A Nuffield Farming Scholarships Trust Report

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Understanding why existing high-tech systems designed for the livestock industry are largely underutilised: and what are the barriers to their successful adoption

Thomas Allison

August 2017

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Date of report: August 2017

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

Title	Understanding why existing high-tech systems designed for the livestock industry are largely underutilised: and what are the barriers to their successful adoption
Scholar	Thomas Allison
Sponsor	The Trehane Trust
Objectives of Study Tour	• To identify factors that impair the utilisation of farm technology. • To identify any beneficial features that system developers ought to integrate into their platforms. • To identify any necessary improvements to the supply and support chain. • To identify what changes may be necessary at farm level to drive optimal utilisation of farm innovations.
Countries Visited	8 states in America (over 2 trips) New South Wales and Victoria in Australia Honshu island, Japan Israel, Indonesia and UK
Messages	• The concept of a "farmer" as a single entity is incorrect; thus many technology systems designed for "farmer" operation within the livestock industry will remain underutilised. • Technical systems are used by operators and specialists. Their expectations, requirements and evaluation of the system will be markedly different. • The perceived benefits of technological systems are unclear at the point of use – operators are prone to hyperbolic discounting. • Specialist understanding (either on-farm or via third party) is influencing investment in new technology. • Confidence in support provision is necessary for successful adoption of technical systems.

EXECUTIVE SUMMARY

Since the first electronic milk meter was developed in 1977, milking machine technology evolved rapidly with the first prototype milking robot operational a mere 14 years later in 1992.

In the intervening 25 years, the apparent progression has been less impressive despite significant technological developments. Many dairy farms invested substantially in technological systems that were designed to improve performance, margins and welfare. Yet many of these systems have failed to fulfil their potential and remain underutilised or redundant.

As someone involved with the installation and support of many of these systems since the 2000s, their significant underutilisation was both frustrating and disappointing. Fortunately, this was not the situation across all farms, with some enjoying spectacular success in similar situations to where others had suffered failure. It became apparent that this was not an issue of progeny or reliability – there are other factors that influence the success (or failure) of systems designed for farm use.

The primary purpose of my study was to determine what factors contribute to a successful outcome of high utilisation and what factors may compromise utilisation. I hoped to identify any beneficial features that system developers ought to implement in future products and if the delivery and support mechanism should be improved. The final considerations concerned the farm environment itself and what changes may be necessary at farm level to drive better system adoption.

To correctly identify necessary improvements to the supply chain and farm operations, I researched several farms that were successfully utilising technology in the USA, Australia, Israel and the UK. My research considered poultry, dairy, swine, arable and mushroom enterprises as well as interviews with politicians, business leaders, academic researchers and farm specialists such as veterinarians. I also arranged visits with technology developers in the UK and Israel to understand their design philosophies and what farm level changes may be necessary from their perspective. I also met with extension officers in both the USA and Indonesia to understand the challenges they face in explaining innovation and techniques to farmers large and small. Finally, I spoke with specialists to understand what influence they have upon the investment decisions of their clients.

The fundamental issue concerns our conceptualisation of a “farmer.” Quite simply it is incorrect; thus it is impossible to develop a technical system that will work on all livestock farms. The success of a farm can no longer be attributed to a single intelligence; rather there are many minds at work seeking answers to very different questions. Furthermore, many system operators, unaware of the benefits of proper system operation, fall victim to “hyperbolic discounting” - opting to complete other farm chores, rather than concentrate on system operation.

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DISCLAIMER

The opinions expressed in this report are my own, based on my professional experience and upon my Nuffield Farming study tour and not necessarily those of the Nuffield Farming Scholarships Trust, or of my sponsor, or of any other sponsoring body.

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Published by The Nuffield Farming Scholarships Trust
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1. Introduction

I'm the eldest of three brothers and a sister, raised on a farm called Sychpant near Cardigan in West Wales. When I was 4, Mum and Dad chose to start milking cows – a practice now continued by my brother Marc.

Figure 1: The author, Tom Allison

Although a farmer, Dad is also a keen engineer and the farm workshop was my favourite space on the farm. I would watch enthralled as cold steel would be transformed beneath a shower of smoke and sparks into a useful farm implement. As a boy, engineering involved welders and grinders to build epic stuff that solved farming problems.

Dad is not the only "engineer" in our family; my uncle's workshop had wheels! Uncle John was (and still is) a milking machine fitter, and I jumped at any opportunity offered to spend time with him. On a hot afternoon in August 1990, we were unpacking a new milking plant which to my astonishment had no glass milk jars to measure milk weight. The jars had been superseded by small plastic vessels called electronic milk meters. This technology awoke my inner geek.

Over the following years, my perception of engineering widened; now engineers design epic technology to fix real world problems. The engineer's dream is tomorrow's reality, and I had big dreams – in which farming did not feature. As teenagers, my fellow geeks and I yearned for the day we could leave West Wales and so, in 1998, I moved to Bath to study for a master's degree in Electronic and Applied Electrical Engineering.

My teenage aspirations hadn't accounted for *hiraeth* [1] and having graduated in 2002, I returned home in 2003 to work with my uncle installing the latest generation of milking machines including Automatic Milking Systems (AMS), commonly known as milking robots.

Within a year of returning home, I realised my professional destiny would be entwined with the dairy industry. I became self-employed and began to seek out and design technologies that would improve water and power consumption on farm, as well as systems that improved animal welfare or reduced antibiotic consumption. It has been my incredible good fortune to have worked on projects throughout the UK, in Europe, the Middle East, North and South America and Australia.

Early October 2015, a fortnight before my Nuffield interview, I met Lisa at a dinner in Madison, USA. Despite her being an American, I'd fallen in love with her before Halloween, and I'm delighted to say that we married in August 2016.

[1] *Hiraeth is a Welsh word for which there is no direct translation. It's a mix of longing, homesickness and nostalgia.

2. Background to my study subject

Unfortunately, I've realised that many high-tech installations designed for livestock farmers aren't being used as envisaged by either farmer or product designer. Clearly these systems do operate as intended on some sites, and so this is an issue that transcends progeny, technical maturity and hardware reliability. Yet new innovations designed for an increasingly sceptical [livestock] industry continue to spew forth.

My study therefore sought to understand why high-tech systems designed for the livestock industry are largely underutilised and what barriers appear to prevent their successful adoption.

By "high-tech systems designed for the livestock industry" I refer to those systems that have been primarily designed to effect change in the following areas:

- Livestock housing
- Livestock performance – growth rates / daily production / fertility
- Welfare
- Product harvesting
- Genetics

However, this is not an appraisal of currently available, emerging or future technologies.

As someone whom has supplied and supported various technical systems to farmers, I wanted to:

1. Understand what (if any) prerequisites may be required by either the farmer or the technology to ensure a successful outcome
2. Understand if there are any ongoing commitments required to maintain usage
3. Understand the role of third parties in driving the use of a technical product
4. Understand if technical events contribute to improved performance.

My intention is to identify the pertinent factors before developing a protocol that will allow farmers to better utilise their investment, be it historic or planned. My hope is that my conclusions will also become useful considerations for designers of technical products or services as they develop their next generation of products.

3. My study tour

When	Where	Why
May 2016	USA Pennsylvania, Michigan, Indiana (2 weeks)	• Visit several AMS installations, including the first farm in the USA to install automatic TMR feeder • Alltech's "The One" conference • Visits to poultry and swine producers • Meetings with professors at Penn State College of Agricultural Sciences
	London	• Specific focus on funding and mentoring programmes for new tech start-ups
October 2016	USA (1 Week)	• Attend World Dairy Expo for meetings with software houses and hardware developers • Visit large scale dairy farms in Nebraska and South Dakota
	Australia (2 Weeks)	• Visit established large scale dairy • Visit rapidly expanding dairy business • Several meetings around Melbourne
November 2016	Japan (1 week)	• Visit equipment importer • Meetings with dealers and hardware suppliers • Meetings with dairy farmers • Meetings with university professors • Meetings with specialist advisors and veterinarians
	Israel (1 Week)	• Visit two innovative technology companies in dairy. • Visit with international control company • Visit several kibbutz farms to observe very successful technology installations
	Germany (2 Days)	• Visit to Eurotier to meet with European manufacturers of control systems
April 2017	Ellesmere, UK	• Visit to Fullwood, home of the only UK designed and built AMS system
May 2017	Indonesia (1 Week)	• GDF Congress • Visit to a number of small dairy farms • Visit to a large dairy farm with processing
	UK 2 Days	• Visit fellow Nuffield Farming 2016 Scholar, Richard Hinchliffe, for an alternative (non livestock) perspective on technology.

4. How are farms currently succeeding in using technology?

I had hypothesised in my Nuffield Farming application that farms which enjoyed the greatest success with technology may share some traits. Because the issue of adoption and use is not a consideration of brand, I felt it important to visit several different types of farm – dairy, poultry, swine and mushroom. So I start off my report with 4 case studies.

4a. Case Study 1: Trusting technology: Westview Farm in Peach Bottom, Pennsylvania

On May 16th 2016, I met Mr Galen Nolt of Westview Farm in Peach Bottom, Pennsylvania. In 2014, Mr Nolt and his sons Darwin and Mike updated their 180-cow unit by building a new barn with three robotic milkers, and became the first U.S. farm to install the Lely Vector automatic feeding system. The Lely Vector automatically mixes and dispenses total mixed feed rations before following a guidance system and dispensing the feed in the barn. A modern calf rearing unit on the farm also featured robotic feeders and was newly commissioned prior to my visit.

