- Reduction of risk from drowsy or unskilled drivers
- Taking personnel out of hazardous working areas
- Centralized control
- Working with a machine that offers 100 percent compliance and observation of road rules
- Lower fuel usage
- Reduced carbon emissions
- Lower tire disposal costs due to increased tire life
- Superior navigation accuracy
- Precision placement of dumped loads
- Absolute control of material destination
- Consistent haul cycle times
- Operationally, more planned and stable operation with reduced variability
- Increased operational utilization
- Minimized stoppage for breaks
- Load and haul total unit cost for AHS users is reduced by up to 15 percent
- A 13 percent reduction in total maintenance costs
- With reduction of sudden acceleration and abrupt steering, estimates are for a 40 percent improvement in tire life

Should there be any doubt about Komatsu's ultimate goal, the International Mining article finishes its report of the media event with the following statement:

Ultimately the plan of course is to have a mine running on artificial intelligence, where you can upload the mine plan to the equipment and the fleet will execute it autonomously, something Komatsu is fully committed to.
<https://im-mining.com/2018/10/08/komatsu-mining-opens-automation-present-future-arizona-proving-grounds/>

Similar to developments in autonomous vehicle design for public roads, where a human driver no longer needs to be accommodated, the design of mining equipment can be adapted to autonomous operation. Komatsu has already indicated how their new driverless haul trucks might look (see Figure 4).



Fig. 4: Komatsu fully automated heavy hauler design.
Credit: Komatsu

The Empa website states:

If all goes as planned, the electric dumper truck will even harvest more electricity while traveling downhill than it needs for the ascent. Instead of consuming fossil fuels, it would then feed surplus electricity into the grid.
<https://www.empa.ch/web/s604/e-dumper>

An economic study for Nouveau Monde Graphite's latest Canadian mine claims that an all-electric open-pit mine can be built that delivers both shareholder returns and the desired reduced carbon footprint. Nouveau Monde stated:

The mine will be using an all-electric, zero-emission mine fleet, consisting of electric battery-driven 36.3-t mining trucks, battery-driven front-end loaders, cable reel excavators and bulldozers, and battery-driven service vehicles.
<https://im-mining.com/2018/10/25/nouveau-monde-graphites-electric-matawinie-plan-stacks/>

2.5 Autonomous Systems in Construction

In 2013, Komatsu introduced the semi-autonomous D61i-23 dozer, the world's first dozer with fully automatic blade control. Caterpillar and John Deere are working on similar technology. The large haul trucks and earthmoving equipment developed and used in the mining sector can already be transferred to work on suitable large construction sites, although the economics on construction are probably not as favorable as in a large continuously expanding mining operation.

Smaller earthmoving equipment, however, is already in advanced development, with Built Robotics being one of the leaders in this field with their Autonomous Track Loader – similar in size to the familiar Bobcat track loaders. Built Robotics has already completed a commercial project using their technology, which is overseen by an operative using an electronic pad.

<https://medium.com/@builtrobotics/the-future-of-construction-92bfb85104b1>
<http://www.builtrobotics.com>

Combined with advanced digital modeling, the ability to carry out earthmoving operations appears to already be achievable for many construction sites.

INTSITE is an Israeli company working on an automated construction crane. The crane will be powered by computer vision, machine learning and deep learning. It is expected to be piloted in the UK and France in 2019.

<https://www.israel21c.org/automated-construction-crane-aims-to-cut-mishaps-delays/>

The DARPA Robotics Challenge in 2015 highlighted autonomous mobile robots with working limbs, including humanoid robots that can operate in simulated disaster zones and carry out tasks such as opening plumbing valves, cutting a hole with a power tool and negotiating a cluttered worksite. One task even involved a robot driving an electric buggy. Boston Dynamics has released numerous videos of their robots carrying out impressive tasks such as negotiating very rough terrain, doing somersaults,

carrying and stacking heavy weights, opening doors, and delivering packages to houses. Most recently, a Japanese organization released a video of a humanoid robot called HRP-5P installing drywall (see Figure 5).



Fig. 5: HRP-5P robot installing drywall. Credit: Advanced Industrial Science and Technology

2.6 Autonomous Systems in Agriculture

Within the farming sector, there are many companies developing various levels of autonomous systems, including major equipment manufacturers such as John Deere, Kubota, Case IH and Agco (Fendt). The main thrust for automation has been on the tractor platform, but automation of other types of farm equipment is also being pursued. In the pursuit of precision agriculture solutions, the automation of farm equipment is a high priority.

