A Nuffield Farming Scholarships Trust

Report

Award sponsored by

The NFU Mutual Charitable Trust

NFU Mutual Charitable Trust

Autonomy in Agriculture

James Szabo

July 2013

NUFFIELD UK

A Nuffield (UK) Farming Scholarships Trust Report

July 2013

"Leading positive change in agriculture.
Inspiring passion and potential in people".

Title	Autonomy in Agriculture
Scholar	James Szabo
Sponsor	The National Farmers Union Mutual Charitable Trust
Objectives of Study Tour	Gain an insight into technological advancements in automation of arable processes and what influences this will have on the rural community and economy.
Countries Visited	UK, Italy, Germany, Sweden, Australia and Japan
Findings	Internationally the technologies currently in research are on a par with each other. No individual country is 'leading' in the subject area but the UK is certainly behind. There is little agreement on standards or protocols to which autonomous vehicles should adhere, resulting in a subtle stalemate with a lack of true commitment until several paradigms have been agreed upon; the biggest issue being liability and responsibilities. There is a place for robotics in UK arable agriculture. The higher levels of detail and application which can be achieved will allow maximum productivity by focusing inputs at plant rather than field level. The technology is there and only requires a small push from commercial partners before it will be commonplace.

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Disclaimer

1. Personal Introduction

My name is James Szabo and I live in rural North Lincolnshire on the only hill in the county. I have lived in the area all my life and although, unlike most Scholars, not owning or in succession to agricultural land, I have always had a close link with those who do. At the age of 18, and around the boom period of rural broadband and simpler software accounting, I set up a business supporting the local farming community with basic computer hardware and IT literacy skills. This forced many traditional farmers into adopting new ways of managing their businesses. This led to a wide customer base which I am ashamed to admit I neglected through my time at university.

Me, James Szabo

I studied both Electronic and Electrical Engineering & Information Systems at the University of Leeds for six years, but always related my newfound knowledge and skills to agriculture - to the great annoyance of lecturers who were much more comfortable with hotel booking systems rather than mapping and simulation of disease within greenhouses. Whenever possible I focused my attentions on localisation technologies such as GNSS and radio triangulation as I knew the possibilities for agriculture were just starting to emerge.

Having left university in 2008 I entered the Precision Agriculture sector supporting a range of products from real-time nutrient recommendations to auto steer and auto section control. It was clear that these technologies were proven, with quantifiable results. More and more research was going into the application of these technologies which, in my opinion, were not new and often duplicated; I felt that it was time for the next big push, which I believe is the automation of everyday farm applications. This is where my passion for future technology met up with a Nuffield Farming Scholarship.

In January 2012 my journey started.

2. Autonomy in agriculture

The term autonomy in the meaning of agriculture generally refers to the full or partial replacement of human interaction; this may be physically or even just mentally, with the aim of achieving greater accuracy, constancy, safety and reliability.

There are thousands of tasks which can be defined as autonomous which have crept into everyday operations without real acknowledgement of their presence; draft control, automatic gearbox, traction control, automatic breaking systems, electronic stability, cruise control and perhaps some readers may have automatic parking systems on their cars. My point being, it's not simply expecting a machine to take 100% responsibility of the operation of a farm but focusing on those tasks which are perhaps dangerous, time consuming or just mundane.

Since the first mechanised tillage, fundamentally tractor units are much the same now as they ever were; a power source (horse, ox, tractor) and an implement, usually mercilessly dragged through the ground. This has been the case since the dawn of an agrarian society and still very much the case now. This paradigm has not changed; even to the extent that we still classify the potential of our machines in horses!

The current trend is to increase the size of the implement to be more efficient and cover greater swaths of land in single passes, subsequently requiring more horsepower, causing higher levels of compaction, which then requires more energy to rectify the damage. This is a vicious cycle resulting in larger machines using more fuel, metal, machine hours and man hours to repair its own damage; certainly not reducing energy inputs as every other industry is striving for.

One of my first appointments on my study tour was with Professor Simon Blackmore, who had just taken up a position at Harper Adams University College, UK, as head of engineering. He has a long history of agricultural robotics and thankfully has returned to the UK promoting its future applications amongst UK academia. I mention him now as he has a key quote which really drives home the message of the size and trend of agricultural machinery. "*Large tractors cause significant soil compaction that results in up to 90% of the energy used in cultivation being needed to repair the damage caused by the machinery in the first place.*"

Robotics in agriculture is not a new concept, it has been a target for agricultural visionaries for many years. The first report I came across was from the February 1934 Modern Mechanix journal. This report showcased the concept that a farmer could be disjoined from a machine's field operation; this was a full 14 years before the Nuffield Universal was even launched, showing that the desire to be removed from the dirty conditions of agriculture and utilising robotics is not a new trend, but in fact one as old as the internal combustion tractor itself.

Between 1932, the birth of the concept, and 2005 it was apparent there had been little progress in the automation of arable robotics or indeed any automotive sector. Most manufacturers have tried concepts involving wires, radios and other ingenious systems but all had the same problem: intelligence, or lack of.

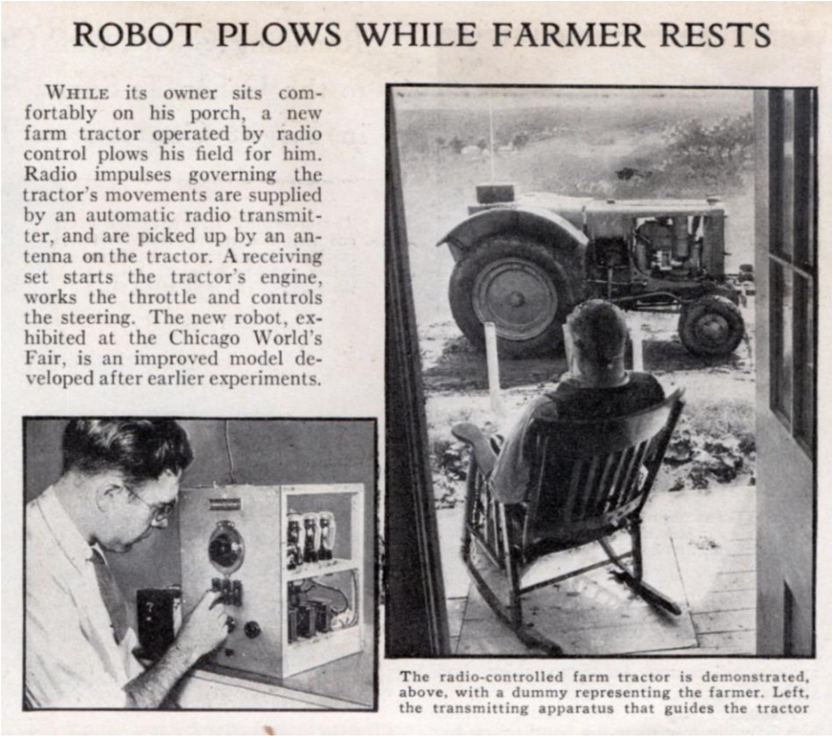
In 2005 the Defence Advanced Research Projects Agency (DARPA) launched its unmanned urban vehicle challenges, allowing entrants from across the globe to rapidly develop new concepts of machine control. Utilising the large amounts of funding, advertising and sponsors available, the DARPA grand challenges led to the advent of many autonomous vehicles across the planet in a range of industries including aviation, mining and agriculture. The most famous provided the seeds for the Google self-driving car which is currently driving around San Francisco unaided.

