Kondinin Group
Research Report
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AUTONOMOUS TRACTORS

THE RISE OF THE ROBOTS

Autonomous Tractors – the rise of the robots

When it first hit the market, the uptake of auto-steer systems was exponential, despite $100,000-plus price tags for high-end units. As with most technology, the 20-year-old tech is now worthless and most probably collecting dust in the corner of many machinery sheds on farms across the country. Those pioneer auto-steer systems have been replaced with systems more sophisticated, capable and for a fraction of the cost. Technology moves at an incredible pace, particularly when improved efficiency or efficacy can be demonstrated. Autonomous systems are likely to follow in the footsteps of auto-steer according to Kondinin Group engineer, **Ben White**, who has seen autonomous tractors implemented on Australian farms successfully.

Arguably, autonomous tractors will be here and commonplace within a decade given the amount of research, development and investment that is happening globally.

In this month's *Research Report,* we look at the companies working in the autonomous farm machinery space and how they are progressing towards making autonomous machinery readily available.

ADDRESSING THE CONCERNS

Social licence is a term used in many conversations where technology is incorporated into agriculture as we strive to make it more efficient. So what social licence is required to address the concerns of the general public when it comes to farm machinery operating without a human in the driver's seat? The main objections to autonomous machinery operation in farming are typically aligned with the perceived threats to jobs or questions around a 150kW+ (200hp+) tractor operating unsupervised

Auto pilot: Autonomous tractors are already operating on farms in Australia with adaptation of existing platforms like this Fendt 936 operating near Moree. Swarm style autonomous machines are also making a mark with at least 50 likely to be working on broadacre farms here in the next 12 months.

Servicing, managing, optimising and observing tractor performance for example, may deliver opportunities for a wider workforce and one that could bring new skill-sets, potentially leveraging the efficiency delivered by the technology.

and without direct human intervention. In addressing these, manufacturers go to lengths to point out that this new technology may actually create new industries and associated jobs with a requirement for observation and monitoring potentially still required, albeit not physically in the cab of the tractor. Servicing, managing, optimising and observing tractor performance for example, may deliver opportunities for a wider workforce and one that could bring new skill-sets, potentially leveraging the efficiency delivered by the technology.

Safety has been one of the primary concerns of manufacturers, with levels of redundancy for safety not seen on other farm machinery previously. Light and Detection Ranging (LIDAR), Sound Navigation and Ranging (SONAR), kill-switches, weather monitoring and GPS drop-out stops are just a few of the detection or errors that will bring autonomous machinery to a standstill.

Earning public trust however will probably see some interim steps towards full autonomy. Master-slave or observed autonomy will probably be the first step for larger equipment.

AUTONOMY PIONEERS

It isn't surprising many of the large farm machinery companies are working on the autonomous machinery front. But there are other players, backed by investment capital and concepts that are also working in the space. There are two distinct approaches to autonomy, the first is the adaptation of existing platforms, primarily larger horsepower tractors that can be adapted to full autonomy.

The alternate approach is the "swarm" style with numerous smaller autonomous machines operating synchronously with a central control to maximise efficiency and eliminate duplication or collision. FA

WHAT IS LiDAR?

Light Detection and Ranging (LiDAR) is a remote sensing technology. LiDAR uses multiple rotating lasers to measure the proximity of objects.

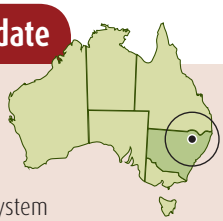
The volume of measurement data is staggering and can be used to build a "3D picture" of the landscape around the sensor making it ideal for detecting objects in the path of an autonomous tractor.

LiDAR has been used by the automotive industry in the development of autonomous cars. This has seen the cost of systems fall dramatically and the size of the LiDAR sensors reduced.