Tractor path planning using GPS technology and simple automation has been in commercial use since the 1990s, but as new technologies have become available and cost-effective, the demand for greater automation and even autonomous operation has grown.

Despite over 20 years of experience in seeking to make tractors self-driving, John Deere still requires a human to be sitting in the driver's seat of all of their vehicles. Although driving in the controlled environment of a field is considerably easier than on a public road with other vehicles, the John Deere engineers haven't yet been able to replace the human senses that are used to drive the tractor and avoid problems. Considering that a collision or a misadjusted item of equipment could have significant effects, the stakes are high to get autonomy right.

Other major issues for the agricultural sector are dust and other weather conditions. Ensuring that sensors can see, and that the information can be interpreted sufficiently well to ensure the safety of all involved, is paramount.

<https://qz.com/1042343/after-trying-to-build-self-driving-tractors-for-more-than-20-years-john-deere-has-learned-a-hard-truth-about-autonomy/>

Case IH, another major tractor manufacturer, has a leader-follower type arrangement that they call "supervised autonomy." A human-driven tractor is followed by a driverless tractor relying on vehicle-to-vehicle (V2V) communications technology for driving instructions (see Figure 6).

<https://www.caseih.com/apac/en-in/News/Pages/2016-case-ih-premieres-concept-vehicle-at-farm-progress-show.aspx>



Fig. 6: Case IH premieres concept vehicle at farm progress show, 2016. Credit: Case IH

Kubota has developed what it says is a fully autonomous tractor, the Agri Robo, developed off the base of an L Series tractor and featuring sensors, cameras and programmable mapping technology, allowing a farmer to pre-program work and then send the tractor off to do it (see Figure 7). <https://www.realagriculture.com/2018/01/kubotas-fully-autonomous-tractor-to-hit-fields-in-japan/>



Fig. 7: Kubota Agri Robo. Credit: Pierre Criado

Canadian technology developer DOT Technology Corporation is developing an autonomous tractor and has designed its vehicle as a square U frame that picks up implements rather than towing them (see Figure 8). Although this improves traction and system efficiency, it requires implements to be designed to work specifically with this platform. Development and testing of this ADS is ongoing.

2.7 Autonomous Systems in Forestry

The forestry sector has seen limited progress with automation because of the harsh working conditions over considerably larger areas than those experienced by the other sectors.

Work sites are often in remote areas, on steep slopes, and in very rugged and variable terrain. In these remote areas, there are generally no cell towers and no Wi-Fi, and communication is currently expensive with limited bandwidth. The next generation of very large fleets of low earth orbit (LEO) satellites is expected to change this.

Of the main work tasks in forestry – felling, extraction, processing and transportation – the most challenging to automate will be felling. The other three tasks are all easier to automate, but still difficult compared to the other sectors considered in this report.

An example of partial automation is the Konrad Ground Carriage PULLY, which is operated via remote control and transports felled tree trunks down slopes to be loaded onto logging trucks (see Figure 9).



Fig. 8: DOT Tractor. Credit: DOT Technology Corp



Fig. 9: Konrad Ground Carriage PULLY in action. Credit: Konrad

2.8 Conclusions

The research results show that there are multiple initiatives leading to automation in the heavy equipment space. The overall impact will not be the sudden arrival of automated heavy equipment in all sectors of the market. Instead, there will be incremental advances, such as driver assistance systems, and certain applications within each market will be automated first simply because they are easier to automate.

This approach is consistent with the way in which autonomous technology is being deployed for cars, trucks and buses: there are easier-use cases which will see deployment first:

- Small, low-speed automated shuttle buses
- Cars for driverless taxi applications in well-mapped urban areas
- Autonomous tractors for moving trailers at low speeds in ports and logistics-handling areas

These low-hanging-fruit applications will be followed by more challenging use cases.

3. In-Depth Analysis of an AED Member

3.1 Introduction

In addition to the board examination of the impact of AVs on AED's members, we also spoke with representatives of two divisions of the Berry group of companies and have examined the impact of autonomous systems on their businesses. This chapter reports on this research and is subdivided into sections on the two divisions, with a final subsection that draws some overall conclusions.


For the record, both people we spoke with reviewed a draft of this chapter, and this version has been approved by them.

3.2 Berry Companies

Current Situation

The Berry Group has seven operating divisions, five of which are Bobcat dealerships. This subchapter addresses the Bobcat dealerships.

Berry is a dealer and is not involved in the manufacturing side.