I knew I had to visit one of these spin-off businesses to really find out how such an influx in funding and public awareness had helped them build a business and product.

I have talked about a general background of automation in tractors but not really covered the commercial technology which was available at the beginning of my travels, quite simply because there was none, or certainly nothing actively commercially running in British fields.

The industry seemed to have got stuck at the point of auto steer guidance and improving the functionality and usability of this - not pushing towards the next milestone of true automation and the partial or complete removal of the human presence in a tractor cab. I knew this was technically possible but wanted to investigate what were the barriers to this next logical step.

The dairy industry across Europe accepted robotics over a short period. It is common-place, and still a growing market, with the majority of milk produced in Holland, Denmark and Sweden having passed through a robotic milker. The benefits to livestock, farmer livelihood and quality are all well proven and covered in many Nuffield Farming Scholarship reports (Paul Lambert, Nuffield Australia, 2012; Pat Minogue, Nuffield Ireland, 2007). This is an example of where technology has been swiftly accepted.


ROBOT PLOWS WHILE FARMER RESTS

While its owner sits comfortably on his porch, a new farm tractor operated by radio control plows his field for him. Radio impulses governing the tractor's movements are supplied by an automatic radio transmitter, and are picked up by an antenna on the tractor. A receiving set starts the tractor's engine, works the throttle and controls the steering. The new robot, exhibited at the Chicago World's Fair, is an improved model developed after earlier experiments.

The radio-controlled farm tractor is demonstrated, above, with a dummy representing the farmer. Left, the transmitting apparatus that guides the tractor

Figure 1 - Article from Modern Mechanix journal, February 1934

What fascinated me was that even though the machines operate in a semi controlled environment, the variables of an autonomous object dealing with a living, moving animal would pose a technical nightmare for any system. I was intrigued by how, firstly, it was technically possible and how that technology may be applied to broadacre arable; and secondly how a herdsman trusted such a machine with his livelihood; and finally how legislation, red tape or liability didn't cripple adoption of such systems.

During the time of my travelling and researching for this Scholarship many projects and new concepts of Autonomy in Agriculture have hit the mainstream media, with many companies professing their new robotic tractor or guidance system.

Through this report I hope to educate the reader as to what the technologies are, what they currently can and can't do and, hopefully, offer a vision into the future of broadacre field operations.

I have done my best not to make this a technical paper or to bore you with detail, but more a snapshot in time as to where the technology is and who is driving it forward. I can only hope when this report is re-read in the distant future all my predictions were correct. If you are that reader, please do not feel obliged to contact and tell me how wrong I was!

> The dairy industry across Europe accepted robotics over a short period. It is commonplace, and still a growing market, with the majority of milk produced in Holland, Denmark and Sweden having passed through a robotic milker.

3. My Planned Study Tour

Parma: Italy, October 2012

Knowing that the technologies I was looking for required straying outside the scope of agriculture I initially focused my attentions to the automotive industry, an industry with greater financial and commercial drive yet with many transposable requirements. In the mainstream media there was much excitement over the testing of autonomous vehicles on the public highways, with the first official licence granted to Google's experimental driverless technology in Nevada (May 2012). The industry outlined its requirements and a law was passed to allow autonomous operation one whole year before any licence was required.

Having attended a UK Seminar on Self-Driving Vehicles in Nottingham I had made several contacts, one being from a spinoff company from the University of Parma. I felt their 'no infrastructure required' approach to vehicle control would be very applicable in agriculture; this will be discussed in greater detail later.

Germany: October 2012

Germany is home to several large agricultural vehicle and implement manufacturers. With its worldwide recognition of engineering excellence I felt I needed to visit Germany to see first-hand how they are attracting young engineering entrants and enthusiasm for agricultural engineering. My visits in Germany included to farmers adopting autonomy to improve their farms' profitability, universities with field robotics, and global machinery manufacturers. Here I saw first-hand the upsides and downsides of European funded projects.

Sweden: October, November 2012

At the start of my travels the world's first commercial robotic rotary dairy was announced. The manufacturing company, based near Stockholm, developed the system on the back of the demand for larger more scalable robotic milking systems. Since the dairy industry has accepted robotics with open arms I wanted to discover how they had overcome legislation, technology limitations and achieved such approval in a relatively short space of time.

> On June 16th 2011, the Nevada Legislature passed a law to authorise the use of autonomous cars on public highways, one whole year before any licence was required.

Australia: February 2013

I was given the opportunity to present at a conference in Adelaide; I took this chance to visit farmers in the area to discover the problems they have with managing large areas with very little labour available. I discovered a culture of technology, innovation and constant improvement and questioning of farm practice, striving to gain the most potential from cropping.

Japan: April, May 2013

I wanted to learn about a completely different kind of agriculture, a culture and industry of small family owned farms and how robotics is influencing their way of life. In the UK the average age (58) of a farmer is a figure which is often quoted as a point of concern. In Japan the equivalent figure is closer to 70 and, with the next generation flooding into urbanised districts, Japan has been pushed to solve this problem. Whilst in Japan I visited and talked at national research centres, universities and farms.

4. The Journey

Throughout my travels I saw many robotic projects or applications which will support the adoption and usability of such systems. Not only did I visit universities and research centres but also industry leaders and their partners. I will follow my travels chronologically and focus on the key developments which I saw on my travels which I feel will have an impact on our industry.

In the UK I visited Harper Adams University College very soon after it had been designated the National Centre for Precision Farming[1] (NCPF). This had been a key moment for both the advancement of Precision Farming in European climates and the agricultural engineering future of the UK. One of my key objectives in completing a Nuffield Farming Scholarship was to discover why, when the rest of Northern Europe had robotics programmes at university level, the UK seemingly had none. The 2013 Field Robot Event held in Prague had 18 competitors from Romania, The Netherlands (3 teams), Slovenia, Finland, Germany (8 teams), Denmark, Turkey, Czech Republic, Iran and Spain. In the history of the event there have been no UK entrants.

Going back to my visit to Professor Simon Blackmore at Harper Adams (mentioned in paragraph above), we covered many aspects of global food supply, the economy and where the technology may go and what has been developed to date. However there were very few of these projects or concepts, of which some spanned decades, which had reached the commercial market. Following the meeting, as mentioned above, the site is now the National Centre for Precision Farming which has created a great platform for the UK agricultural engineering to start from. Through marketing and promotion the centre has shown its intention of focusing the engineering abilities of its students to future innovation rather than simply modifying and tuning what is already there.