The Nolts had concluded that investing in automation was the only means of securing a dairy future for the sons. Mr Nolt reflected that the sons "*have their own families now, and are simply not willing to work as Dad did!"* To realise a 9-5 working day, they have learnt to "trust the technology" - a remarkable mindset considering they had never used a personal computer before.

During my visit, a large party of Amish farmers arrived unannounced to view the barn and observe the technology in action. Such visits have been a common occurrence since the barn was commissioned, and the Nolts are rightly proud of their facility. For the Nolts, the technology represented an opportunity to maintain the family tradition of dairy farming. However, there had been issues, particularly in the beginning, with steep learning curves and patience needed.

An early frustration was described by Mr Nolt, in which a certain feedstuff wasn't being admitted to the feeder. Despite being able to observe the machine in person and verify that the ingredient was not being loaded into the mixer, Mr Nolt was told by remote support staff that they believed the ingredient was being administered but the machine "wasn't reading it." Mr Nolt accepted there would be "teething issues" but became further irritated by software updates that would remove or add features without explanation by local support.

The automation has enabled Westview Farm to continue milk production whilst affording the sons a more "conventional" work-life balance. Consequently, there is less interaction time with livestock to provide an opportunity to observe and diagnose any [animal] health issues. To compensate for this, the robotic milkers feature milk fat and protein analysis, and sensors monitor cow rumination and activity.

From my own personal experience, the farms which have had greatest success with technology have tended to be those which have deferred all trust to the technology. The Nolts were no exception, with the first destination of the day being the computer and not the cowshed; an action echoed by other AMS herds I visited.

> *Understanding animal health is becoming a function of digital information, not a consideration of experience and empathy.*

The Nolts, like many others, are developing new skillsets alien to traditional farming - such as IT competency - to enable them to interpret the machine. Additionally, they are learning the know-how to undertake most of the maintenance themselves and address the simpler faults; effectively replicating skills of the local support team with whom they have an excellent relationship.

Excellent animal welfare and production metrics are a testament to the reliability of the technology installed at Westview farm. However, on a farm where animals are fed, monitored and milked autonomously and human activities are limited to hardware maintenance and data interpretation, is the "farmer" label still accurate or relevant?

4b. Case Study 2: Precision and specification: Pietro Mushrooms of Kennett Square, Pennsylvania

Chris Alonzo is the third-generation owner of Pietro Mushrooms of Kennett Square, Pennsylvania. The company produces 22,000,000 lbs of mushrooms every year, with half of that being produced from one state of the art facility - equal to 1% of the entire white mushrooms produced in the USA.

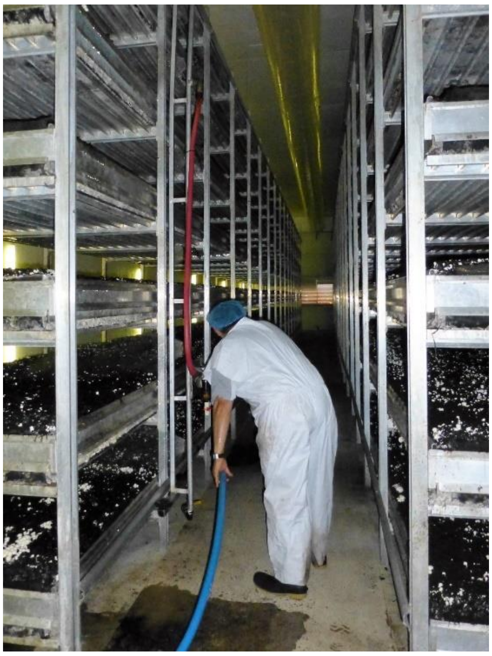

Figure 2: A worker watering mushrooms at Pietro Mushrooms, Pennsylvania

Figure 2 is of a worker watering mushrooms in one of 24 growing rooms. The worker is surrounded by growing beds, each one laden with 4.5 tons of compost. At Pietro, the growing process is an 8-week cycle – 5 weeks to prepare and 3 weeks of harvest. Mushroom harvesting is carried out by hand, the timing of which is the consequence of precise humidity, temperature and air quality control. In turn, these variables are automatically managed via a network of sensors and controllers that terminate at an enormous workstation for human observation. As mushrooms are grown to customer specification (for example mushroom size is specified to within ¼ of an inch), any miscalculation or equipment failure can affect the timing of the harvest which has severe repercussions: a delay in harvest of only a few hours will affect the sale price by 25-40%.

Challenged by hourly risks, Mr Alonzo's approach to technology is fearless; this precision in coordination is only achievable with very specialised hardware. The company employs several technicians to develop, build and maintain bespoke equipment for use in the growing rooms. Support for the more complex controls is outsourced to a local company, contractually obliged to diagnose and resolve an issue within 12 hours of notification.

Mr Alonzo studied for a BS (Bachelor of Science) degree in economics before returning home to grow mushrooms. He explained that the company has a strategy of vertical integration, and is part of two co-operatives. The first, "Laurel Valley Soils", is a special compost producer (essential in mushroom production) and the second, "Country Fresh Mushrooms", is involved in marketing, packaging and trucking. Pietro Mushrooms is therefore actively involved with the businesses that can have a direct influence on their profitability.

As a third-generation producer, Mr Alonzo's business acumen and strategy have clearly contributed to the success of this inspiring company. As the critically timed harvest is manual with repetitive work undertaken by a largely foreign workforce which has limited English, the company developed stringent operating procedures that include training. Mushroom production at this scale is a complex and skilled process; the product must hit specification during a harvesting widow of hours at the end of a 5-week process. This is only achievable with science, precise automation, logistics and [human] resource management. The success of this business is testament to Mr Alonzo's business acumen and complete confidence in the technology to perform as expected.

4c. Case Study 3. Standard operating procedures: Kreider Farms, Pennyslvania

In addition to strong Standard Operating Procedures (SOPs), Pietro Mushrooms also had clear role definitions where all workers understood their roles. Dr. Gregory Martin, a poultry extension educator with Penn State, offered me a tour of Kreider Farms near Manheim, Pennsylvania.

Kreider Farms is a third-generation family farm combining dairy and egg production. With 450 employees, they produce a range of flavoured milk and ice-cream which they distribute along with their eggs via their own logistics company.

The winners of several prestigious awards, the farm has made significant investment in technology over the past decade, including state-of-the-art egg production, renewable energy, water treatment and tourist infrastructure. A fortnight prior to my visit, they opened their "silo observation tower" (*see photo on next page*) whereby visitors could climb to a viewing platform affixed to an old silo and enjoy panoramic views of the county. With sophisticated LED lighting, the tower has already become an iconic landmark. These enterprises are included in a strong social media offering which not only encompasses both Facebook and YouTube, but also local television news.


Figure 3: Old Silo repurposed as a tourist attraction, Kreider Farms, Pennsylvania

Our visit began at the dairy facility, where Dr Martin highlighted custom built controllers for managing milk cooling.

We met the general manager for the dairy who outlined the dairy SOPs. Policies had been developed to encompass all critical aspects of herd management and responsibility for certain tasks vital to herd performance to be covered by a dedicated employee such as Reproduction Manager.

At Kreider Farm, Mike, the reproduction manager, had executive responsibility for all breeding decisions – including performance targets, technology adoption and breeding programs. Technology featured very heavily in the dairy, and both managers I interviewed described the business as “early technology adopters.” A hallmark of almost every dairy farm I’ve visited is that the brand of utilised technology is seldom universal. I.e. the farm uses several different technologies from different manufacturers to achieve its objectives.

As with the Nolts at Westview Farm, they had experienced “teething issues” with hardware reliability but had also found challenges in synchronising information between platforms; for which new SOPs were developed. In addition to the dairy unit, Kreider Farms manage 5 million laying hens, supported by an on-line computer system that guarantees eggs are packed on the day laid.

The business had recently commissioned a new egg washing and packing facility capable of processing 2.2 million eggs per day at the main Kreider site. For both Kreider staff and Dr Martin, technology must not only improve food source, but also prove (the) food source.

4d. Case Study 4. Innovative technology: Whiteshire Hamroc, Indiana

A family business for over 100 years, Whiteshire Hamroc were primarily pig farmers in Indiana, with interests in crop production and retail pork. But brothers Charlie and Mike Lemmon grew frustrated by the performance of commercially available ventilation and heating systems for their swine-barns, and established their own company, Airworks, in the 1980s to address these perceived issues.

The original challenge was to capture heat lost from the nursery in the stale air that was being replaced with fresh air. As there is a correlation between comfort and performance, the fresh air required heating, so the availability of fresh air was a consideration of energy costs vs [stale] air quality. Charlie and Mike (a registered veterinarian) began to develop products that improved pig comfort, the most significant invention being a patented Vertical Ventilation design for swine barns. (http://www.whiteshirehamroc.com/airworks.html). By addressing these issues of energy and air quality, their system could provide abundant warm, fresh air uniformly to all animals in the nursery: improving animal welfare and reducing energy consumption.