Its primary market is compact construction projects. Its customers include private- and public-sector organizations involved in compact construction such as the preparation of ground for pouring concrete, agriculture, municipal government, colleges, etc. Its customers range from small to large operations. Some homeowners rent a Bobcat for a home project.

Berry is also active in the servicing and maintenance of the Bobcats.

The majority of the revenue is from sales and service, with a minority coming from lease and rental contracts. The business model is similar to that of a car dealership that also rents cars.

In the large majority of the use cases, the Bobcats are used on private ground, not public roads. And for transportation to and from sites, they are typically carried on a trailer.

The design of the current generation of Bobcats is generally traditional with no automation and few driver assistance systems, although wired remote control of the vehicle is now possible as newer vehicles have moved to drive-by-wire control systems. Some Bobcats are equipped with GPS systems. All of the current generation use diesel power, and there is no intelligence on any evolution from that.

Berry's service technicians have trade school experience and qualifications, and there is an in-house Bobcat technical trainer. Some technicians also take Bobcat online classes.

Ongoing trends:

- 10-12 years ago there was an evolution from tires to rubber tracks.
- There is growth in the compact excavator market.
- There is an evolution from levers to a joystick to control the vehicle.
- The Bobcat market is growing.

Expected Impact of Autonomous Technology

It is useful to predict the impact of autonomous technology in the three time frames defined for this research study: 5 years, 10 years, and 15 years.

- Next 5 years: Given the current state of Bobcat technology, autonomous vehicle technology in general, and the compact construction projects undertaken, it is difficult to envisage any significant changes in this time frame. A home construction or renovation project, for example, frequently involves operation close to adjacent homes or in an environment where there may be children or pets. The current and near future of AV technology is not really designed for these use cases.
- 5-10 years ahead: We can expect that AV technology will start to be introduced in Bobcats that are used for certain tasks, such as automated snowplows on long lanes and in agriculture for moving a large number of bales from point A to point B.
- 10-15 years ahead: By about 2030, it is expected that AI will have reached a point where its capability exceeds that of a human for many tasks, including operating a Bobcat. In the 2030s, AI technology will allow most, if not all, of the Bobcat use cases to be automated. This will likely be achieved by a significant redesign of Bobcat, rather than by a humanoid robot operating the current generation of vehicles.

The overall conclusions for this market segment are the importance of keeping developments on Berry's radar screen and starting to plan for changes.

When these changes start to appear in a robust form at commercially competitive prices in the 2025-2030 time frame, the impact on Berry's Bobcat business will initially be gradual, ramping up through the 2030s to become substantial. These impacts will be seen in both the skill set required of Berry's technicians and the need to retrain customers in how to program the Bobcats for specific tasks. It is well-known in the auto sector that many consumers have trouble and are frustrated with some of the high-technology features in modern cars. We can expect that Berry's customers' level of satisfaction will depend in part on how intuitive it is to use automated Bobcats and how well they perform.

3.3 Berry Tractor

Current Situation

The Berry Tractor division markets heavy equipment for soil compaction, asphalt compaction, aggregate carrying, commercial buildings, and projects for utilities. The equipment they market includes wheel loaders, crawler dozers, excavators, motor graders, articulated trucks, rigid frame trucks, soil compactors, asphalt compactors, pneumatic tire compactors, landfill compactors, crushers, screens, asphalt pavers, concrete pavers, curb and gutter machines, construction brooms, material trailers and equipment trailers. They also provide conveyor systems for cattle feedlots. The equipment brands they sell include Komatsu, Bomag, Screen Machine, Superior Broom, and other manufacturers.

A large majority of the revenue is from the sale of equipment, rather than from rental or lease.

The vast majority of the operating time of this equipment is spent on private land. Very little time is spent on public roads, and transportation is usually via a float.

Berry Tractor is very involved in maintenance, service and repairs. They currently find that technicians need training in the specialized technology and programming. There are specialists just for this requirement.

This equipment is starting to incorporate some advanced technology features such as GPS and advanced driver assistance systems. These assistance features require a human operator.

Trends in this space:

- Remote control: Dealers have investigated this use case. Applications include repair of sinkholes and working over known caverns.
- There is also interest and ongoing work in linking machine operation with drones; an “eye in the sky” can lead to productivity and quality benefits.
- The trend toward automation has started, with associated interest in the cost savings.
- Although the primary power comes from diesel engines, there is a trend toward higher-technology regenerative braking that stores energy in capacitors for use by the motor-generator.