A key aim is not to simply automate processes currently undertaken but to perhaps stand back and examine what we do and why we do it. All being well over the coming years new concepts and completely new agricultural paradigms will evolve. The research and future developments here are focusing on better crop and soil husbandry. The term Phytotechnology was one used several times. Broadly speaking this is the study of the actual plant requirements; by focusing on what an individual plant requires rather than what we currently provide it with. By focusing on the plant's needs with no pre conceived idea as to what is required, the current practices of agriculture become very inefficient. Prof. Blackmore believes concepts such as plant

> "Large tractors cause significant soil compaction that results in up to 90% of the energy being used in cultivation to repair the damage caused by the machinery in the first place"
>
> ***Prof Simon Blackmore***
> ***27 November 2012***

[1] Launched in March 2012

level health monitoring, plant specific nutrient and chemical requirements, by meeting individual needs rather than focusing on field averages, suddenly allow for a far superior crop. By having smaller machines this will lead to less compaction (remember 90% of the energy put into establishment is simply repairing soil structure damaged by compaction) leading to lower fuel usage, more management information, an overall increase in production whilst at the same time enabling a reduction of inputs.

4a. Parma, Italy: October 2012

In Parma, Italy I spent my time with VisLab, a spinoff company from the University of Parma. I first met my contact at the Self Driving Vehicles seminar in Nottingham earlier that year, promoting autonomous vehicles on public highways. Specifically I attended with the intention of gaining an insight as to the current thought process on adopting or accepting the use of autonomous vehicles on the public highway.

This was my opportunity to see first-hand how an industry with traditionally far superior safety and tighter legislation would be able to cope with a whole new archetype of transport. Ultimately there was very little discussion at the conference about this; rather it was an arena to display the latest technology.

One concept caught my eye due to its use of intelligent vision systems. I felt the project needed following up due to the "no infrastructure" approach they had to augmentation or positional accuracy. This is to say that rather than relying on an accurate GNSS signal or some other third party, the system is self-contained and only reliant on itself. I learned that this project, along with many globally, had leap frogged its research in the 2005-2007 DARPA grand challenges. In 2005 the challenge was to navigate through a desert environment. The 2007 challenge involved navigating in urban environments with unknown variables such as traffic and pedestrians, with a focus on increasing the reliability of machine decisions and the ability to operate within an uncontrolled environment, using lessons learned in earlier grand challenges. The research has continued with other epic journeys in autonomous operation including Parma to Shanghai, a 10,000 mile journey of autonomous driving and, in June 2013, a completely unaided drive through unmapped roads in Parma.

> Utilising 3D vision cameras on agricultural vehicles is the next logical step towards automation; it can make a complex task simple for the operator. These sensors can already be found commercially in agriculture.

The technology has the potential be fitted to a range of semi-standard machines, which will be able to allow, perhaps not for a few years, a tractor to navigate its own route to do a specific job at a specific time without altering current agricultural practices or infrastructure – thus making it an ideal bridge between old and revolutionary concepts.

The VisLab group are using similar technologies to effectively map the loading process of grain trailers. Although this is a useful tool for a human, small abilities like this will ultimately be a key part in developing self-reliant systems. Having a robot chasing a harvester is a resource and time saver, but not efficient if its only utilising 75% of the loading capacity. Real time intelligent vision systems will play a key part in adding pseudo intelligence to operations, something which humans take for granted. There are commercial systems available utilising cameras which build a 3D model of the trailer, which then has the ability to control the direction and flow of the harvester discharge ensuring an even and high utilisation of the trailer, simplifying both the harvester's and trailer driver's job.

4b. Germany: October 2012

Germany has a worldwide reputation for high quality engineering. Alongside the facts that they entered eight separate teams into the field robot event 2012 and it is the home of several large agricultural machinery manufacturers, I felt it would be a must to visit. My aim was to find out how a culture of engineering excellence is built and an interest in agricultural engineering is seeded.

My first visit was to the University of Hohenheim which has a robust robotics platform from which to develop. The Autonomous Mechanisation System (AMS) is a mid-sized utility tractor which is used for a range of applications including mowing, seeding, inter-and intra-row weeding plus spraying of a range of crops. Although in relative terms the machine is only small compared to current machinery, the principles are fully scalable. Several projects had been completed at this site to ensure a whole-systems approach to the problem of autonomy. Past research has included organic weeding using a cyclic hoe: a clever piece of mechanics and vision which collapses the tillage legs when a wanted plant is detected.

More recently the project has developed into safety and mission planning. The project, titled safe and reliable, specifically looked at systems which will provide the key selling point to authorities, legislation makers, farmers and ultimately the public. The systems focused both on physical object detection with crash barriers, laser scanners (lidar) and easily accessible emergency stop buttons; but more interestingly further research has been directed towards mission

Figure 2 - Autonomous Mechanisation System
(University of Hohenheim, Germany, October 2012)

planning and a generic way to issue a plan to a variety of machines – one of the first steps towards an industry standard.

More recently the research has been directed towards mission planning and a generic way to issue a plan to a variety of machines, one of the first steps towards an industry standard.

The second stage of this is to adjust the mission plan based on real time information. SLAM algorithm (simultaneous localisation and mapping, which is a poor name for a system to avoid collisions!) allows the machine to learn and adapt to its current environment, rather than try to work to a previous situation. Further developments into altering machine behaviour, based on location and working area changes, will essentially lead to a more user friendly, useful and flexible machine. Simple path-following systems will completely fail for both practicality and safety reasons in an agricultural environment; a machine operator doesn't want to be constantly restarting a robot if it has detected an object it was not expecting - such as a fertiliser bag, telegraph pole, implement left in a field or even a human. It will be expected to make its own, safe and intelligent decision.

The majority of the projects involving the robot base unit involved cross country partners and funding, usually with Denmark where the robot was initially designed. Funding sources included the Danish National Research programme, Sustainable Technology in Agriculture. Danish Technical Research Council (STVF), Danish Agricultural and Veterinary Research Council (SJVF), Danish Ministry of Food, Agriculture and Fisheries and, in more recent projects, ICT-AGRI whose aim is to strengthen the European research area and develop a common research agenda channelling the development of ICT and robotics in agriculture. This in turn is funded by the European Commission's 7th framework programme for research.

From Stuttgart I headed north to Harsewinkle, home of international agricultural machinery manufacturer CLAAS. Here I met with Dr Hans-Peter Grothaus, head of systems and services development, to primarily discuss an industry's prospective into agricultural automation.

Project 'MARION' was introduced which is to develop complete autonomous logistical chains from harvest through to storage. The project is split into two distinct operations: in-field operations – harvester to grain wagon, and in-storage logistics.

Several concepts of automation were discussed, from small machines to large harvesters and the economics of each. The opinion of CLAAS was that larger machines make more economical sense to operate and they are confident that it will remain this way; so much so the base units for the robotics projects are the Xerion tractor range (13.5 tonnes). This is in complete contrast to many other robotics developments across the world which are focusing on small, light, low compaction machines.