Because the innovation created a uniform environment across the nursery, it allowed Whiteshire Hamroc to identify genetically superior animals for breeding and sale. The company is now at the forefront of global swine-genetics with industry-leading purebred lines. Furthermore, the system enables them to raise a special group of pigs which produce tissue under stringent conditions for use in human medicine and research. Using the AirWorks system enables higher stocking densities and improved operational efficiencies with energy consumption, labour and maintenance costs of 5-15% lower than conventional systems. The company also claims their systems generate an average of 7-15 days faster growth with less mortality and sickness – in turn reducing the need for antibiotic therapies. Little wonder that AirWorks is now a successful company.

Whiteshire Hamroc have continued to innovate and have developed concepts for pig manure processing that vary from conventional to radical. During a conversation with company president, Rebecca Schroeder, several challenges were highlighted – concerning the utilisation of technology and development of new tech. She also observed that specialists such as farm veterinarians are considered the biggest challenge as many are unwilling to consider alternative models.

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4e. Summary of these visits: the secret formula on farm

Complex, technological systems were responsible for undertaking core processes at these businesses, yet the farmers all trusted the technology to function as intended. Why?

- Be it family legacy, genetic reputation, product innovation or product consistency, these businesses had clearly defined visions for the future and their application of technology was aligned with this strategy.
- Every business had developed clear, specific operating procedures to ensure that the technology worked for them and that they did not work for the technology.
- All workers achieved a minimum level of competency for operation.
- The technical literacy was sufficient for the undertaking of basic repair.
- Stringent service and repair contracts with suppliers of mission-critical hardware had been agreed.
- Management had great market insight.
- The farm technology was used to provide additional reassurances on quality and care to the market.

5. The challenges to successful technology deployment on farm

In their application and trust of technology the farmers (described in the previous chapter) were exceptional. My own personal experience has shown that most livestock farmers seem unable, unwilling, or both, to surrender trust to the technology.

To understand more about technology used on livestock farms and failure vectors, we can consider two extreme scenarios:

- The first scenario assumes flawless technology performance
- The second considers the requirements for flawless operation.

5a. Scenario 1. Reliable technology, unreliable operatives

An animal's response to stimulus will be unique and will vary with time and environmental changes. Hence, animals may be described as Complex, Individual, Time Variant and Dynamic (CITD) systems: an idea that forms the cornerstone of modern Precision Livestock Farming (PLF). Thus, modern livestock technologies do not consider an animal as an average of a population, they adapt to the time-variable responses of an animal.

What is Precision Livestock Farming?

PLF technologies enable the farmer to provide individual care for each animal. This is accomplished by integrating (combining) a measured bio response together with a predictive process to create a control algorithm or monitoring system. Continuous measurements are key to the success of PLF systems.

Because PLF systems function by generating a "model" of the process, their accuracy and eventual success depend upon:

1. Quality and timing of initial information offered - such as date of birth, calving date and time.
2. Continuous, quality measurements of the bio response – sensor data.

However, all living organisms are CITD systems, including farmers and engineers. Just as an animal's response will be a function of environment, stimulus and time, so too will be the response of farmers and farm workers. In a world of perfect technology, failure is the consequence of imperfect operation.

Howard Straub III is the Dairy Manager at the W. K. Kellogg Biological Station, Pasture Dairy Center (part of Michigan State University). Mr Straub is responsible for managing the 150-cow grazing herd, milked on an Automatic Milking System (AMS). Resulting from his experience with using AMS equipment, he also visits farms to facilitate with "robot start-ups" and provides advice to AMS users.

He says:

> ***The least successful [technology] deployments occur in situations where nobody takes ownership of the system; perhaps fearful that the technology will replace them.* - Howard Straub III**

On a livestock farm, taking ownership of a technical system requires a willingness to learn the proper operating procedure and regular interrogation of the system. The reality on most small livestock farms I've visited professionally and for my Nuffield Farming study is that very few farm workers are motivated to "take ownership" of the technology. Furthermore, many of these farmers will prefer to delegate operation to spouses or even children.

> *The reality on most small livestock farms I've visited … is that very few farm workers are motivated to "take ownership" of the technology.*

When farmer owners fail to share their plans with employees, suspicions are aroused. The parochial politics of the "farming family" manifests on farm as a "them and us" culture. These attitudes become amplified across the industry, creating a barrier few outside the farming community can penetrate – indiscriminately frustrating new entrants, repelling new ideas and eroding consumer trust. To encourage universal ownership, farmers should consult with all farm staff (including family) during the researching and implementation of any technological systems. Conversely proponents of technology into the livestock sectors should develop strategies to better engage with personnel who may fear for their livelihoods; and strategies that improve intra-farm communication.

Without clear standard operating procedures, the routines of (smaller) livestock farms can be easily disrupted. Variables such as inclement weather, harvesting considerations, sick animals etc will force personnel to prioritise – ensuring tasks which directly impact upon animal welfare are completed first. The importance of soft tasks (advised for optimal operation of technical systems) are easily under-estimated particularly by personnel who have not engaged with the technology. These tasks, with no obvious, immediate benefit are easily deferred to "a later time."

These micro decisions pose the greatest threat to the viability of technology on livestock farms as management is the consequence of decisions: thus, the management of the technology is radically altered from proper use. There are three fundamental issues here:

- First, many farmers I have spoken with on this issue do not perceive the time spent on data entry as being important.
- Second, many algorithms used in PLF technologies require accurate initial data for optimal performance: information that may not be readily available. In this situation, the farmer will either defer the process to a later time or populate the system with "educated guesses".
- Third, the accuracy of PLF technologies also depends upon quality measurements – usually from electronic sensors which must be precisely deployed. Wireless sensors (such as those

affixed to livestock) will also be stamped with a unique identification. On a livestock farm, these sensors are expensive and usually reused; however, the physical demands of the environment in which they operate can frustrate redeployment:

1. The sensor ID can become difficult to read.
2. The attachment system used to fit the sensor to the animal can become compromised – resulting in difficult attachment and position adjustment.

Convinced that sensor deployment will take precious time, the farmer may either defer the activity to a later date or, challenged for time, misapply the sensor. Because of issues like these, the operator has inadvertently developed a strategy that reduces the efficacy of their system: further compromising the system's perceived value. When we prioritise tasks, we are essentially sorting them by their perceived importance and value. On farm, a task "*essential to the correct function of a technical system*" will be evaluated and compared to several other farm tasks. However, calculating the benefits of "*using the system properly*" is cognitively complex, and so the alternative task is often chosen.

Selecting smaller, immediate rewards rather than larger, later ones is a cognitive bias (mental shortcut) known by economists and psychologists as **hyperbolic discounting**. But this is not exclusively a livestock technology issue.

At the W K Kellogg Biological Station, Mr Straub had identified issues with manual plate metering – a device used to monitor grass growth. Walking around each paddock with a plate meter is a time consuming and laborious process. In inclement weather, the temptation was to compromise on number of readings made and the area covered; furthermore, to achieve consistent plate meter readings, the operator should stop walking and action the instrument vertically. For accurate measurement "*the key is to make the process easy*."

Their solution was to buy a C-Dax pasture meter, designed to be pulled behind an ATV as shown in the picture on next page. It was also realised that the operator would have to dismount and remount the ATV twice to enter a paddock and again to exit it - a total of 192 dismount/mount routines would be required to measure the entire grazing platform. To address this, they designed and built a cage onto the ATV (also shown in the photograph) allowing the operator to drive directly "through" adapted fences between the paddocks.

The approach taken at the centre was to correctly identify all on-farm challenges: the requirement for a better measuring device as well as improved farm processes. They then developed a strategy that maximised the chance of success as opposed to trying to manage the system.

See photo on next page

Figure 4: Modifications made to an ATV to facilitate grass observation, at the W K Kellogg Biological Station, Pasture Dairy Center

5b. Scenario 2. Reliable operators, unreliable technology

In our second scenario, we must first consider that the users of the hardware are fully competent, and an array of SOPs are followed. The following is a short consideration of some of the technologies typically used on farms:

- Mobile phone
- Farm robots, including an AMS system, robotic feeders and manure scraper
- Traditional "desktop" computer
- Barn automation
- Animal sensors / PLF hardware
- Weather forecasting website / app
- Social Media website / app
- Superfast internet connection
- CCTV system

Should any of these technologies fail suddenly and catastrophically, the issue is apparent and appropriate action can be taken. When possible, the farmer has worked with his hardware providers to develop contingency plans that are enacted when mission-critical hardware fails. For example, staff have received training and can accomplish simple AMS diagnosis themselves. For more complex issues they are unable to resolve, a service contract has been agreed with the local hardware supplier.