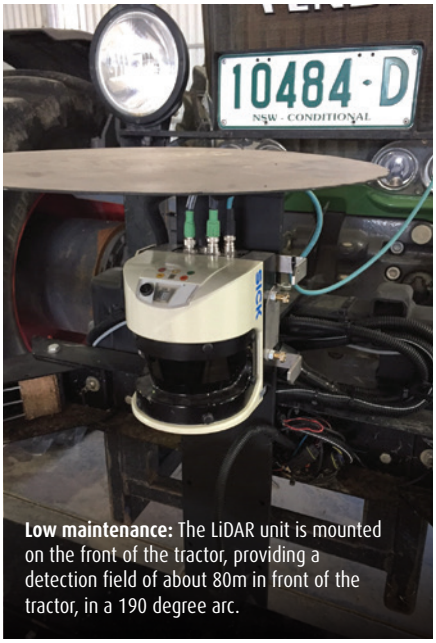
Driverless expansion continues at Beefwood

Light work: Beefwood's 243kW or 326hp Fendt tractor is fitted with LiDAR, which allows it to operate without a driver and detect obstacles.

Case study update



"Beefwood"
Moree, NSW
Driverless Fendt 936 tractor
Upgraded to LIDAR system
10,000ha spot sprayed
5000ha wheel track renovation



Low maintenance: The LiDAR unit is mounted on the front of the tractor, providing a detection field of about 80m in front of the tractor, in a 190 degree arc.

Gerrit and Pam Kurstjens are sold on the benefits of autonomy on their property "Beefwood" at Moree in New South Wales.

Kondinin Group first caught up with the Kurstjens almost two years ago when they started using a driverless tractor – a 243kW Fendt – for spot spraying to help control Flea Bane and other weeds.

With 10,000ha of spraying and 5000ha of wheel track renovations now completed by the autonomous Fendt, the Kurstjens plan to add another two tractors to their driverless fleet in the next 12 months.

Gerrit said there have been several improvements to the driverless technology, including software and hardware upgrades and moving to a LiDAR detection system instead of radar. The LiDAR or Light Detection and Ranging system uses a laser which sits on the front of the Fendt in a module not much bigger than a shoe box. The LiDAR unit – branded a SICK LMS5 – is sold by Precision Makers, located in the Netherlands, and handled in Australia by Precision Control Australia.

"The upgrades have definitely made the system more user friendly and reliable," Gerrit said.

"One of the problems with the previous radar was that it detected trees and other obstacles on fence lines and stopped the tractor. If we reduced the sensitivity, it might not detect objects in the field or it detected them too late.

"But the second generation has a lot of improvements including it only has one CANBUS connection and one connector on the back of the tractor to connect the different implements to the controller."

The LiDAR unit on the front of the Fendt covers a forward facing arc of 190 degrees to a distance of about 80m in front of the tractor.

If an object is detected in that viewing field 40m in front of the tractor, the tractor will slow to 4km/h ground speed and if the tractor gets to within a few metres of the object, the tractor will stop.

If the tractor is stopped for 15 minutes, then a text message alert is sent to a mobile phone.

Prior to the tractor operating in a paddock, the paddock is mapped (using localised base stations) and permanent features such as dams and power poles are marked on the map. The driverless technology also includes a "Play and Learn" feature where the tractor can be driven normally (with a driver) and whatever operations are performed are recorded, which can then be re-enacted by the tractor without the driver.

Gerrit said other improvements have been made to the sensitivity of the on-board system. "For example, with the previous system, in a rough part of a paddock, the gear lever may move and the system would then think a person is in the tractor and disengage the system. Now it's much more tolerant," Gerrit said.

"Another handy improvement is the addition of an isolation switch. Previously, if the tractor finished a paddock, we would get a message and then we had to go to the field to switch off the ignition."

Gerrit also hopes to be able to incorporate the driverless technology into harvesting operations, such as chaser bin hauling.

The driverless technology is undoubtedly getting better and is proven in several other industries such as mining and shipping ports where it is used for collision avoidance and moving containers.

Precision Control Australia is also working on making the driverless tech compatible with other brands of tractors.

At Beefwood, Gerrit estimates he has saved about 600 hours of manned driving to date but he also believes the driverless system can lead to lower maintenance costs.

"I have seen data from the mining industry which shows even compared to skilled drivers, driverless trucks get 40% more hours out of the tyres and require less than half of the repair costs." FA

What's the cost of sitting on unsold grain?