> "It has taken a long time to get the efficiencies we see in today's harvesting and tillage equipment. The economies of operation favour larger and greater throughput"
>
> *Dr Hans-Peter Grothaus, CLAAS (2012)*

By further questioning I learned the strategy which CLAAS is adopting to ensure rapid acceptance of such systems. With small seemingly inconsequential modifications to the traditional range of hardware they intend to build up trust and reliance on the automation. This may begin with a GNSS-based auto steer (AUTOPILOT), then a self-optimising combine thresher (CLAAS Electronic Machine Optimisation System CEMOS) and then an autonomous grain chasing system (MARION). Ultimately the operator will have very little to do and from this point it's not a great step to removing the operator altogether once the reliability, robustness and safety of the system has been confirmed and reaffirmed in the farmers' and public's mind.

By executing the small stages in parallel to the existing business model very little needs to change on the manufacturing side of the operation. The infrastructure is there and if an end-user wished to adopt a stage of automation that option may simply be chosen at the time of purchase.

Osnabrück, home of **BoniRob,** an autonomous field robot platform for individual plant phenotyping, first hit the agricultural press in 2009 when it featured on the Amazone trade stand at Agritechnica. This was one of the first moments when a commercial partner put their resources into developing a public agricultural robotics project. The robot is being developed with several partners; Osnabruck University of Applied Sciences, Amazone (de), Bosch Automotive and the German Ministry of Agriculture, are all showing a commercial interest in agricultural robotics development and future markets.

What makes the Bonirob project interesting is its scouting capabilities. It doesn't claim to be a solution to all agricultural processes but focuses on a single aspect and does its very best at that single task. Its design and structure show the advantages of corporate funding and resources in developing projects. The structure itself is like no other platform with a special focus on manoeuvrability and opera-tions in less than ideal conditions. Bonirob's core operation is to examine and record information about individual plants. Its features offer the high level of crop husbandry I mentioned earlier. Using arrays of sensors it can determine at every single pass the following characteristics:

- Number of plants
- Plant spacing
- Plant height
- Stem thickness
- Spectral reflexion
- Ground cover
- Phyllotaxis
- Biomass
- Growth rates

This level of information can be utilised with endless possibilities. Having such quantities of detail can be used to create organic breeding programmes, detect and select resistant characteristics or eliminate the detrimental. The BoniRob concept is that of an open platform, where developers and researchers can utilise the moving, planning and execution capabilities but with their own payload or sensors, resulting in a rapid and flexible unit which has already been designed

Figure 3 : BoniRob - Plant Phenotyping Scout Robot (Osnabrück University of Applied Sciences)

to cope with the stresses of working in the diverse and challenging environments of agriculture, where wind, dust, varying temperatures and especially water are all natural enemies of electronics.

My hosts Arnd Kielhorn and Marius Thiel gave me a tour of the rest of the department and site. This gave me an opportunity to ask why Germany has such a tradition of engineering capabilities. The answers were simple and obvious. Engineering like maths, language and science requires its fundamentals to be understood at an early age. The university is host to several youth engineering engagement activities; the biggest of which is the Schüler-Forschungs-Zentrum or Student Research Center where children from primary age can engage in extra-curricular activities involving maths, engineering and science. The students were given specific tasks and scenarios and they would be required to build a solution. The projects were not simple, single day activities, as the scenarios are stretched over several weeks with increasingly more complex requirements, thus matching a real life development cycle. As a bonus the children were able to take their own hardware home to build and improve on their own designs. Supported by 92 commercial partners, listed on the initiatives website, there is clear support from industry in ensuring the longevity of a scientific and engineering culture as well as guaranteeing future engineers to employ.

> "Engineering, like maths, language and science, requires its fundamentals to be understood at an early age"

4c. Sweden: October-November 2012

Heading further north to Sweden, I wished to leave the comfort zone of arable agriculture and learn more about the dairy industry, an industry that is facing extremely narrow margins, an industry that is facing a labour shortage, an industry that has accepted the concept of robotics over a decade ago - perhaps an industry which is highlighting a future trend for arable agriculture? With over 17,000 commercial voluntary robotic milking systems sold it is hard to argue automation is not an accepted and popular technology.

Figure 4 : DeLaval Automatic Milking Rotary Germany, 2012

DeLaval, one of a limited number of voluntary robotic milking system manufacturers, announced prior to my travels the launch of the world's largest robotic dairy. Traditionally the autonomous systems were limited to smaller herds of 50-60 cows per robot and further investment did not scale well with larger herds; however the new design can cope with up to 800 head. Following my time at DeLaval and neighbouring farms I learned that the life of a Swedish dairy farmer is family orientated. With ever reducing milk prices, and labour being the second highest overhead, farms could no longer afford the workforce, so dairy farms were family owned and operated. Wishing to maintain family life and remain in agriculture, robotic systems allowed smaller units producing 1300-1400L / day to remain viable at no detriment to product quality or - a key concern in Sweden - animal welfare.

The latest developments are orientated around biosensors (bio-receptors) which offer real time detection of chosen protein structures or chemicals. This technology, along with thousands of other applications, can be used to pre-emptively detect disease, contamination or any number of health issues. One argument against automation is the lack of extended human attention given to each animal. Biosensors could provide an extra layer of herdsmanship previously never available. The future of these systems is inevitable, the investment is 30% of what it once was and, combined with more efficient disease and health control, the arguments against autonomous systems are few.

4d. Australia: February 2013

Whilst in Australia I had the privilege of touring and visiting a myriad of farmers, not specifically to discuss robotics but to gain an insight into farming in not-so-ideal conditions. The scale of operations and land areas certainly shadow the operations of UK farmers; suddenly an average field size of 57Ha didn't sound so impressive. I experienced a culture of striving for continuous improvement at both farmer and government organisational level. Among the people I visited most had some form of homemade contraption which did something special for their needs. They were not scared of what can only be described as tinkering, rather than waiting for a manufacturer to build something for them.

The GRDC, a major funding body towards agricultural research, is a key supporter of farmer-led technology and the commercialisation of prototypes, and currently supporting a different concept of robotic tillage which is being developed at the University of New South Wales. The disconnection of power and guidance allows better navigational accuracy and weight distribution whilst allowing the costly navigational computers to be moved between implements and tasks whilst keeping the overall weight to a minimum.

Project leader Jay Katupitiya introduced me to his newly developed seeding robot. We discussed his key motivation for pursuing robotics and autonomous machines in agriculture. Primarily his reason was to increase actual cropped area, rather than lose up to 20% of a field's potential through wheel tracks and compaction. Jay believes operating multiple smaller, reduced-weight, unmanned implements will allow an increase in profit which in turn makes multiple machines viable.