Moving beyond this to full automation has potential, but as in other types of AVs, some pushback from customers – or, more precisely, from the workers – is to be expected. Some equipment has a single owner-operator who may well be more interested in investing in a high level of technology.

One of the issues is, of course, safety. Some of the work sites are complex and the sensors and software will have to be designed to avoid/minimize collisions. These issues are not unique to automated heavy equipment and there is every expectation that they can be mitigated.

Expected Impact of Autonomous Technology

It is useful to predict the impact of autonomous technology in the three time frames defined for this research study: 5 years, 10 years, and 15 years.

- Next 5 years: Full automation in this market sector has already started. Komatsu is well-known for producing fully automated heavy haulers that are already in use in mining operations. This trend will continue and more types of vehicles in the sector will become automated, especially those that travel a significant distance.
- 5-10 years ahead: The trend toward greater use of AV technology will be in parallel with advances in AI. We have seen with Komatsu that the approach was to initially add AV technology to an existing heavy hauler product, and then to develop and manufacture a new version that was designed from the ground up to be autonomous. Car manufacturers like GM have already announced plans for a car with no steering wheel or pedals. Truck manufacturers like Volvo have announced and demonstrated a prototype of a cabless tractor that will initially be used in ports and logistics-handling sites. We expect the same approach will be used in the other segments of this market.
- 10-15 years ahead: As we mentioned above, the enhancements of AI technology will lead to capability surpassing that of humans by about 2030. This means that in the 2030s, almost any heavy equipment that is marketed by Berry Tractor may well be fully automated. This leads to the requirement that the skill set of technicians will change substantially.

3.4 Conclusion

There are three key takeaways from the discussion and analysis of these two Berry divisions:

- The trend toward automation has already started in the heavy equipment part of the market, a trend that will extend to smaller equipment in the years ahead.
- The advances in AI will lead to major changes to the product lineups in the 2020s and 2030s.
- As mentioned elsewhere in this report, there may well be a trend toward selling a service rather than selling equipment. This will clearly have an impact on Berry's business model.
- There will be substantial changes in the expertise and training of the service and maintenance technicians, as well as the need to train customers in programming the use of this equipment.

4. Implications for AED Members and Their Workforces

4.1 Introduction

This section of the report addresses the expected implications of automation on AED members and their workforces by answering the questions outlined in Section 1.4, Study Scope.

There are three key parameters to these implications:

- Market sector – e.g., construction, agriculture, mining and forestry
- Business model – e.g., manufacturer, dealer, maintenance, training
- Technology type – e.g., on/off-road, ADS or AWS, automated or autonomous, electrification

There are complex interrelationships between each of these principal parameters and considerable overlap of the implications caused by automation.

4.2 Background: Exponential Technology

Before exploring the implications of automation technology on AED members, it is important to understand one dominant trend: technology development is exponential.

The rise of the computer has been instrumental in the development of almost every new technology society has seen in the last 30 years. All of the technologies described in Section 2 above rely on computer chips to function. Computing power, or the number of transistors on a chip, has closely followed Moore's law, the observation that the number of transistors in a dense integrated circuit doubles about every two years. Moore's law is therefore exponential, as doubling every two years quickly starts to produce very significant compounded improvements every single year.

Artificial intelligence (AI) is the technology that has effectively become "the new electricity" that is powering the majority of technological change (on the foundation of exponential growth in transistors on a chip).

Possibly the most accurate futurist alive, Ray Kurzweil, a Fellow with Google, predicts that computers will have human-level intelligence by 2029, based on the continuation of current exponential growth trends in technology development.

Growth in AI development really took off in 2012 with the widespread deployment of neural networks and reinforced learning. Making machines automated based on traditional software "if, then" coding can only go so far in developing truly useful autonomous functionality. But by the application of advanced image recognition algorithms and safe decision-making algorithms, all facilitated by neural networks, it

TECHNOLOGY:

Technology has never been developing at a faster rate than it is today, and tomorrow it will be even faster. A major prediction about exponential technology development is that a computer will have human-level intelligence by 2029. All AED members developing business strategies beyond the next 10 years should consider the profound impacts that artificial intelligence in particular could have on their business and operational models.

has become increasingly possible to develop autonomous systems that are closer to the ultimate goal of fully autonomous systems.

If Kurzweil is correct, then 2030 or something close to it could prove to be something of an “event horizon,” as forecasting past this date will be open to even greater error than before, since an intelligence smarter than humans could well be driving the greatest changes.