Andrew Marwood, Carwarp, VIC

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Autonomous machinery: who is playing the game

CNH ACVs

Case IH and New Holland Agriculture, global brands of CNH Industrial released two Autonomous Concept Vehicles (ACVs) at a large farm show in the United States in 2016. These ACVs were subsequently also shown in Europe in Paris early in 2017, and more recently in Brazil. The ACV platforms utilise technology developed in collaboration with US-based Autonomous Systems Incorporated (ASI).

Despite two distinctly differing approaches demonstrated in red and blue livery, New Holland high horsepower tractor product manager, Don Forrester explains that while the cab-less approach represents the ultimate expression of autonomy, it's possible that when it is eventually launched the technology will, at least initially, be in the form of a cabbed tractor.

The Case IH ACV shown is based on the Magnum tractor albeit without a cabin. The ACV retains conventional 2cm auto-steering technology and radio communications for control. The Magnum 370 based ACV is powered by an 8.7L FPT Cursor 9 engine delivering rated power of 275kW (370hp) and mated to the CVX Constantly Variable Transmission (CVT) giving it unlimited working ranges and a top speed of around 50km/h, although it is unlikely an autonomous machine would need to operate at roading speeds.

New Holland has named the autonomous concept tractor "NHDrive". The demonstrated NHDrive unit is based on a T8.410 Blue Power tractor utilising the same 8.7 litre FPT Cursor 9 engine delivering rated power of 250kW (340hp) via an Auto Command CVT, the NHDrive concept vehicle retains the cabin allowing operators the ability to conventionally control the tractor.

Both platforms utilise LiDAR and visual cameras for monitoring and safety. The ACVs are able to identify objects and prevent collisions, while GPS signal dropouts and manual stop buttons also prompt the vehicle to come to a halt. After being alerted by the machine to check camera feeds from the machine, alternative path options are selected by a remote operator via a desktop or mobile platform.

Field efficiency is optimised as the software uses implement width, paddock dimensions, shape and topography to plot the most efficient in-field path for the vehicle to follow. According to CNH Industrial, the systems optimise field-efficiency for instance where there are multiple machines operating in the same paddock.

Case IH and New Holland Agriculture, brands of global capital goods company CNH Industrial, unveiled their concept Autonomous Concept Vehicles (ACV) in August 2016. While taking two distinctly different approaches, the cab-less and traditionally cabbed tractor platforms are likely to be interchangeable between the brands.

CNH Industrial has gone to lengths to explain that while the two platforms are operational and video footage of them operating independently is the real-deal, they are concept only. The company is hoping to gather end-user feedback around the concept to assist in the development of a future commercially available product.

According to Don Forrester, there is "certainly demand" for the product with Australian farmers reinforcing their reputation as early adopters and asking when they can purchase an ACV.

Rob Johnson is the regional marketing manager for precision solutions and telematics at CNH Industrial and says that while the ACV is designed as a discussion catalyst, he expects autonomy to come in stages. Most recently, the release of IntelliTurn, for automated headland turning, is another step along the automation path for CNH Industrial. Conceptually, a master-slave or mirrored system could also be part of that journey towards autonomy.

Johnson says that Australia provides the perfect environment for testing and development. In particular, at least one state government has encouraged manufacturers of autonomous equipment to use the state as a breeding ground for technology development, facilitating discussion around development and legislation.

Johnson points out that legislation and technology discussions around on-road vehicles will eventually filter down to off-road equipment and that companies working in the autonomous machinery space need to be involved in those discussions. ▶

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AUTONOMOUS TRACTOR CORPORATION (ATC)

According to the Chief Operating Officer of ATC, Kraig Schultz, we are more likely to see "observed" semi-autonomous operating systems in the next 5-10 years, that is, systems which operate with a lead machine in the paddock operated by a human.

But Schultz says that the automation of implements will be required before we see full autonomy. Implement automation will include monitoring and adjustments normally made by the operator for seeding depth, stubble blockages and other field conditions that may influence the task.

Schulz believes logistic efficiency will drive the implementation of semi-autonomous machinery. But the lack of qualified labour may ultimately drive the final step from semi-autonomous operation to full autonomy.