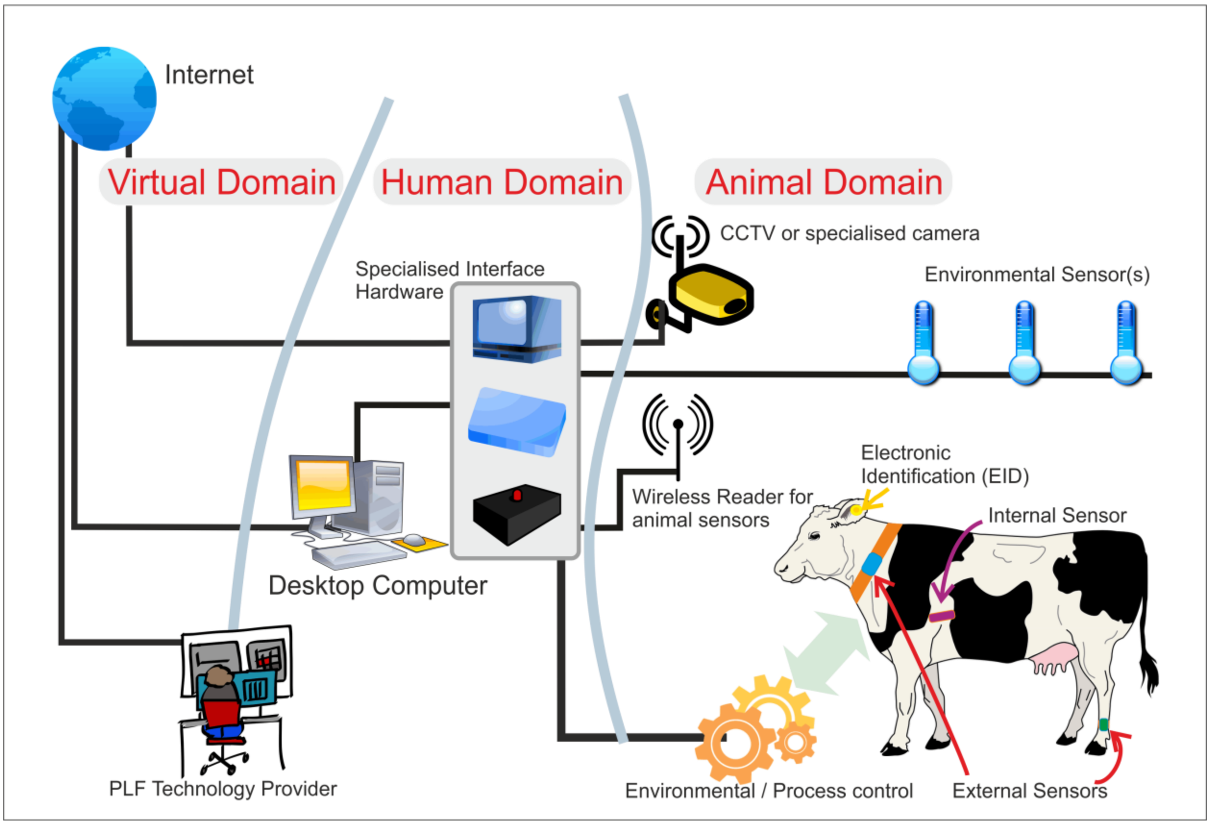

Figure 5: How technology is used across three domains. (Diagram by the author)

Assuming perfect operation helps us to understand how vulnerable such systems are to component failure. Consider figure 5, showing how a typical PLF system is constructed over three domains:

- Virtual domain
- Animal domain
- Human domain

5b.i. Virtual domain considerations

A relatively new frontier, the virtual domain, I believe provides unparalleled opportunities to all farmers. Just as the printing press advanced science, the internet platform allows for the sharing and dissemination of new ideas in a flash. Social media platforms enable us to establish digital identities that we can use to instantly share our experiences, emotions and opinions with anyone, anywhere. The ability to engage directly with the consumer is a fantastic opportunity for mutual understanding and insight. So, the virtual domain can be likened to a universal gateway between consumer, producer, processor, retailer, equipment manufacturer and all other parties. It will become the driver for future farm innovation.

As my topic concerns the adoption and operation of technology on farms, I have deliberately restricted my considerations to focus solely on matters pertinent to technical (system) function. As precision livestock systems evolve, both developers and farmers can benefit through adoption of cloud techniques. By uploading data to their cloud systems, manufacturers can:

- Refine their algorithms and develop new ones before deploying in the field.
- Identify potential hardware problems and develop a remedial strategy before catastrophic failures occur.
- Identify operational deficiencies and provide guidance to the customer
- Offer a back-up facility for farm data
- Provide real-time support

The benefits to customers are derivatives of these innovations – for example continuous data backup is incredibly useful in the event of on-farm hardware failure. It was the processing of aggregated farm data that made many of the cutting-edge discoveries that I witnessed during my travels possible. Individual farm datasets are of very little value for development purposes – however that is not to say they are not without value.

The main threat to the viability of agriculturally-focused cloud services will not originate on farm but from the developers and legislators. Any perceived threat to privacy or an abuse of trust is likely to galvanise farmers into abandoning that platform. A secure and reliable internet connection is essential for any cloud service to operate effectively. Rural geography and sparse populations deter competitive deployment of fast internet in the countryside: this is the reality observed in the UK, USA, Australia and Japan. Alternative technologies such as mobile or satellite internet are not without issue and are not universally available.

The migration towards cloud applications in general is fundamentally changing software development and support. Previously, stand-alone computer programmes (software) were developed to be compatible with a given computer operating system. The operating system was designed for stability; thus, the software should run indefinitely providing its host operating system does. As the operating system matured to capitalise on changes in internet and computer technology, software developers were encouraged to deploy regular updates to ensure compatibility.

To ensure user satisfaction and security, this trend of deploying frequent, small updates has continued onto cloud applications. For example, in the year leading up to November 2014, the Amazon Apollo deployment service (http://www.allthingsdistributed.com/2014/11/apollo-amazon-deployment-engine.html) "*was used for 50M deployments to development, testing, and production hosts. That's an average of more than one deployment each second*." As consumers become accustomed to this pace of new feature implementation and security updates in their favourite applications, the old software development approach fails.

Typically, the development pace of software to accompany equipment such as milking machines was dictated by the rate of hardware development. This will no longer be the case in future. As cloud platforms mature, there will be an acceleration in understanding. Deployment of novel algorithms will lead to the replacement of old management standards providing competitive advantages to those farmers engaged with the system. To survive, manufacturers must be prepared to develop and deploy software updates at a pace not determined by them, but by the market and research.

5b.ii. Animal domain considerations

This is the realm of the livestock and technology designed to:

1. Observe and measure bio-responses
2. Manipulate the livestock environment

Monitoring technology is designed to function and operate in the environment under consideration. For example, in a laboratory- or factory-based process, the sensors are subject to a consistent environment for which adequate protection can be designed. The more variable the environment, the greater the challenge to protect the hardware without sacrificing performance. In PLF (Precision Livestock Farming) systems, most monitoring technology is situated in the animal domain which is a highly variable environment. Commercial equipment destined for use in the animal environment must:

1. Be positioned to be free from mechanical interference (by animals or farm machinery)
2. Function with exposure to:
    a. Livestock
    b. Moisture
    c. Temperature fluctuations
    d. Dust
    e. Manure
    f. Poor air quality (including corrosive gases)
    g. Variable power quality
    h. Aggressive cleaning agents (for example in a milking parlour)

Additionally, equipment designed to be fitted onto livestock must also be robust enough to withstand violent blows, yet yield (break off) should animal welfare become an issue. And hardware designed for use inside the animal (for example a bolus) must comply with stringent regulations pertaining to food safety. Finally, any equipment mounted on livestock will require a power source and wireless communication with sufficient power to communicate with the supporting ecosystem.

Irrespective of the quality of hardware design, every component positioned in the livestock realm is susceptible to contamination or mechanical force. Technical processes such as wireless communication are also vulnerable to interference or may even be affected by animal location. Left unchecked, the cumulative effects of these environmental challenges will eventually overwhelm hardware, leading to component failure; a scenario that many systems have evolved to detect. However, in these situations, there is a prolonged transition from correct component function to failure, ergo data integrity may be compromised before the component is deemed to have failed. Because PLF (Precision Livestock Farming) systems fundamentally rely on continuous accurate measurements, the gradual erosion of data integrity is a critical problem.

Signal-processing techniques, including machine learning, may provide a mechanism to alert operators of issues; however, this is a virtual manifestation born of the physical world, and it is here (in the animal domain) that solutions must eventually be implemented.

To prevent issues, farmers using PLF systems should implement maintenance plans in the animal domain. These should include monitoring sensor positions on livestock and adjustment; and monitoring and maintenance of associated hardware deployed in the livestock environment.

5b.iii. Human domain considerations

The human domain is where all logistical endeavours and operational activities converge, and the greatest threats to PLF systems originate here.

Having now measured the bio-response with sensors, the data is collected (via readers in the animal domain) for further processing by technology situated in the human domain and/or "cloud" services. The human domain exposes hardware to less environmental and physical challenges (than the animal domain) although some risks are shared - such as electric quality.

Functionally, the human domain is where software or web applications are used to populate the PLF system with essential data required for operation, and actionable information is presented to the user. This is also how PLF technologies implement managerial objectives, themselves a consideration of:

- Legislative obligations
- Farm strategy
- Consumer demands
- Environmental sensitivities

Legislative requirements relating to what information is held per animal on farm varies from country to country (and state to state). Furthermore, official (governmental) agencies may demand that certain information be shared with them. Reconciling these two requirements to satisfy legislation in all their operational territories is a demand on resources most developers of PLF technology are unwilling to commit.