4.3 Estimates of Technology Deployment Rates and Key Milestones

The questions being answered in this section from the Study Scope are as follows:

- Given the rate of technology development, what are the optimistic, most likely, and conservative timelines for autonomous system deployment?
- What are the milestones that will indicate key advancements in autonomous systems?

First, we note that a universal goal of most businesses is to reduce costs, improve efficiency, grow revenues and increase profit margins. In this instance, automation is universally attractive as it seeks to remove the cost of humans while providing machine-like efficiency. Thus, automation is a no-brainer once it is proven to “do what it says on the tin.”

Second, with AI being new electricity that is powering the majority of technological change, it is important to understand the role that AI will play in the automation of machines and how general developments in the sphere of robotics could play into the realm of AED members.

Thus, the statement from Komatsu in Section 2.4 can be expanded to every single aspect of the work carried out by AED members:

Ultimately the plan, of course, is to have all work operations (design, management, operations) running on artificial intelligence, where you can outline the work plan and the equipment and the fleet will execute it autonomously.

In addition, just as Nouveau Monde Graphite anticipates that all-electric mines are the future, reinforced by the trend toward electrification in general transportation networks, it can reasonably be expected that there will be significant benefits for almost all end users of equipment supplied by AED members if that equipment is electric.

Third, we note that the most significant developments in AI are primarily being driven by major tech companies like Google, Amazon, Facebook, Apple, Microsoft, Softbank, Baidu, etc. So, although there are numerous companies within the AED realm of operations that are investing in the development of automation, we suggest that the most impactful breakthroughs in technology development are most likely to come as by-products of the large investments being made in AI and robotics by the major tech companies.

Having set this background of exponential change being led by major tech companies, our response to the Scope of Work questions is as follows:

Autonomous system development is already in advanced stages for a few specific applications, such as the Waymo self-driving vehicle on public roads. Optimistically, that technology could easily be developed into a wider autonomous systems operating system (ASOS) and transferred into almost all of the types of machinery and equipment that AED members are involved with, in approximately five years. In addition, the new ASOS will facilitate the development of new types of robots that will provide even greater amenities to the end clients of AED members.

Optimistically, if AI does achieve human-level intelligence by 2030, then it is almost certain that an ASOS will already be capable of carrying out relatively simple manual tasks on almost any work site several years before 2030.

Pessimistically, we see that safety is the single greatest concern in the development of any ASOS, and we can already see how this is delaying the rollout of ADS on public roads. However, the majority of equipment use cases for end clients of AED members are in controlled environments on private land. This represents a simpler set of problems from a safety perspective. Therefore, commercial rollout could be sooner for AED member clients than for many other sectors. It is easy to see rollout of a commercial ASOS in AED-related sectors happening before 2033 (15 years from now).



The following milestones will indicate key advancements in autonomous systems:

1. ADS/AWS technology development that can demonstrate minimum viable operation in test environments
2. ADS/AWS technology that is robust enough to operate in working environments
3. ADS/AWS technology that is safe enough to be released commercially
4. The development of regulatory approval mechanisms for the deployment of ADS/AWS systems
5. Confirmation that ADS/AWS technology can satisfy legal and liability requirements
6. First commercial rollout of an ADS/AWS system
7. Substantial investment in ADS/AWS from one or more key players in AED sectors

4.4 When and How Might AED Members Begin to Be Impacted?

The questions being answered in this section from the Study Scope are as follows:

- When will autonomous systems be deployed and when might this affect the business plans of AED's members and their customers?
- What forms might these autonomous systems take and what services might they perform?
- What are the opportunities and threats that autonomous systems present to the end-user ecosystem?

Autonomous systems have been in commercial use in the mining sector since around 2008-2010, and now those autonomous systems are becoming more cost-effective and widely available. Meanwhile, the major tech companies have been developing more advanced AI-based ADS/AWS that are also close to commercial launch on public roads.

Therefore, the stage is already set for ADS/AWS to either enter mainstream use via simpler technologies developed/deployed by AED sector incumbents, or via more complex technology as a side-product of work by major tech companies. Such competition generally results in business competition and acceleration of development programs to maximize capture of market share.

Optimistically, we foresee exponential growth in the capability and availability of commercially available ADS/AWS systems from the date of this report. In five years, we anticipate that there will be a wide offering of highly automated equipment across all sectors, with some of the equipment capable of full autonomy in controlled environments.

Pessimistically, we foresee the same outcome in 10 years. It is difficult to conceive of this not being achieved in 15 years.