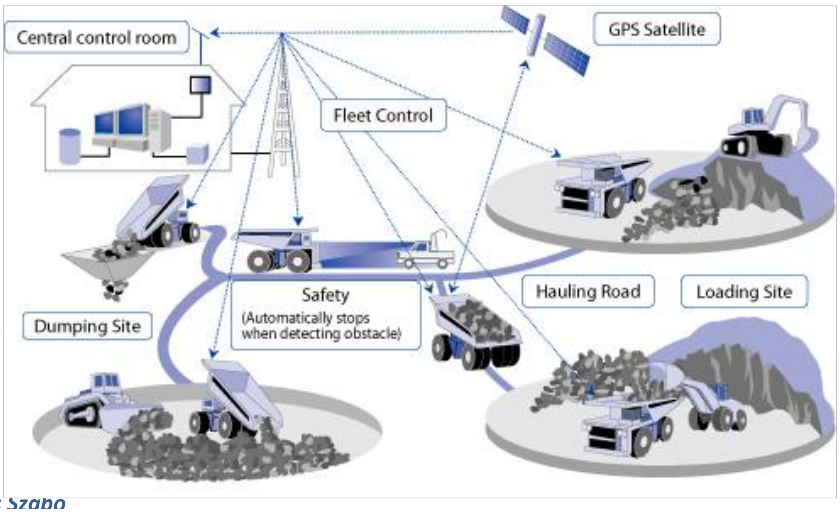


Figure 5 : Komatsu Autonomous Haulage (Komatsu.com, accessed June 2013)

One industry with similar limitations and complexities in operation to those of agriculture is mining, the major industry of Australia. Unable to actually visit a working site due to their remote locations I discussed at length with a site traffic operations manager the trends and technologies available.

Autonomous traffic has started to become an accepted practice in open cast mines. The repetitive driving tasks and unfavourable arid conditions have made perfect conditions for robotic operations. The ore extraction chain starts with an autonomous loading bucket loading a 290 Tonne unmanned truck. The truck autonomously navigates via GNSS plus real-time object detection for safety, along a predefined route to a tip location where it will discard its load and return directly under the loading bucket ready for the next tip. The machine can operate 24/7 without any human intervention making such systems ideal for operating at high altitudes where the truck driver may have to cope with extreme changes in atmospheric pressure. Commercial mines across the world have adopted this technology and it is proving to increase profitability through reduced maintenance costs, energy conservation, vastly increased safety and reduction in CO_2 emissions.

4e. Japan: April/May 2013

The final leg of my journey took me to Japan, once the largest consumer electronics exporter, recently overshadowed by South Korea and Taiwan. The tradition of innovation, appealing to mass consumer markets plus changing agricultural practices makes Japan the ideal location for developing robotic platforms. The driving force behind modernising and automating the farming practices is the problem of an ageing farming demographic. In 1980 the average was 51 and by 2012 approximately 68. At the current rate there would be no more farmers in Japan by 2030! - clearly a huge problem for any country striving for self-sufficiency. Younger generations are heading towards 'clean' jobs in the larger cities resulting in an aging rural population. Add to this, tight laws on the sale and purchase of land, increasing land prices and farmers hanging onto land in the hope of development - and Japan's agriculture is being forced into modernisation.

Currently an import tariff on rice of 777% keeps Japan's rice industry in its current profitable state, with no reason to economise, scale or increase production simply because it doesn't need to. However the Trans Pacific Trade Partnership is seeking free trade between Japan, the United States and Australia as well as others. Claims have been made that 90% of rice production in Japan would go. However, speaking to a profitable, commercial farmer, who would welcome the TPP, he said:

> *"Good farmers are not scared, worried or threatened by the Trans Pacific Trade. Entry into the system would allow myself and other large farmers to purchase and lease more land, creating a more stable production, then re-invest and ultimately breathe more life into an industry which is currently reluctant to change. Every day I see 10% of agricultural land around me not in production and a complete unwillingness to lease the space. It breaks my heart to know that land could be utilised to further both my business and my neighbourhood, and be one step further to being competitive on the international market. The artificial price on rice is good for those farmers holding on, but not a good deal for consumers".*

The Japan Agriculture (JA) co-operative is a very strong lobbying body, with a very traditional membership. However younger, business-focused co-operatives are entering the market and determined to support the larger scale commercial farmers.

A visit to the National Agriculture and Food Research Organisation's Bio-oriented Technology Research Advancement Institution (NARO) demonstrated a range of sustainable and forward thinking projects. However for this paper I will focus on Dr Yoshisada Nagasaka's autonomous rice transplanting robot, winner of the 2008 Robot Award grand prize for outstanding performance.

This machine is capable of transplanting rice at a much higher rate compared to a human or even equivalent non autonomous machine. Currently mechanised machines take seedlings from a nursery on a tray and transplant into the ground. However the trays occupy a large space and require to be reloaded every few minutes, thus reducing the productivity, and the process requires constant human interaction loading fresh transplant trays. With conditions being exceptionally wet underfoot and the transplanting season being in spring the conditions are less than favourable to work in.

This problem of having to reload the trays was overcome with a novel approach to growing the seedlings. Rather than creating a seed tray a long, thin hydroponics-based system of growth was developed which, when mature, can be rolled up and unrolled during operation, allowing greater transplanting distances to be achieved between reloads, and thus ideal for autonomous operation.

Whilst travelling in the middle of the seeding season I was able to see a big difference between the levels of technology implemented. Purely from observation whilst travelling through a small area, I could see 5-10% of the fields were being planted by hand achieving approximately 0.05Ha/day/person. This is laborious, backbreaking work.

A mechanised 6 row planter, which is a standard machine for a technically advanced

Figure 6 : Manual Rice Planting (Japan 2013)

commercial farmer, can achieve up to 0.3 Ha/hr, of consistent depth and inter row spacing.

Figure 7 : Six row mechanised rice transplanting (Japan, 2013)

However with autonomous operation of the same machine, consistent pass-by-pass width and greater distances between restocks, an automated machine can achieve a productivity increase of 25% and, with the average farm size being 1.5 Ha, suddenly the limitation to transplantation is no longer workforce but the distribution and availability of land to farm.

Other robotics projects including soft fruit and orchard operations have been undertaken at this site; however they are already covered in David Gardner's 2010 Frank Arden report titled : Appliance of New Science and Frontier Technologies to Transform UK Agriculture And UK Agri-Food.

Figure 8 : Robotic Rice Planter (NARC, Japan 2013)

Heading further north to the Island of Hokkaido, I spent a week in Sapporo visiting Hokkaido University. The island, having a not dissimilar climate to the UK's, is a major arable producing area for the country, and plays a key part in the local economy. Its university is formally named Sapporo Agricultural College and was formed in 1876 by American leader in agricultural education, William Clark. Although he was only at the college for 8 months his legacy still remains throughout the entire city, with quotes and buildings erected throughout the town centre and university. His parting words were "Boys, Be ambitious!" Certainly this was a heritage that the locals have adhered too.

In the college workshops I wasn't greeted by a single autonomous platform which had obviously been built for a single purpose, I was confronted by a fleet of vehicles which would not look out of place on a UK arable farm. There was a complete array of vehicles and implements to cover all aspects from tillage, seeding, nurture through to harvest; certainly the most complete solution which I had seen. The taskforce included tracked vehicles, standard tractors, crop sprayer, accurate seeding systems, boats and even a small helicopter, all capable at varying levels of autonomous operation.