Livestock farmers subject to legislation will achieve compliance via either a legislative portal (e g government website), paper documentation or farm management software. Farm management software is not a precision farming technology: the former features a hardware element, the latter does not; nonetheless, demands upon the farmer's time exposes farm management systems to similar risks of inaccurate, poorly timed data entry.

For example, PLF systems require accurate data relevant to the system if they are to work well. For example, a dairy system may require animal identification number, breed, birth date, sex, service date, calving date and a sensor identification number.

> ***A comment:***
>
> *Sensors affixed to livestock have been designed to work at specific body locations. To achieve this, a snug fitment is preferable with some consideration given to animal growth (e.g. not too tight). But an animal may also lose condition as a function of health status, feeding policy etc. Hence a properly positioned sensor may become slack and fail to operate optimally despite the hardware function being okay.*

For farms without herd management software, this information (if recorded) will likely be distributed across several different event diaries which will require collation before being entered onto the PLF system. For farms using a management programme, all legislative information will be available but other information which is subject to voluntary submission (for example service date) may not be, for reasons previously discussed.

To avoid "doubling up" on data entry, most farm management software can electronically link with established PLF system manufacturers. Users will select one dominant system for data entry which will synchronise (either manually or automatically) with the subordinate application – usually the PLF system.

Case Study: Kurtland Farms

Kurtland Farms is a third-generation dairy farm in Berks County, Pennsylvania and is owned by Tim and Deborah Kurtz. In March 2012, they moved into their new 220 cow free-stall barn with 4 AMS machines, automated manure handling and treatment and ventilation.

Tim described himself as a competent and experienced PC user, having first started to use computers for business purposes in the 1980s with "MS-DOS" operating system. Since then, they have always used electronic records on farm, and Tim has installed his own CCTV system as well as learning to fix internet issues.

To run his operation, Tim uses 4 different primary software systems: 2 on his PC and another 2 on his phone. All data entry is either performed on PC-Dart software on the office computer or on the PC-Dart mobile phone app "Pocket Diary". The PC-Dart system then synchronises with the AMS software.

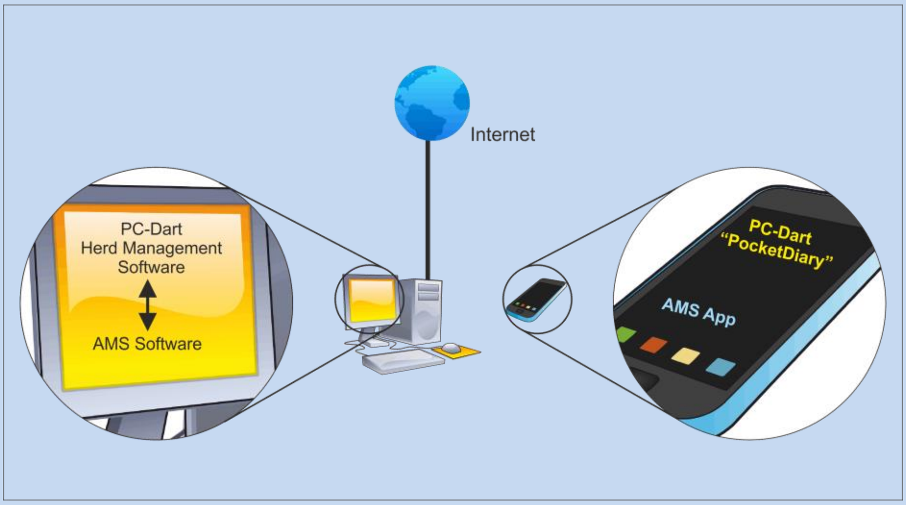

Figure 4: Coping with multiple technologies at Kurtland Farms, Pennsylvania

Tim observed that support from PC-Dart was better than that offered by the AMS providers; and support was an important consideration for them. Like other farmers invested in farm technology, the Kurtzes had learnt to undertake much of the essential maintenance themselves and manage some breakdowns.

To clarify the above argument, a brief summary of the detailed points made in Scenario 1 (sub chapter 5a) and Scenario 2 (Sub chapters 5b and 5b.i-iii) is given overleaf.

5e. Summary of the two "thought experiments" outlined in 5a and 5b above

1. The first (thought experiment) is to assume perfect technology, so all failures are down to human behaviours on farm. This forces us to conclude that:
    a. Poorly developed SOPs are an issue.
    b. Tech is not always understood or embraced by all stakeholders: therefore its operation will be compromised.

2. The second (thought experiment) is to assume perfect on-farm operation, so all failures are down to:
    a. Vulnerability to failures in other technologies (internet etc).
    b. Hardware deployment/vulnerability in animal environment.
    c. Poor design: i.e. a lack of insight from the designer on how the technology will be used or the challenges (both practical and legislative) that face the operator.

The success of (a new) technology deployed on a livestock farm is not assured by mere hardware reliability alone. Those wishing to implement novel systems must engage with all stakeholders, including farm staff who may feel undermined or threatened by the introduction of new technology. Manufacturers must develop their platforms to accommodate evolving legislative and consumer demands, and develop strategies to overcome challenges imposed by geography and the rural workforce:

- Internet reliability
- Limitations and availability of deployment/support workforce
- Limitations of operational workforce
- Environmental sensitivities

Such challenges are not unique to agriculture: indeed, their resolution may come from greater collaboration between rural businesses.

6. Managing for different purposes

Prior to the advent of PLF systems, farmers identified two separate needs: to manage farm livestock for legislative purposes on the one hand, and a need to manage livestock for practical purposes on the other.

Distinguishing between these needs helps us understand the current situation - as one demand could be satisfied with paper (and software) but the other required hardware development. Two distinct types of solution providers emerged: software houses and equipment manufacturers. Software houses traditionally operated on a national level, developing solutions that helped with farm management and compliance. Processes such as development, testing, sales, deployment and support were all performed "in house."

Equipment manufacturers operated internationally, developing hardware to improve livestock-orientated tasks. Development and testing were carried out "in-house" but processes such as hardware installation, maintenance and fault resolution would be offered locally by dealers or franchisees. The dealer network developed complementary skillsets to support hardware. As equipment sophistication increased, the development of an associated software component became necessary – requiring new installation and support competencies, alien to most of the incumbent agents.

The industry has evolved with manufacturers able to provide structured training to technicians; however, these personnel are seldom specialists in both hardware and software; consequently, their ability to provide effective cross-platform support is limited. This contrasts with software (houses') support staff whose sole focus is software – here customer support is perceived to be better. Ambitious equipment dealerships will have developed a strategy to provide adequate support for both hardware and software – with the business loyal to one or two brands. The exodus of youngsters from the countryside - who mostly have inherently greater facility with digital developments - is not only a challenge to farm business, but to all business with rural interests. This has implications for how technology is both installed and supported on farm.

Deploying and supporting hardware in a livestock environment presents a unique set of challenges: working conditions can be tough, dirty and dangerous. Tools and equipment used during the installation will usually require thorough cleaning and few people are prepared to undertake the work. Incumbent hardware manufacturers can utilise their existing, loyal network of dealers or franchisees to deploy new innovations. For non-traditional manufacturers, access to a competent network of installers is a significant challenge that hinders the introduction of their innovation onto livestock farms. This has forced them to consider novel installation mechanisms, collaborating with other firms with on-farm interests such as veterinary practices, genetic, and feed firms. Such collaborations are leading to a paradigm shift in not only in how technology is installed on a farm but also on how it is used and supported.

Veterinarians, semen companies and feed firms are capitalising upon the potential of technology. Hasegai Dairy Farm is situated in the Hyōgo Prefecture of Japan's main island Honshu. The farm is run by Mr Imanaka Katsunori, whom has farmed since Heisei 11 (2000). In Heisei 22 (2011) the business embarked on an ambitious expansion project by:

- Constructing an American-style free-stall barn for the dairy herd.
- Installing Asia's largest rotary herringbone milking parlour, complete with Auto-ID (commissioned 2012).
- Construction of compost processing and storage facility.

Farm labour is undertaken by a team of 4 Japanese, 4 Philippine workers and Mr Katsunori himself. The herd consists of 500 animals with 420-430 milking at any moment in time. Calves are reared in the (on-farm) calf facility for 6 months before being moved to Hokkaido for further rearing. They will remain in Hokkaido until 2 months before calving. Mr Katsunori travels extensively to both the USA and Europe to research equipment and the latest farming trends. He is very keen to adopt new technologies and systems; unfortunately, this philosophy has not always served him well with several redundant systems about the farm.

Figure 6: Mr Imanaka Katsunori with me beside one of his rice paddies, Haegai Dairy Farm, Hyōgo Prefecture, Japan

In addition to the milking system, a separate collar-based oestrus detection (activity monitoring) system was used for effective reproductive performance. Mr Katsunori explained how the data entry routine used to be a three-step process:

1. Animal information would be entered onto the milking system.
2. Animal information would be entered onto the activity monitoring system.
3. The official government system would be updated.

To simplify this process, a farm management programme was installed for data entry. This programme would then synchronise with both milking and activity monitoring systems. However, the management programme was deemed unnecessarily complex and expensive with software support being provided by one person for the entirety of Japan; it was subsequently decommissioned. The software that accompanied the milking system was described as "strange and difficult to use" with a decision made to disable most of the offered features - only basic identification and milk yield recording features remained in operation. The technological bloodletting did not end there – as the activity monitoring system aged and collars failed, they were not replaced with new and this system too was finally removed.