Optimistically, we foresee almost all equipment being capable of fully autonomous functioning in 10 years.

The form of the ADS/AWS is likely to be on equipment that offers capability similar to that of existing AED member equipment, but is likely to have been redesigned more efficiently, as a human operator no longer needs to be accommodated. For example, a crane will still look similar to a crane, but there won't be a need for a driver's cab. This sort of design thinking can already be seen with the DOT automated farm system.

In addition, the ASOS allows the creation of new modes of equipment, such as humanoid robots capable of performing multiple functions on work sites as an enhanced replacement for human labor. Such robots may also be capable of operating legacy human-driven equipment where it is more economical to retain the legacy equipment for operational and/or cost reasons.

This obviously raises the specter of AED members and their clients being in possession of stranded assets, where the machinery they own has been replaced by more efficient and cost-effective autonomous systems.

As can be seen from the Volvo self-driving haul truck example (see Section 2.4), manufacturers of autonomous equipment see commercial benefits in moving from a sales-based business model to a service-provision business model. This service model business thinking is very strongly in evidence with ADS developers for public road use, with companies like Waymo, GM, Uber, Lyft, Ford, Baidu, etc., all strongly supporting a shift from traditional car sales to service provision. One major benefit to the manufacturer of providing a service is the ability to own all, or most, of the data produced by the vehicles. Since these vehicles are literally sensors on

wheels that “see” and record everything around them, this data could eventually be worth multiple times the cost of the vehicle on public roads.

Since autonomous systems are very suited to electrical propulsion, the other major trend that AED members should be aware of is the move away from traditional fossil fuel propulsion to battery electric vehicles. Although fuel cells and hydrogen power are possible alternative energy storage for electric vehicles, the main consensus that we are seeing is that battery electric is the future, with the possibility that supercapacitors could in turn replace batteries.

The end user might therefore end up renting (as opposed to owning) a wider variety of equipment that is autonomous and electric.

However, there are very broad socio-economic impacts from AVs on public roads that could have major effects on the end-user ecosystem. For example, an increasingly popular first business model for AV developers is the provision of large fleets of shared AVs that are used for ride-sharing. Given that most cities in peak periods see an average vehicle occupancy of 1.1 people per vehicle, ride-shared fleets could significantly raise the average vehicle occupancy rate. This could lead to reduced congestion and a dramatic reduction in the need to widen or build new roads. Consequently, it would significantly impact road construction.

Also, if these shared fleets of ride-sharing AVs replace private cars at a rate of about one AV to five or six private vehicles, there will be a dramatic reduction in sales of new vehicles. This would have a consequential impact of reduced output from automakers and therefore reduced demand for the mined raw materials used to build vehicles. This could affect plans for expansion in mining and possibly even cause a contraction in the mining sector, thus reducing demand for equipment from AED members.

4.5 Implications for the Workforces of AED Members

The question being answered in this section from the Study Scope:

- What are the impacts on the workforce and the future skill set requirements for technicians employed by AED members for support, maintenance, etc.?

With the growth in automation and electrification, we foresee equipment support becoming more technical with a greater number of electronic components/modules/systems and the associated software, and a significant decrease in demand for work related to fossil fuel engines.

Although ADS/AWS equipment will be much more complex due to advanced electronics, software and mechatronics, we expect that it will also be more modular. This means that fault detection will mostly be made automatically by the equipment and will often require module replacement and off-site repair, as opposed to on-site repair.

As a result, we foresee a typical workshop composed of a small number of specialized robotic engineers alongside a larger number of technicians that will carry out standard work. All technicians will need to be trained to be familiar with the new ADS/AWS equipment. During the transition period from legacy human-operated equipment to autonomous and electric equipment, there is likely to be pressure to either increase the number of personnel in a typical workshop to cover a greater variety of equipment, or pressure for technicians to retrain on a larger range of equipment.

TECHNICIANS: TRANSITION FROM DIESEL ENGINES AND POWERTRAINS TO ELECTRIC MOTORS AND BATTERIES.

Within the next 10 to 15 years, based on exponential trends, we estimate that more than 80 percent of heavy equipment machinery will be powered by electric powertrains and have systems centric to autonomous operation.

These technology disruptors will require the heavy equipment industry to develop a new type of technician. They will require the industry and AED-accredited schools to produce a skilled technician who has a blend of the standard mechanical skill sets with a much more extensive background in electronic and automated systems. Not only is the current technician shortage at a record high, but the industry must now begin developing the technician of the future, today.