The technologies were different on each machine to make better decisions as to its effectiveness when directly compared to others; the tractors had excellent navigational abilities and had recently had modifications for safety, notably in partnership with automotive component manufacturers. With ultrasonic, physical object detection in the form of an ultra-sensitive barrier, simple laser

Figure 9 : Autonomous Tracked Tractor (University of Hokkaido, Japan 2013)

object detection from the automotive industry, clear audible alarms and visible warning; these machines were clearly the closest to commercial products seen.

Two machines were of particular interest, as no other research sites, manufacturers, or businesses had working systems. These machines were an autonomous grain harvester and an autonomous crop sprayer. Functionality in both systems was complete; however safety was still a concern on both these machines due to the full width not being monitored in the case of the spray boom or, in the harvester, the most forwardly part being the intake mechanism and no method to identify objects below the canopy of the crop.

These are all situations which, I'm sure, will be rectified within a five year timeframe.

5. Discussion

Because of the world's food problems - which will, I'm sure, be covered by many past and future papers in far greater detail than I will cover them now - it's an acknowledged fact that production needs to increase. Useable agricultural area decreasing through population expansion, the quality of land reducing globally through irresponsible and intensive farming, and workers migrating towards urban conurbations are all negatives. In fact the only trend which will currently benefit UK farmers is climate change which may provide a beneficial growing environment (this is in no way me condoning possible causes of climate change!)

Something needs to change. Perhaps the UK may only play a small part in the actual production of food but we have the potential to play a big part in shaping and designing the way that food is produced globally. As I point these discussions to an international level, I'm afraid it's not going to be a solution on how to gain a marginal 3% yield increase or reduce fuel and wages, but more focused on the drivers behind autonomy and how robotics ***IS*** going to change the farming practices in the long term; how public acceptance *can* be gained; and finally on the economic and social gains which can be achieved.

5a. Drivers to Automation

So who is pushing the move forward? Who is requesting and who responding? Quite simply - everyone. So many aspects of life and production can and will be changed by autonomous operation.

5a.i. Labour

Whilst in Australia I witnessed weed spraying across vast hectares of land. Yet approximately only 5% of the area *needed* chemical. However the operation required man time, machine time, and vast amounts of water and chemical. A small lighter vehicle, performing the same task but with intelligence, could offer potentially huge savings. With multiple machines plus 24/hour operation - suddenly more can be achieved in a shorter time.

Commercial products are already available for the autonomous removal of bulk grain from fields through modified tractors and chaser bins. Once again this offers labour saving and - although against public perception - safer operation.

Removing the variability of human performance can increase efficiency and consequently fuel usage. In areas where there is a shortage of labour this is all very beneficial. However many of the areas visited had not yet implemented any form of mechanisation, and this has left me with further questions. How will any autonomous situation be carried out in such areas? Will it ever be? If so, is it actually socially responsible to do so?

5a.ii. Safety

From the autonomous operations I have seen, all have taken due diligence to make safety a key part of the design. Google's autonomous car has now travelled 300,000 miles in full autonomous operation accident-free, although it has had two accidents when driven by a human; Vislabs BRAiVE, PROUD and the 10,000 mile intercontinental challenge has had no reported accidents.

Autonomous mines in Australia have seen a reduction in injuries from operators not having to climb in and out of large vehicles.

Two reported accidents in 2008 - but where there were no actual injuries - were reported during the very early stages of implementation. This was overcome and autonomous operation soon returned. I believe fields should be regarded as public places for purely safety factors. The laws and liabilities may differ country to country; however making a machine which is designed to operate in a controlled environment and assuming there will be no obstacle, human or otherwise, may save time and resources but could ultimately set back the adoption or acceptance of robotics by several years. There is a real responsibility to ensure the equipment is safe. Currently there are no guidelines, tests or accreditations which autonomous agricultural equipment or vehicles must abide by.

5a.iii. Agronomics

As demonstrated by the BoniRob project, the extra level of agronomic detail which an autonomous machine can offer will allow endless opportunities resulting from phyto-technology and individual plant husbandry.

Being able to monitor so many aspects of individual specific plants throughout its growth stages is a very powerful tool in any agronomic arsenal. Possibilities include: selective breeding programmes, picking plants with specific favourable traits such as drought resistance, thicker stem for reducing lodging risks, and even monitoring leaf area to perhaps develop breeds ideal for lower light levels. Teamed with laser weeders such as the projects at Leibniz University, Hannover, a very rapid organic breeding program can be generated. The shift from field level operations to individual plant level operations will result in plant optimums and not field optimums raising overall yield whilst enhancing input requirements.

5a.iv. Social and economic impact

For the social impact it may have on the community and workforce I looked at industries which have already adopted such systems, for example manufacturing, transportation and aviation. I discovered an array of situations where it has had a negative effect. Automation can induce new forms of stress due to information overload, skill-degradation, boredom, complacently and over-reliance on the system. Most failures are caused by poor training, poor human computer interaction or lack of understanding of responsibilities. Better communication between designers of the system, managers and operators will help manage the expectations of what any autonomous system can and can't perform. Ultimately this will aid any adoption allowing maximum use from the machine as well as acceptance by the operators.

In due course it is inevitable the introduction of robots will make some jobs and skill sets redundant; however it will create other opportunities. A skilled workforce of technically literate staff will be required for the lowest levels of operation, whereas further up the chain highly educated engineers will be required to design the systems and control the approach which will be implemented across agriculture. For situations where a large workforce will be required to operate side by side with autonomy - such as fresh produce - management styles will have to change from a dictative stance to a bidirectional understanding to ensure both humans and machines are operating efficiently. Any system implemented needs to be managed effectively otherwise there will be a risk of rejection by the traditional workforce. Failure to do so can result in very costly implementations of hardware with a complete unwillingness to co-operate over its proper utilisation. Social trials have shown that low-skilled workers reacted negatively toward the implementation of robots, perceiving them largely as threats to their job security. High-skilled workers reacted more positively toward the robots and perceived the implementation as providing opportunities to expand their skillset and knowledge. Finally, management will act positively once the benefits are explained. *(Chao & Kozlowski, 1986*). Within agriculture there is a very well established culture which will have to be overcome; this needs to be managed respectfully.

Although automation will result in less human input, it will cause an increase in technical support roles. These roles will require knowledge in subjects not currently within any agricultural college's syllabus and currently the skillset would only be available from a few companies across the UK. If the new systems are to be readily adopted the responsibilities will in the short term fall upon the manufacturers to effectively train and educate the service field staff. However, as noted in Germany, having general engineering knowledge is a key part of understanding the processes and systems in place. The concepts of the technology, that are not manufacture specific, will need to be taught as soon as an agricultural engineering or design path is chosen. As a bare minimum GNSS[2], systems and control, electrical circuitry as well as fundamental electronic principles will be required by the majority of field support staff.