At Hasegai, the technologies *per se* didn't fail; however, their perceived benefit to the business was considered less than the cost of operation. A confluence of cultural and support considerations compromised system usability to a point where the product was deemed worthless. The arrangement of the supply chain severed any possible farmer-manufacturer communication; the deployed technology was predestined to fail and trust in the manufacturers irreparably eroded.

Veterinarian Dr Hiromichi Ashizawa is a trusted partner with significant influence at Hasegai dairy farm. At the farm, Dr Ashizawa provides an advisory service to Mr Katsunori concerning:

1. Calf rearing
2. TMR formulation
3. Herd fertility and performance

Dr Hiromichi Ashizawa is a veterinarian and esteemed nutritionist and his services are sought all over Japan. He explained that Mr Katsunori (the farmer) would email his office every week to submit a reproduction report and a file containing milk production data from the milking machine software. This information would then be loaded into an American software package, licensed to Dr Ashizawa for analysis and reporting. His other clients similarly submit farm records to his office via email or facsimile machine. Sufficient data was submitted (daily) by facsimile to keep two people in permanent employment as data transcribers. The free stall barn built during the expansion project did not perform as well as hoped, with inadequate ventilation being identified as the underlying issue. Several different ventilation systems for the barn were considered; however, the design proposed by Dr Ashizawa was chosen and implemented, despite being more expensive than the alternatives. With access to herd performance data, Dr Ashizawa has a proxy for the effectiveness of the new barn ventilation – and will advise the farmer, Mr Katsunori accordingly.

Figure 7: Dr Ashizawa at Hasegai Dairy Farm, Hyōgo Prefecture, Japan.

Because Dr Ashizawa is moving toward a "preventative" veterinary service, he has pushed the boundary of his influence to cover the barn environment. During farm visits, he can discuss any concerns with Mr Katsunori, advise on corrective action and propose how to evaluate the efficacy of the correction. Support from the equipment supplier may still be necessary; however, Dr Ashizawa is effectively intervening before minor issues become failures.

For Dr Ashizawa to fulfil his objective of preventa-tive medicine effectively, both the equipment supplier and Mr Katsunori surrender certain responsibilities to him; fundamentally changing the relationship between farmer and equipment vendors.

Historically, equipment suppliers enjoyed a simple transactional relationship with farmers and customer loyalty was simply a function of price and service. By adopting symbiotic strategies with both hardware providers and farmers, independent specialists such as veterinarians and nutritionists are fundamentally disrupting traditional mechanisms for the deployment and support of innovative technology on farm.

From the farmer's perspective, a competent professional analyses the data and provides them with actionable information. From the manufacturer's perspective, their system is being better utilised with professional feedback offered for product improvement. However, is this utopic state sustainable or even desirable?

On farm, the provision of actionable information trumps technological features. Manufacturers whose systems require supplementary interpretation or support risk customer loyalty. Specialist advisors are judged on results and may therefore be motivated to make the technology work; however, they may also be aligned with competitors. In either situation, specialists like Dr Ashizawa are directly influencing the farmer's spending choices, therefore challenging the manufacturer's concept of a customer as a single entity.

Marketing theory defines a customer as someone who purchases and pays for a product or service, whilst a consumer is the ultimate user. It is not necessary that the consumer should purchase the product or service.

To understand why specialists such as veterinarians and nutritionists are designated as customers and not consumers, it is necessary to consider the nature of the consumer and the specialist-farmer relationship.

6a. Customer or consumer?

In my introduction chapter, I mentioned the unboxing of a new milking parlour many years ago which featured electronic milk meters, not the traditional glass jars I was expecting. Those milk meters were made by Afimilk, an Israeli company which developed the world's first electronic milk meter in 1977.

Afimilk's Research and Development department now employs over 65 people and boasts a diverse range of skills including theoretical chemists, biologists, food technologists, veterinarians and many other disciplines. The company focuses on delivering innovative solutions and technologies for dairy farms including animal sensors and milking equipment (although they do not produce a complete milking parlour).

> *"Milk is second only to oil in the number of derivatives that can be obtained from it," says Gil Katz, fundamental Research Group Leader at Afimilk*

One of Afimilks' most recent innovations is the "AfiLab" milk analyser – an in-line, milk component analyser which measures fat, protein and lactose concentration in real time. This sensor enabled Afimilk to study how milk quality changes during a milking cycle, specifically coagulation properties - an important proxy for cheese yield. Dr Gil Katz explained how Afimilk researchers realised "*that milk coagulation properties could be used for online sensing and separation of milk according to the manufacturer need*."

From this, Afimilk developed a system that channels milk into one of two milk lines per its coagulation potential. On farm, there would be 2 milk silos, one containing "regular milk" destined for drinking, and the other containing "coagulating milk" destined for cheese production. Classifying milk at the dairy farm in this manner increases the cheese yields by up to 15% with further efficiencies gained in logistics and plant operations (cleaning etc).

The system is supported by the "Afimilk MCS Operation and Management service" – a cloud-based service where milk buyers specify the desired milk traits for optimal cheese yield and quality. These specifications are then broadcast directly to Afimilk hardware for automatic configuration on participating farms. In Israel, Afimilk hardware automatically classifies over 100,000,000 litres per annum without farmer intervention.

It should be noted that the Afilab benefits extend beyond that of improved (milk buyer) margins. By analysing milk constituents on an individual or group basis, the system can alert the farmer to nutritional deficiencies, metabolic diseases or other health issues. However, these benefits are contingent on farm staff skillset (correct operation and timely data entry).

Afimilks's ingenious platform appeals directly to the consumer (milk buyer) even though the farmer is the customer. On-farm challenges, such as technical competence, or lack of time for hardware configuration, are essentially circumnavigated by the Afimilk MCS system. With direct influence over an on-farm process, the consumer is reassured of an optimised product.

For any business, success is a function of how well the product satisfies consumer demand. Companies developing technology for livestock farms should therefore consider how their offering helps their customers satisfy consumer expectations.

6a.i. Summary of "Customer or consumer"

At Hasegai Farm, Mr Katsunori had invested considerably in new milking, monitoring and management systems, which stood largely redundant at the time of my visit. Why?

- The hardware vendors had failed to develop adequate local support.
- Therefore the necessary protocols were not developed in the workforce to ensure correct system function (to the benefit of the farm).
- Poor local support obscured issues from the manufacturer, thus frustrating potential remedial action.

The introduction of new technology at Hasegai essentially created a skills vacuum in the farm workforce which was filled by an independent specialist (Dr Ashizawa). New technology often challenges conventional farming concepts, and this requires a change in farm management.

Therefore, if management change is necessary for proper technological operation, the manufacturers must develop strategies that develop on farm skills. Failure to implement rigorous farm training and support risks both product function and vendor reputation whilst creating opportunities for specialists. Both Dr Ashizawa's involvement at Hasegai and Afimilk's "AfiLab" are solutions that shift management focus off-farm - suggesting that modern farming decisions can be distributed.

6b. Specialist-farmer:specialist-technology relationship

Veterinarians, nutritionists, agronomists and other specialists are synonymous with modern livestock farming. Specialist advisors on-farm are considering data from sensor systems and management software with increased frequency. Whereby these systems were originally treated with suspicion, many specialists are now adept at interrogating on-farm systems as part of their service to the farmer. Furthermore, as specialists become exposed to a variety of different systems, their opinions become recommendations that directly influence the farmer's spending.

"The Angle" is the main dairy base of Moxey Farms, Gooloogong, and is Australia's largest single-site dairy. In 2015, the business was acquired for $100m AUD by the Sino-Australian milk processing and farming consortium.

In October 2016, Janet Moxey, her children Quentin, Gill and Rose and their spouses were operating the farming business which employed 150 people. The company had recently expanded to 5,500 milking cows - completing the first phase of an ambitious expansion programme which required the construction of a new milking, education and training centre and 2 large climate-managed barns. As general manager, Quentin Moxey has been instrumental in the company's growth and future strategy. However, his siblings play equally important roles in the business. Rose is a practising veterinary surgeon whilst Gill manages accounting and IT, and Gill's husband, Andy Smith, is responsible for procurement. The scale of operations at The Angle enables the business to:

1. Exclusively employ specialists.
2. Better negotiate with suppliers, often commissioning bespoke solutions as deficiencies in readily available systems are identified.

At the farm, all decisions pertaining to the herd were Rose's responsibility and evidence of her veterinary expertise was apparent throughout the farm, especially in the following areas:

- Milking technology
- Animal identification
- Breeding decisions
- Herd management
- Welfare and medicine (Including udder health, locomotion, condition and fertility)

6c. Expert influence

To accommodate the expanding herd numbers at The Angle, the Moxeys have built the first "Tunnel Ventilated" dairy barns in Australia and a state-of-the-art milking centre, comprising an 80-point rotary milking platform with automatic animal identification and separation.

Conventionally when buying a new milking parlour, dairy farmers will first consider the merits of the incumbent dealer and their product offering. They are then encouraged (by salespeople) to visit several installations showcasing the technology on offer before undertaking a more detailed dialogue on specification and price – usually with 2 manufacturers.