4.6 How Can AED Members Maximize Opportunities and Mitigate Downsides?

The questions being answered in this section from the Study Scope are as follows:

- What are the pros and cons of a “watch and wait” approach while autonomous systems are deployed?
- How can AED’s members best position themselves to maximize the opportunities and mitigate the threats presented by autonomous systems?

Whatever predictions we make about the future, we will never be completely accurate. In many ways AED members are caught between a rock and a hard place. There are many unknowns with future exponential technology and its direct and indirect impacts, so planning has to be very flexible to accommodate multiple outcomes. If the planning can accommodate the range of outcomes considered most likely, the chances of success are maximized and the risks mitigated.

TECHNOLOGY:

A few heavy equipment end users have already expressed a desire for fully autonomous work sites and electric equipment, as this helps them to lower overall costs and to meet efficiency and environmental targets. The indications are that it is a no-brainer for heavy equipment operations to transition to fully autonomous and electric operations at the earliest commercially viable opportunity.

Our recommendations for AED members:

- Actively monitor technology developments both within and outside your sector, looking for potential disruptive trends that may well come from ADS/AWS technologies being developed by major tech companies.
- Develop business model flexibility to accommodate changes in equipment automation and electrification.
- Network with manufacturers, dealers, service operations and end clients to develop a greater understanding of needs and concerns as automation is introduced into the various business sectors.
- Be aware of commercial pressures toward a more service-based (as opposed to sales-based) business model and prepare a business strategy for that.
- Expand technician training to accommodate as much experience as possible relevant to automation and electrification.

5. Action Plan and Recommendations


This chapter pulls together the previous results and conclusions and develops an action plan with recommendations for AED and its members.

It is clear that the world is moving toward automation in its many different forms. The technology advances in sensors, artificial intelligence and connectivity, coupled with the productivity gains and other benefits, will change the equipment industry as much as the transportation industry. These changes have started, but they will be gradual and will extend into the 2030s.

In total, these changes will have a substantial impact on the business plans and operations of AED’s members. The impact includes both opportunities and challenges. The opportunities include new designs of equipment and the associated technologies, and new business models. The challenges include upgrading the skill sets of sales and service staff.

It will be obvious from the results of the above research that these disruptive changes are definitely coming – and coming faster than some people may expect. We do not recommend that AED’s members adopt a wait-and-see approach. It is important to get ahead of the curve and plan for these changes. We understand that many aspects of the future are not yet clear, but developing the best estimate of the future and preparing a business plan based on that is definitely better than assuming that the past is a guide to the future.

One corporation that we have worked with (not a member of AED) says that they know their industry will be disrupted, and they want to be on the leading edge of the disruption rather than to be passive and wait to be disrupted. This is an excellent strategy and



one that we suggest AED's members follow. It is important to be open to new technologies and to see it as an added value, not a competition.

Planning for a future with unknowns is very challenging. The following is a toolkit of ideas to help with planning for these very disruptive changes. We recommend that AED's members adopt the following action items:

- It is important that planning for changes of this magnitude involve top management, so we recommend an early briefing to the board of directors and/or senior management to put this on their radar screens and to obtain their buy-in for the planning phase.
- An in-house presentation/seminar for managers is useful to explain both what we know and what we don't know about the future.
- A variation of this is an in-house workshop that gives managers an opportunity to discuss, in a moderated format, the opportunities, challenges, issues and implications.
- A comprehensive review of the corporation's business plan will be important, including a SWOT analysis for each of its business areas.
- If there is a newsletter that goes to a member's customers, a useful idea is to include an article about the future. This will inform the clients that there will be changes, and it will position the corporation on the leading edge of these changes.
- An extension of this is to provide presentations to members' clients. This positions them to their clients as being proactive, up-to-date, and on the leading edge.
- Continue to monitor the technology changes in the relevant part of the industry. One way to do this is to subscribe to CAVCOE's free monthly newsletter, AV Update: go to <http://cavcoe.com/> and follow the links.

Conclusion

The future is getting very close – in fact, it is starting to happen right now. These changes will impact cars, buses, trucks, mining, construction, forestry and agriculture and even possibly replace many manual laborers. There are opportunities and challenges, knowns and unknowns. We encourage all of AED's members to take an active role in planning for the future rather than waiting for it to happen to them.