However at higher design levels, software programmers, engineers and project management will need to complement the technical skills they already have with fundamental agricultural practices, to learn and appreciate the conditions any designed hardware needs to operate within. I believe these will be the hardest roles to fill as training and engineering ability requires higher education, time in industry, and practical experience resulting in at least a six year training period.

5a.v. The inconvenient truth

Machines will inevitably be designed and built by a range of manufacturers with a range of different ideas and concepts; this will cause a technology and standards battle. Extensive work is needed defining standards and recognising the requirement for interoperation between machines. This, however, is internally at each research project level, and there would be very little discussion externally. This is going to lead to multiple standards of machine interoperability, and a lag in the technology until one system has become adopted by the others.

This could unfortunately lead to poor investment and/or longevity of some autonomous products for the early adopters. This problem needs global attention to prevent. As proven time after time, manufacturers will create a bespoke system and then ultimately have to change to a more widely adopted standard.

Furthermore some major questions are still not even asked, let alone not answered, around the liabilities for autonomous systems. Who is responsible for their operation? The only place to seek any hint on direction for these questions is the automotive autonomy industry and even they are struggling to build a structure of transparency.

Currently any system which is legally on the road must have a human who at any stage can take control of the system; they are ultimately responsible for the safe operation. However

[2] Global Navigation Satellite System

this is already being challenged due to the definition of a driver being suitably vague, even to the extent that a corporate body can be classified as a driver, in which case even today a vehicle may be considered to have multiple drivers, one human, one controlling the electronic stability, one controlling the braking systems and so on. This then opens up a new world of issues as, in the event of operation, if a human took control of an autonomous vehicle and caused an accident, is it the human's fault or the robot's fault for allowing it to happen?

A very comprehensive analysis of such liabilities has been undertaken by The Centre for Automotive Research at Stanford. The report concludes that all stakeholders involved - international, national and regional - should adopt standard approach to the definitions behind autonomous operation, resulting in clarity of liability prior to its requirement *(Smith, 2011)*. Unfortunately this may take many years to even be drafted out, which inevitably will prevent designers and manufacturers from releasing product into the public domain without first knowing the legal risks involved.

5b. The vision

So finally, how will it pan out, what will the overall operational structure look like? Currently there is no single answer to this so I will offer my best guess, my interpretation; perhaps even just what I hope will happen.

This may turn out to be an optimistic or even pessimistic view point depending how well the technology is adopted by the end user. Take the mobile phone; if, even 20 years ago, I had said you would get your emails, take photos, watch live TV, play 3D games realtime with someone anywhere in the world – that may have been seen as very optimistic. However mobile phone technology is now an essential part of modern life and every day new concepts and ideas for the technology are emerging.

As stated above, many tasks have already become autonomous and this natural evolution will continue until the operator is no longer needed.

Most agricultural tasks can be split into three areas; seeding, nurture and harvest.

5b.i. Seeding

As discussed, tillage is usually to repair damage already caused via heavy machinery. If heavy machinery is not used then this is a task no longer required. All that the operation of seeding requires is for a seed to be placed in the ground - perhaps a small amount of micro tillage at placement to break the surface, but nothing more. Low ground pressure implements working long hours un-supervised, using its higher resolution of operation (narrower pass by pass) to utilise background maps obtained from previous sensor information for variable seed rates and fertiliser placement, can do the job. With slower operational speeds seeds can be intelligently placed in uniform patterns, not only suppressing weed growth, but also achieving an even, light distribution, even fertiliser extraction and space for the plant to grow. Herbicide applications can be reduced between 50% and 100% *(Olsen J. M., 2011)* utilising such system.

There is always going to be a bulk element required: firstly for the seeding processes and secondly for the harvest processes. This point has often been overlooked by most researchers. A viable solution to this problem is to have bulk traffic pathways with the same principles as controlled traffic. Inter machine co-operation, loading and loading of bulk product, can be done from the bulk traffic pathways allowing overall increased cropping area. Scouting and nurture robots having minimal weight can operate in much smaller, narrower paths allowing access to the whole cropped area.

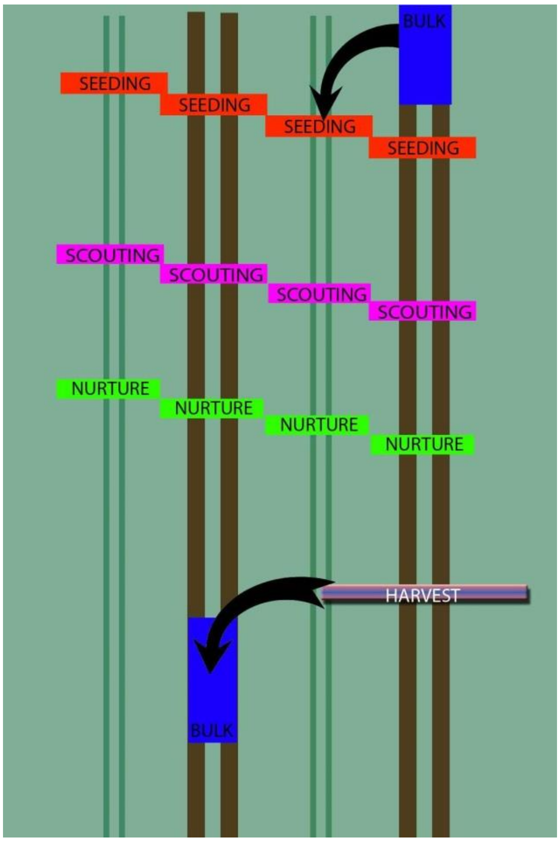


Figure 8 : Autonomous Traffic Operation (James Szabo)

5b.ii. Scouting & Nurture

Due to the removal of time constraints, the advancements in sensor technology and the reliability of GNSS steering, machines will be able to acquire very high resolution information about the current crop health and nutritional situation. This in turn can be used to make management, or even autonomous, decisions as to what the appropriate action will be. The large amounts of data that this will generate will require an operator, manager, agronomist or even a new job title to interpret the information.

As mentioned above, new roles for individuals will be created and one of these new roles is to be able to comprehend visual data and create a relevant mission plan. Systems such as BoniRob have proven the concept of creating plant level databases containing an array of variables to base decisions upon, and are possible and viable. This in turn needs to be supported by a mechanism of providing a physical application of the plant level agronomy. High resolution spray application and inter/intra row weeding will reduce the need for blanket chemical treatments. Some of these tasks can be completed on the scouting pass, others with require a set mission to complete. Complemented with arising technologies such as laser and inter row mechanical weeding, the overall application and treatments will be reduced.

Once a mission has been created the vehicle must be prepared with the relevant tool or chemicals. This I believe should also consist of an operational safety check ensuring correct operation of sensors and equipment. Once the vehicle is prepared it can be released to perform its operation autonomously, achieving the goal set. In the short term the goals will be specific to an individual machine; however, with better interoperability and inter vehicle communicational standards, a general plan may be released and the machines may design and execute the mission themselves. Utilising a mixture of real-time nutrient analysis and background layer maps from earlier scouts, treatments may begin. By following the dedicated traffic lanes, compaction is kept to a minimum, whilst still being able to treat individual plants using a mixture of vision and GNSS location systems. Again this does not need to be a rapid application and multiple machines may work on a single task.