ATC has a different approach to most other machinery companies working in the autonomy space, insisting diesel-electric drive-train tractors offer lower capital, operation and maintenance costs. Schulz suggests that ATC is working with Original Equipment Manufacturers (OEM's) to install diesel-electric drivetrains on the manufacturing line. In the meantime, the company has converted old and broken equipment to diesel-electric, for "less than would normally be spent on rebuilding the old system". The example given is a self-propelled sprayer, which, for $80,000 USD (around AU$107,000) had hydraulic drive systems removed and converted to diesel-electric by ATC.

Orders for conversions to diesel electric drives are already filled for 2017 with conversions being the main component of the ATC business.

But don't expect to see ATC units operating in Australia for some time, with Schulz suggesting that while they may evolve, ATC has not yet "found a suitable partner who is willing to support the expansion into those geographies … and since we are an American company we have tended to focus mostly on our home market."

KUBOTA FARM PILOT SERIES

With the 2012 acquisition of Kvernerland and the intellectual property (IP) around implement ISOBUS, Kubota also picked up a stable of high-level precision farming resources.

Kubota has extrapolated this IP, developing and trialling autonomous machinery designed for operation in rice production known as the Farm Pilot series. Some of the initial trials in the development of these products took place in Australia, but at this stage, Kubota is not looking to expand that autonomy to match broadacre Australian cropping requirements.

The autonomous push by Kubota is responding to the requirements of farmers in Japan who are getting older, finding skilled workers more difficult to source and seeing farm consolidation drive an operational scale increase.

While the scale of Japanese rice growing operations is building, the equipment being developed is still aimed at relatively small plot size by Australian broadacre standards. A Kubota 45kW (60hp) hydrostatic drive tractor, 66kW (100hp) harvester and rice transplanter demonstrated autonomous operation in early 2017. Trial sales of the autonomous line-up in Japan are chalked to start in mid-2017 starting with the tractor and rice transplanter. ▶

Kubota built and demonstrated autonomous equipment in rice in early 2017 with a 45kW (60hp) hydrostatic drive tractor, 66kW (100hp) harvester and rice transplanter.

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Chaser call: Automated chaser bin operation after it is hailed by the harvester operator. Image credit: precisionag.com

KINZE

Kinze has demonstrated a Jaybridge Robotics designed chaser bin system. Responding to the call of the harvester operator when required, the Kinze tractor drives to the harvester and into the outload position before being filled and heading back to a mother bin or defined location. Kinze has also demonstrated the system planting seed.

BLUE RIVER

While it isn't strictly autonomy, this technology is likely to be integrated with any future developments in autonomous weed control.

Weed detection taken to the next level is the control of weeds in crop or green-on-green detection. To date green-on-brown technology, for example Weedseeker or WeedIT detect weeds in a fallow or stubble situation but cannot be used in-crop.

Technology from Blue River uses a complex algorithm to detect weeds by shape amongst a growing crop. The weed is then precisely sprayed with a stream of herbicide to a 25mm resolution.

Smart Sprayer: Weed detection in cotton using shape algorithms from blue river allows precise application of chemical down to a 25mm x 25mm square.

PRECISION MAKERS

Dutch company Precision Makers has already implemented autonomous machinery on Australian farms (see case study on page 28) and are looking to expand their offering nationally. Handled by Precision Control Australia, the ability to implement autonomy at "Beefwood" has yielded a lot of interest from Australian Farmers.

The Fendt 936 in autonomous operation in Moree was the first to be implemented in Australia for Precision Makers. Precision Control Australia is also working on making the Precision Makers autonomous system operational on other brands of tractors.

Operating in Oz: A Precision Makers autonomous Fendt tractor is operating near Moree NSW on wheel track renovations and selective spraying. Precision Control Australia who handle the product in Australia are looking to expand the offering for other makes of tractor.

Simon says: Fendt developed GuideConnect around 6 years ago, a mirroring application where one driver controls two tractors.

AGCO FENDT

The most prominent AGCO brand working in the autonomous vehicle space is arguably Fendt. Mirrored driverless operation using the Fendt GuideConnect allows two tractors to be connected using GPS and a radio link and be driven by one driver. The GuideConnect system was launched in 2011 and was awarded a gold medal for innovation at Agritechnica.