Barrie Kirk, P.Eng.
Executive Director, CAVCOE

Barrie Kirk, P.Eng. has been a consultant since 1982 specializing in the management and engineering aspects of information and communications technologies (ICT), especially ITS, transportation, telematics, telecommunications and satellite communications. His projects over the last few years have focused on connected vehicles, automotive infotainment, traveller information services, real-time traffic information, and vehicle use surveys.

Mr. Kirk's wide range of private and public sector clients include Bell Mobility, Rogers, Shaw, Environment Canada, Industry Canada, Transport Canada, Telesat Canada, the National Research Council, ITS Canada, the Bank of Montreal, Transdev, the European Space Agency, and the Government of Bermuda.

Mr. Kirk's current responsibilities include:

- Executive Director, Canadian Automated Vehicles Centre of Excellence
- Member of the Board of Unmanned Systems Canada.
- Member of the Automotive Advisory Committee, Centennial College.
- Member of the Canadian Advisory Committee for ISO TC204 (Intelligent Transport Systems)

Over the last 40 years, he has worked in the technology industries in Canada, the U.K., and the U.S., including senior management positions at Telesat Enterprises and Lapp-Hancock, and management positions at BNR, Nortel, and Bell Canada. He has presented research workshops across Canada and in the US, UK, and Mexico.

Mr. Kirk holds a B.Sc. (Honours) in Electrical Engineering (Telecommunications and Electronics) from Coventry University, U.K. He is a Professional Engineer.



Paul Godsmark, P.Eng., C.Eng.
Chief Technology Office, CAVCOE

Paul Godsmark, P.Eng., C.Eng. is the Chief Technology Officer of CAVCOE. He is a widely-respected specialist in emerging technologies in transportation and on the implications of fully automated vehicles. He has presented internationally, he has authored many papers, articles, and he has been interviewed on the subject. Paul's blog on AVs is read around the world, and he also very involved on the principal internet fora where the technology is discussed and ideas disseminated. Mr. Godsmark founded the ITS Canada AV Task Force and is an active campaigner raising awareness of AV technology.

Mr. Godsmark has been invited to speak to and advise numerous clients on the subject of how autonomous vehicles will impact on their business and operational models including Transdev, City of Calgary, City of Toronto, Regional Transportation Commission for southern Nevada and Nevada Center for Advanced Mobility.

Through Mr. Godsmark's networking efforts CAVCOE have partnership arrangements with the Central North American Trade Corridor Association (who are developing the concept of an Autonomous Friendly corridor), the GoMentum Testing Station in California and the Australian Driverless Vehicle Initiative.

As a civil engineer he has worked as a project manager, team leader and technical specialist on various complex, high profile and multi-disciplinary highway projects around the world.

Mr. Godsmark holds a B.Sc. (Hons) in Civil Engineering from the University of Southampton, UK. He is a Professional Engineer, licensed by the Association of Professional Engineers and Geoscientists of Alberta (APEGA) and a Chartered Member of the Institution of Civil Engineers (UK).

2019 AED FOUNDATION BOARD OF DIRECTORS

OFFICERS



Whit Perryman
Vermeer Texas-Louisiana
Foundation Chairman



Jeffrey Scott
Intermountain Bobcat
Foundation Vice Chairman



Darren Grahsl
BOKF Equipment Finance
Foundation Treasurer



Brian P. McGuire
Associated Equipment Distributors
Foundation President



Dennis Vander Molen
Vermeer MidSouth, Inc.
Past Foundation Chairman



Craig Drury
Vermeer Canada, Inc.
AED Board Representative

DIRECTORS

Robert K. Henderson
Associated Equipment Distributors
President Emeritus

James McCann
McCann Industries, Inc.
Director

John D. Crum
Wells Fargo Equipment Finance, Inc.
Director

Dennis G. Romanson
CMI Roadbuilding, Inc.
Director

Logan Mellott
Ritchie Bros.
Director

Judy Worrell
Berry Companies, Inc.
Director

Kenneth Silverman
Volvo Construction Equipment
Region Americas
Director

Otto Breitschwerdt
Caterpillar, Inc.
Director

Mike Hayes
Komatsu America Corp.
Director

Jason Daly
Deere & Company, Worldwide C&F Division
Director

Brett Reasner
Pennsylvania College of Technology
Director

Thomas Casey
DLL
Director

Kenneth Taylor
Ohio CAT
Director

Kate Fox Wood
Association of Equipment
Manufacturers
Director

Buck Baird
Coastline Equipment
Director

Todd Hystad
Vimar Equipment, Ltd.
Director

Joel DiMarco
Admar Supply Co., Inc.
Director