During extensive travels, Quentin, Rose and Gill had evaluated what they considered to be the best and worst dairy equipment on the market. They had concluded that there were weaknesses in every manufacturer's portfolio - for example "Brand A" has an excellent parlour but poor separation gate whilst "Brand B" only had a decent separation gate.

In any milking machine, the fixtures that are in contact with the cow for milk removal are known as milking liners (or inflations). The liner is supported by a shell and is attached to a claw piece – the final assembly (of 4 liners, 4 shells and a claw) is known as a "milking cluster". Despite appearances, cluster assemblies are the product of significant research and resources, with most manufacturers offering a range of clusters. Regardless of the milking machine complexity, poor cluster design, use or selection can have a severe and detrimental effect on herd health.

With expert knowledge of animal physiology, Rose could identify issues with "showcase installations" that would not be apparent to or considered by a "conventional" farmer.

Having decided upon the main "brand" of milking machine, Rose was concerned by the efficacy of their cluster and so the Moxeys decided to use a rival brand of liners and shells. However, these were not the only system components exchanged for those of rival manufacturers. Systems installed at The Angle for cow drafting, milk processing, water management and ventilation systems had all been spliced with non-OEM (Original Equipment Manufacturer) hardware for improved function as defined by the Moxey family.

Because of both internal expertise and scale, the Moxeys have been able to successfully encourage rival manufacturers to cooperate. The net result is that the new milking centre is an amalgam of many brands. All major functions were considered and the best solution chosen - even if the integration of products from rival manufacturers was required. Clearly, as consequence of being a key person within management, Rose's expertise directly influences the expenditure decisions taken by the company. Concerning technology at the Angle, the specialist not only specifies the hardware, she also manages it and is the customer.

It is important to understand that scale is not a prerequisite for the leveraging of expertise.

It is important to understand that scale is not a prerequisite for the leveraging of expertise. Scale can be leveraged during economic negotiations and may assist with procurement. As a very large "farming operation" the Moxeys operate Australia's largest farm-milk collection tanker which is custom built.

(See photo at foot of page). However, as a business, their scale is not yet sufficient to allow them to implement bespoke accounting software. Scale is relative, expertise is not.

6d. Schrödinger's customer (*see Appendix*)

What Dr Ashizawa (veterinarian in Japan – see Chapter 6) and Rose demonstrate are two different approaches to the procurement of expertise on farm. The first method is to consult with external specialists such as nutritionists or veterinarians who are increasingly adept at interrogating on-farm technology. The second approach is to acquire on-farm expertise – either through direct employment or "fact-finding expeditions" to learn and understand new concepts.

In either situation, understanding that different skill sets are required to realise the full benefit of these systems suggests a user dichotomy between farmers and specialists.

> *There are two fundamentally different users, an "operator" and a "specialist".*

How the farmer – as a technical novice - and specialist interact with technological systems will be different, ergo different approaches are required for user engagement. In instances where the farmer has acquired the necessary expertise, they are effectively wearing two caps, "farmer" and "specialist", and will again engage with the system in two different ways.

Manufacturers are increasingly aware of the diversity in user abilities, yet the current approach remains a "tailoring" option for the user interface. The issue with this approach is that it assumes the operator is simultaneously both a novice and an expert until the moment of use – a nonsensical proposition that fails both category of user.

There are two fundamentally different users, an "operator" and a "specialist". On the farm, both operator and specialist fulfil different roles. Therefore, they will expect to engage differently with the system and be presented with the tools and metrics that match their role on farm.

Merely developing a system in which an administrator can assign features to certain users is not desirable as common features may not be relevant to the operator or specialist. Furthermore, as Rob Morrison, product manager at Fullwood explained, developing a platform in which an administrator is offered unlimited variability "*would make efficient technical support impossible – as all sites would be different*."

Figure 8: Custom built milk tanker at The Angle Dairy Unit, Gooloogong, New South Wales, Australia

7. The changing farmer diversity and effect on innovation

> ***"100 years ago, dairy farmers were the same around the world. Now there are huge differences between dairy farmers"***
>
> **Rotem Rabinovich, SCR**

For about 7000 years, the farmer took some inputs, applied them to land or livestock and, having gauged the results, produced a product for harvest. The relationship between input and output is linear with the farmer responsible for all decisions and processes at every crucial stage of production.

However, to find a livestock farm that complied with this model, it was necessary to visit Indonesia. Indonesia is a country that imports 84% of its milk, a figure it hopes to reduce to 60% - this is equivalent to 1.5 million tonnes / year. To enable the necessary 2.5-fold increase in native milk production:

1. Several programmes have been designed to facilitate smallholder production and performance improvements. These are envisaged to deliver production improvements of 900,000 tonnes/year.
2. Governmental incentives are available to attract "Mega Farm" investment to deliver 600,000 tonnes/year.

Case Study

Pak Suwiknyo is a 48-year-old dairy farmer from Dadapan Kulon, in Malang, Indonesia. He has 7 cows in the herd (1 of which will be dry) and an average total production of 102 litres/day. Until recently, the herd was fed and watered twice a day; however, as a Nestlé demonstration farm, his cowshed had been recently renovated with the installation of an *ad libitum* water system and forage chopper.

Figure 9: *Ad libitum* water trough, Dadapan, Indonesia

Figure 10: Chopped forage, Dadapan, Indonesia

The smallholder farmers in Indonesia are still very traditional. The average herd size is 4 animals with most farms restricting cow access to drinking water. Nestlé has partnered with government and education agencies to deliver the smallholder development programme. The programme will impact 20,000 farmers and focus on feeding, welfare, housing and genetics – the very same issues as on-farm technical systems aim to resolve in the developed world. To understand if there are any lessons to learn, I spoke to one of the men responsible for delivering this programme, Rudi Syahrudi, head of milk procurement and dairy development at Nestlé S.A, Indonesia.

Rudi explained that there are two issues in dealing with the Indonesian farmer; the first concerns the adoption of new ideas, whilst the second relates to the adoption of technology. Relating to new ideas, the "classroom" approach had failed and so a "door-to-door" programme had been established. New processes had to be simple and their focus was on "basic things that have an immediate impact." Whilst the national focus was on increasing productivity, farmer margins were paramount, and this required creative thinking. The issues with technological adoption were clear – existing solutions are too costly. For example, a commercial grass chopper would cost $1000 US – a prohibitive price. However, it could be simplified so that the cost is $200 US, and with a $100 subsidy the unit becomes affordable with a payment plan.

The behaviour of an Indonesian smallholder who resists the concept of ad libitum water isn't any different to that of a dairy farmer who doubts the computer printout.

The behaviour of an Indonesian smallholder who resists the concept of *ad libitum* water isn't any different to that of a dairy farmer who doubts the computer printout. The justification for both is rooted in tradition and emotion – not science and logic. This suggests that there may be some universal characteristics shared by farmers across time and geography.

SCR is an Israeli company, established in 1976 and specialises in the development and manufacture of innovative technological solutions for the dairy industry. Today, the company portfolio offers a range of milking technologies, animal sensors, conventional (desktop computer) software and a cloud platform. Acknowledging the limitations of end users, SCR has combined several different measurements relating to animal activity and performance to generate a dimensionless **"Index"** figure. SCR research scientists simultaneously developed a range of suggested actions for the end user to implement as a consideration of the index figure. Associating SOPs to a single figure (that is representative of a range of complex observations) creates an elegant recommendation engine that is easily understood.

Rotem Rabinovich is the engineer in charge of New Heatime Applications at SCR. He summarised the philosophy behind the Index concept:

> *"Mr Farmer will spend 10 minutes per day on analysing data. But this time should not be on data analysis, it should be on taking decisions, and for this to work the data should be to 'your taste'."*
> Rotem Rabinovich

The genius of the "Index" figure is it's a dimensionless quantity, and is therefore impossible to contest. It's not a figure that can be interpreted by the farmer as a criticism nor can it be explained as anomalous. Whilst the underlying science is complex, it's simple to interpret.

7a. What do farmers want from technology?

> *"The kit must be simple to use and reliable. For me, it's about my sons; I want to be able to spend time with them as they grow. Hopefully they'll be inspired by what we've done here and at least one of them can farm it in the future."*
>
> Richard Hinchliffe

Richard Hinchliffe is a fellow Nuffield Farming 2016 Scholar. Based in Yorkshire, he farms in partnership with his father and uncle. Across 1400 acres they grow wheat, oilseed rape and beans. He is also responsible for all the farm agronomy and is both BASIS and FACTS qualified. Like Rose from The Angle in Australia, Richard is both farmer and specialist. As a host to BASF fungicide and biodiversity trials, the farm welcomes 600 visitors a year, including governmental agencies, supermarkets, NGOs and international visitors.

Figure 11: Richard Hinchliffe, NSch

Like most traditional farmers I met during my travels, Richard's foremost reasons for investing in precision technology systems are aligned with familial considerations. He explained that he does not consider himself an early adopter - the technology must be proven before he will invest. As a mainstream consumer and a farmer with an "inner expert" Richard has the skill to use the technology as intended and his rewards will be "as advertised."