5b.iii. Harvest

Perhaps the most damaging time to soil structure is removal of harvest bulk from the field. With time and resource pressures I do not believe the paradigm of smaller machines will be suited for harvest operations in arable situations. However in vegetables or row crops smaller machines will be able to pick individual produce based on the latter's current attributes, and only harvest that which is ready or meets certain criteria. Traditionally this relies on human knowledge and interpretation which can lead to inconsistencies in product quality, damage to the crop and lost potential. Once harvested, the produce will enter an automated supply chain such as those being developed by the German project MARION.

5c. Why has this not already happened?

So why are we not doing this? The scenarios laid out above are all technically possible today, with no new technology but simply by applying several individual technologies together. Having visited so many projects and read so many papers I know the academic and technical ability is there, the end user demand is there, and the hardware is there. However the missing piece in the majority of projects witnessed is a route to commercialisation.

Most European academic developments are sporadic and lack continued maturity once a particular project funding stream has finished; machines lie dormant in laboratories, scavenged for parts having served their purpose, with no real enthusiasm to push the technology forward through commercial partners.

This is not so true in Japan and Australia, where the workshops had an entire history of developments, with robots over 20 years old in Japan still with the original hardware attached. There was a culture of commercial support provided by machinery, implement and electronic manufacturers working in conjunction to solve problems and offer a route to market.

This is not to say academia is holding up progression; they are clearly pushing forward but just lacking the bridge to commercialisation. The larger manufacturers all have protoypes of some description, some with very good press releases making claims about the abilities of their future machines, often exaggerating the capabilities - very frustrating. Nearly all the global manufacturers I visited perceived the demand for robotics in an unenthusiastic way, not as a concept but as a business model. It is so different to current machinery requirements and there is an apparent lack of interest in changing the paradigm away from high horsepower machines. Perhaps it's the fear of less metal sell or perhaps the increased complexities of dealing with the agronomic requirements rather than just physical requirements; either way I felt almost a negative attitude to the change.

I may have read this completely wrong and each wanted to keep the full details of their systems a trade secret until the confusing issues of liability are resolved.

Overall I feel it is the large manufacturers that are going to have to adopt and launch dedicated development of such autonomous systems. However communication with other manufacturers will be needed or - at least - standards to follow for mission planning, and implementation arranged. if not, SMEs will creep in with fresh business models, small fast developing agile teams of software and design engineers who have no preconceived ideas and no manufacturing infrastructure to change, and who, with the right product, will offer a very disruptive technology compared to the traditional redesigned horse with wheels.

> Having visited so many projects and read so many papers I know the academic and technical ability is there, the end user demand is there, and the hardware is there.
>
> However the missing piece in the majority of projects witnessed is a route to commercialisation.

6. Conclusions and Recommendations

- Robotics and Automation are the future.

  It's going to happen within a generation. It will be iterative and gradual but once the concept is accepted adoption rates will be high and the technology cheap.

- Academic research often lacks a route to commercialisation.

  More incentives should be offered to co-operate and commercialise with research institutions. So many projects seen throughout my travels have been a viable product offering real benefit to agriculture. Unfortunately most academic institutes are more focussed on central funding systems rather than funding through commercialisation.

- The UK is lacking in innovative, engineering entrants in agriculture.

  We need to modernise the way agricultural engineering is taught at university, college, school and even primary levels. Design and Technology is no longer making a birdhouse or trowel but understanding circuitry, transistors, systems and control mechanisms. Ultimately this should be funded by those who will gain from the applicable knowledge it will provide to future employees.

- Threat of liability is holding back autonomous technology.

  Legislation needs to be pro-active, not re-active, with clear responsibilities and transparency. Only then will designers, manufacturers and ultimately farmers be ready to accept and manage the perceived risks of autonomous vehicles.

- Robotics is regarded as guilty until proven innocent.

  Autonomous automobiles have been driving for the last few years with very few incidents, and those usually caused by a third party. The technology is rapidly improving and has a wealth of safety and efficiency benefits which help everyone. Agriculture has different variables to compete with - on top of road travel - but the safety mechanisms will be the same.

Autonomous machines will be safer, more consistent, more efficient and offer levels of plant agronomy never thought possible, and the best part is…..

The technology is ready to go….

7. After My Study Tour

Having met and made so many contacts throughout the world I will be closely watching those projects which prosper and those which fail, to try and gain an insight as to what paradigm is going to succeed; big, little or a mixture?

Discussions have started to develop and commercialise projects which I feel have a future in the industry. I hope my gained knowledge will be utilised by those who are going to have to adapt and learn new technologies and develop new skills at farmer, dealer and educational levels.

I hope, too, it will provide advice to policy makers to help prevent any barriers to entry for new technologies: technologies which will provide a skills, economic, safety and production boost to the UK agricultural sector.

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9. Thank You

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And many, many more		

10. Executive Summary

Since the industrial and agricultural revolutions of the 1700s, food producers around the world have strived to increase outputs to feed growing populations. However one thing has remained constant: human interaction. With fewer people working larger cropped areas, crop husbandry is becoming shadowed by greater reliance on and usage of agrochemicals. With pressure to reduce inputs and increase production there needs to be a complete paradigm change, removing the focus from field level operations to plant level. Robotic technology has now reached a point where systems are robust, reliable and cost effective enough to make a huge impact on the way food is produced.

The goal of my report was to see where the world was with agricultural robotics in terms of technology, requirements and the inevitable legislation which would be involved with unmanned machines. My focus was to find out how this will affect the everyday life of those involved at farm and support levels within the agricultural sectors. The journey took me to commercial manufacturers in central Europe, long running agricultural robotics projects in northern Europe, remote farmers in Australia and a fleet of robotic tractors including harvesters, sprayers and rice planters in Japan. The range of concept and commercial projects I learned about was astounding: from autonomous mines operating in the remotest parts of Australia to self-driving cars in the busy, unpredictable streets of Parma, Italy, robotics and automation are set to become part of everyday life - and sooner than one may expect.

In academic agricultural robotics research, primary focus was on smaller, plant-centric devices which could monitor and treat individual plant requirements through the study of Phytotechnology; a term we will hear more often in the future. At the same time the traditional commercial manufacturers were focusing attentions on automating the current agricultural practices, thus improving throughput at the expense of crop and soil health.

One common issue highlighted across the globe was safety and accountability. With no clear guidelines or responsibilities acknowledged outside of the projects, and little government or legislative involvement, many systems are soon to be denied a route to market. Paradigm-changing technology in agriculture is traditionally met with distrust, and robotics will inevitably be met with questions of redundancy, safety and detriment to plant health. I hope my report will inform and help to alleviate the concerns of both producers and legislation makers, for robotics and automation are the future and are going to influence every part of everyday life, both on and off the farm.