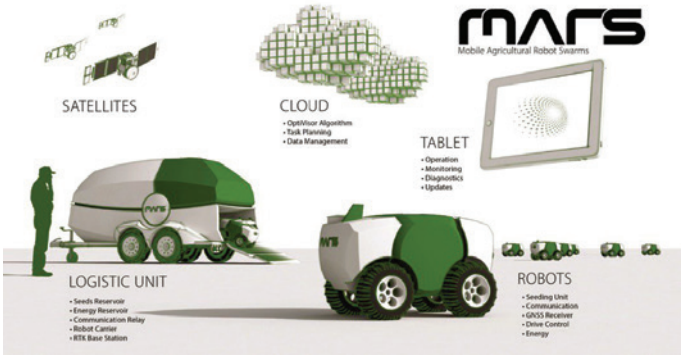
While GuideConnect focuses on autonomy application of full-size tractors, Fendt has also been working at the smaller scale with a swarm concept.

Dubbed the MARS project (Mobile Agricultural Robot Swarms), AGCO's Fendt team are working with the Ulm University in Germany and the project is sponsored by the European Union (EU).

The concept involves a mobile trailer filled with communicating electric drive robotic tractors for seeding operations. The trailer also carries bulk seed and energy to refuel the fleet of robots as well as functioning as an RTK base station for improved positional accuracy.

Operations are planned using a cloud-based algorithm called OptiVisor to maximise field efficiency. Control and monitoring is via a tablet which is continually fed diagnostics and operation details including individual seed placement.

We aren't convinced that level of detail is useful, but it does demonstrate the integration of big-data and autonomous farming equipment.



Martian invasion: The MARS project from AGCO brand Fendt uses a mobile trailer for logistics and Real Time Kinematic (RTK) base station duties. The trailer transports a fleet of small robotic tractors which are refuelled and refilled with product from the trailer.

DeepField weed destroyer: Bosch has been working on a multi-tool field robot packed with intelligent algorithms and sensors including a mechanical weed destruction tool.

BOSCH DEEPFIELD ROBOTICS

The DeepField robotics BoniRob has appeared at two Agritechnica shows in Germany, making its debut in 2013. The multi-purpose platform has four steerable electric drive wheels and a number of application module tools which can be interchanged.

Positioning is via video and LiDAR based positioning with GPS to navigate paddocks and crops.

The most impressive application module is arguably the mechanical weed destroyer which uses complex algorithms to analyse video images to identify weeds in a crop and dispatch them mechanically with a ramming probe.

Expect to see integration of the Bosch technology into other autonomous platforms in the future. ▶

TRIMBLE – AUTONOMOUS SOLUTIONS

Trimble has been delivering continuous steps in guidance system technology, most recently, extending their Autopilot systems to make automated headland turns with NextSwath which was launched in the first half of 2015.

The shift to full autonomy for the market is expected to continue to follow these graduated steps with a further extension of their precision farming equipment suite.

A video posted to the Trimble YouTube channel in late 2016 reveals a fully autonomous tractor being demonstrated in the United States.

The CaseIH Puma 150 CVT is shown driving autonomously around an obstacle course. The Trimble Autonomous Solutions system adapted to the Puma utilising the machine's CANBUS system. LiDAR and camera imaging looks to be used for object detection as is the case with many other autonomous solutions being developed.

Machine telemetry including engine diagnostics in the autonomous demonstrator are shared via mobile phone connectivity. Remote machine shutdown and emergency stop systems are also fitted.

Trimble Autonomy: Trimble Autonomous Solutions has shown off a tractor operating with full autonomy. The technology combines existing auto-steering with other sensors including video and LiDAR.

We estimate the step from auto-steer with an operator to full autonomy for the wider market is likely to happen within the next five years and we would expect Trimble to be in the mix. It is expected that Trimble will look to offer autonomy solutions that retro-fit conventional machines allowing for the option of having a human operator for transport to and from paddocks, service locations and between farms.

Connectivity between machines is already available from Trimble using Vehicle Sync, part of Trimble's Connected Farm package and allows up to six machines to communicate, share and combine information including coverage maps.

JOHN DEERE

John Deere has been actively working on autonomous machinery for nearly two decades. Having developed an autonomous cab-less tractor based on their smaller 6-series machines a number of years ago.

Whether autonomous equipment sporting the John Deere badge will be with or without a cabin will be driven by customer and market demands according to the company.

According to John Deere, steps toward autonomy include AutoTrac steering, Machine Sync coverage map sharing and speed synchronisation and iTECPro automated headland turning. We believe the combination of these technologies place Deere well to deliver a master-slave solution initially prior to full automation into the future. But Deere isn't giving much away, suggesting the company is "looking at all potential solutions and will evaluate these solutions to ensure that the performance quality and support of the product is maintained."

John Deere currently sell a "Tango E5" autonomous lawn mower and supply autonomous "R-Gator" UTV's to the US military. The R-Gator can autonomously follow soldiers on foot carrying their equipment, ammunition and supplies. Visual guidance using infra-red optical and LiDAR technology scans forward terrain, detects obstacles and prevents collisions.

Whether LiDAR technology would feature on any autonomous John Deere machinery in the future is unclear with the company pointing to a range of other sensors for soil moisture or stubble blockages that would be required in an autonomous seeding scenario.

One thing John Deere have been clear on is around product testing, suggesting many products are validated and verified in Australia, hinting a Deere autonomous platform would get some testing time on Australian soil if the "requirements, seasonality and timing" was right.

Photo: John Deere

Swarming: Commercial availability of 50 SwarmFarm autonomous platforms is expected in late 2017 with machine delivery planned for the first half of 2018.

SWARMFARM

Kondinin Group member and Central Queensland farmer, Andrew Bate has spearheaded SwarmFarm since its inception around 10 years ago.

Currently, SwarmFarm has a total of five autonomous platforms operational and being used for spraying applications on-farm. With thousands of hectares of in-field experience to draw on for successive iterations of prototype development.

But after a significant investment in platform development, SwarmFarm is about to go commercial with 50 units being built to be directed into a range of broadacre industries. Orders are being taken for delivery in early 2018 but as a full-service programme, the SwarmFarm units will be leased out on a monthly basis. Pricing is not confirmed yet, but will be made available prior to the order book opening.

The 23kW (30hp) diesel-powered platforms can be fitted with any configuration of spray boom the operator desires although most to date have been an 8m boom width. With a 1400kg platform carrying 600kg of product, Andrew Bate points out that extending boom width to minimise compaction is no longer necessary with a significant design consideration being weight minimisation to reduce compaction from wheel tracks.

Bate says the platforms will run for 12-hours before refuelling and although automated refuelling and product refilling has been developed, checking on the machine every 12-hours or so is just good practice.

According to Bate, the SwarmFarm platform is driven hydraulically for two reasons, the first being that compact, light and affordable electric motors are unavailable, but more importantly, hydraulic systems can be easily repaired by farmers.

Repairs and maintenance is an important focus of the SwarmFarm design with harnesses, computers and components designed as modular and easily swapped out.

Machine vision utilises 3D cameras as opposed to LiDAR.

The SwarmFarm platforms are controlled using an iPad app. Positioning comes via RTK but with many Australian farmers having experienced GPS dropouts due to poor satellite constellations, or tree-lines, the SwarmFarm platform also incorporates sensors and gyros to maintain reliability and operation in case of limited GPS signal.

SwarmFarm has partnered with a number of commercial sponsors including Adama, who can see value in the SwarmFarm platform to assist in redefining labels to extend the safe use of spray chemicals with automated record keeping and automated cessation of the operation where ambient conditions fall outside those stipulated on the label.

US based Farb Guidance Systems has designed a 56kW (75hp) tractor costing around US$160,000.

OTHERS

There is a lot of activity in the autonomous tractor space with other less familiar brands investing effort and funds into research to be a part of the autonomous. These include US-based precision agriculture company Farb who claim to be working on a larger 150kW (200hp) tractor for around US$250,000.

FUTURE

There is little doubt this is a space that will continue to grow with a lot of interest coming from farmers. We predict that within five years, commercially available autonomous machinery will be available, operating and commonplace on Australian farms, most likely utilising existing platforms for seeding and harvest in the interim but with specialist swarms used for spraying and other product application. FA