In apparent agreement with Richard's reasons for technological investment, Dr Taketo Obitsu, an associate professor at the Graduate School of Biosphere Science at Hiroshima University, suggests that farmers invest in milking robots for three reasons:

1. To save time and physical labour.
2. The average farmer's age is increasing, so robots will play a role in making a "success of succession."
3. To make time for other activities – improve lifestyle.

In the Israeli Kfar Vitkin kibbutz, there is no sentiment of tradition or legacy. Here the decisions are all based on economic logic, with no ideology behind it. Nonetheless, the technology investment must offer personal and economic benefits – with welfare benefits more important for public relations.

Technological investments are based on necessity, themselves defined in economic terms and made only if benefits can be derived.

> *"The business must be considered in broad perspective; the farmer must have a vision for the business which is strategic and not technical in nature. Investments should not be about novelty, but about Return on Investment and economics – if there is any hesitation then the investment should not be made."*
>
> *Arnon Oshri*

Arnon Oshri believes that the problem is not with the equipment: it is more to do with farmer psychology and anthropology – which means that "tradition" is an issue. Traditionally, decisions relating to livestock were made based on experience. To defer the decision to a machine requires a change in perception. Don't go to the farmer on a tech level, go to them on managing perception. If the equipment reduces antibiotic use, it's about preventing additives - which is an advanced way of describing revenue increase.

7b. What do experts want from technology?

At The Angle, in Australia, the specialist approach is somewhat different. Andy Smith explained that their approach was to first understand precisely what was needed and why. Once this was defined, they would look at what would be the derived outcomes before developing a strategy to measure the benefits. Therefore:

1. Define need.
2. Define the measurement.
3. Evaluate with the measurement.

This approach allowed them to properly identify the fundamental requirement and "work back" to identify the correct solution. For technology developers, the expert customer strategy is a double-edged sword. An activity-monitoring system had been deployed at The Angle; however, reliability issues forced them to develop a workaround strategy that eventually consigned the activity system to the skip. The equipment manufacturer was not invited to tender for further work.

8. Discussion

In applying for a Nuffield Farming Scholarship, my hope was to identify:

1. What frustrates the utilisation of technology on livestock farms.
2. How are farmers successfully using technology.
3. What measures are necessary to facilitate greater usage.
4. What features should future systems offer to encourage complete and total use.

To understand the issues, I met with farmers, scientists, researchers, veterinarians, politicians and many more professionals. As my interview tally increased, I realised that my notion of a farmer was flawed. The website www.BusinessDictionary.com offers the following definition for a farmer:

> *"An individual whose primary job function involves livestock and/or agriculture. A farmer takes all the necessary steps to ensure proper nourishment of the items that he/she raises and then sells the items to purchasers."*

In the early 2000s, my brother Marc's farm skillset was acquired from working on the farm from childhood and would have been recognisable to a farmer from Dad's era or even the 1950s - we could describe the farmer as being the person responsible for transforming a seed into corn or grass into milk.

Historically, large and complex farming estates required a large, hierarchical workforce to complete the work. As machinery enabled lower tier work to be carried out by fewer staff, the complexity of management roles increased – however, a management structure did exist.

On smaller farms, all the work, including management decisions, became the charge of a single person or family. Society described these people as farmers. As traditional skills are abandoned in favour of technology and new lexicons emerge, the general conception of what it is to be farmer is breaking down. To conceptualise the modern farmer as a single intelligence or being is no longer valid.

When we automate a process, we cede certain responsibilities to the automation architects, sharing in both liability and credit. Ergo, if a farm task such as milking a cow is automated, we must acknowledge the system designers as being the legitimate "milkers" as the automata is a manifestation of both their skills and expertise.

My travels have shown that the farms which enjoy greatest success with technology are those with clear strategies for its implementation.

My travels have shown that the farms which enjoy greatest success with technology are those with clear strategies for its implementation. Furthermore, as traditional processes are automated, today's farmer is increasingly reliant upon specialists to manage new challenges. Such challenges include elements of marketing, public relations, meteorology, veterinary and pharmacology, data science, electronic engineering, finance and brokerage, agronomy, conservation and many more.

If modern farming is indeed a collaboration of skills, where did the farmer go? If we were to list the characteristics of a "traditional farmer" and then eliminate those traits that have been delegated to technology or specialists, the residual list describes an asset owner who makes decisions – in other words, a businessman. But, the "traditional farmer" understands that technology and specialists do not release you from the responsibility of observing the animals in your charge. So livestock farmer "DNA" is husbandry and compassion.

To reconcile both Pak Suwiknyo and Quentin Moxey as dairy farmers when the former employs none and milks 7 cattle, and the latter employs 150 and milks 5,500 cattle, is illogical. In this context, the "dairy farmer" description fails to acknowledge the vast discrepancy in scale, challenges, opportunities and accomplishments. A homogenous solution does not exist and can't be developed – different businesses have different needs.

An argument can be made that in modern livestock farming, the "farmer" still exists and this is the person who makes the decision. But, behind every decision lies a question, so perhaps a better definition would be that the "farmer" is the person who asks the questions?

The issue with this logic is that everyone involved in the process asks questions; the key is realising that the questions are different based upon the person's role.

I believe that the "traditional farmer" as conceptualised by society no longer exists. The space / role once occupied by the "farmer" is now in a state of flux, influenced by technological advancements and consumer expectations.

I believe that the "traditional farmer" as conceptualised by society no longer exists. The space / role once occupied by the "farmer" is now in a state of flux, influenced by technological advancements and consumer expectations. This may appear an over-laboured point of semantics, but I believe this observation has consequences for developers, customers and also political considerations.

At worst, this conventional view distorts political discourse, skews fair allocation of support funds and hinders innovation. At best, we should describe a farmer as "*one who is involved in the production of food.*"

I therefore conclude that most existing platforms, currently offered to livestock farms have been designed for a non-existent operator.

Technology developers need to evolve their platforms to cater for the "different questions" – this is not the same as designing for different technical abilities or restricting access as a consideration of privilege. For further illustration, I will distinguish between an operator and a specialist. The operator will tend to be a person who carries out data entry and implements the recommendations in the animal domain. The specialist may be directly involved with the farm activity, or an external expert.

- To promote proper utilisation, strategies that discourage hyperbolic discounting (i.e. opting to complete other farm chores, rather than concentrate on system operation) must be technically implemented at the operator level.

- An "engagement metric" calculated as a consideration of system utilisation or deliverable farm benefits might encourage proper operator interaction.
- Information should be presented to the operator in a simple and agreeable format.
- Better recommendation engines should be developed that present the operator with actionable information.
- Specialists are less likely to suffer from hyperbolic discounting; however, the system should advise the specialist of any inconsistencies in operator use.
- Smaller, frequent updates should deliver benefits to both operator and specialist.

Conversely, the producer must:

- Manage employee perception to encourage correct operation.
- Learn to trust their technological investment.
- Establish strict Standard Operating Procedures (SOPs) for proper operation, including:
    - Hardware management (sensor replacement etc.).
    - Data entry

Relating to historic systems that are underutilised, there is a retrospective opportunity for dealers and manufacturers to discuss system use with the customer. In many situations, independent specialists will already be advising the customer, so future business opportunities may depend on improved system utilisation. Sites that had the greatest technological success were those that were fearless in its use and confident in the manufacturer's support network.

During my farm visits, I observed a fundamental difference between those businesses that dealt direct with customers and those that did not. Businesses like The Angle, Pietro Mushrooms and Hasegai Dairy Farm were all actively engaging with their customers and had strategies to ensure customer satisfaction.

Just as I have proclaimed that a modern farmer is no longer a single entity but a cluster of collaborating intelligences, I believe this collaboration should extend further along the production chain. New protocols should be developed to:

- Improve communication between developer and specialist. As specialists develop strategies on behalf of their clients, the development of new features may be necessary. Similarly, specialists may be better qualified in evaluating new developer-motivated features.
- Integrate consumer and market data into farm technology platforms. With the advent of cloud services, platforms that exchange production and market data should be developed. These have the potential to reassure customers (food integrity) and allow the specialist and producer to respond to consumer trends.

Finally, as cloud platforms evolve, producers must become aware of how and where their data is stored. In offering "free backup products" manufacturers are accessing vast quantities of data that may be invaluable in the development of new and beneficial features. However, without careful consideration, this information may also be of interest to related industries with vested interests such as pharmaceutical firms or even processors and retailers.

9. Conclusions

1. The concept of a "farmer" as a single entity is incorrect. Thus many technology systems designed for "farmer" operation within the livestock industry will remain underutilised.
2. Technical systems are used by operators and specialists. Their respective expectations, requirements and evaluation of the system will be markedly different.
3. The perceived benefits of technological systems are unclear at the point of use – operators are prone to "hyperbolic discounting".
4. Specialist understanding (either on-farm or via third party) is influencing investment in new technology.
5. Confidence in support provision is necessary for most successful deployments of technical systems.

10. Recommendations

1. To allay confusion, the industry needs to propose, consider and adopt new terminology that better represents the person's role on farm.
2. System developers should consider developing new "operator" and "specialist" interfaces that allow the system to be interrogated per the immediate need.
3. Developers should consider the development of:
    a. An "engagement metric" to encourage proper system use and discourage hyperbolic discounting.
    b. Better recommendation engines that present the operator with actionable information.
4. When looking at new technologies, "farmers" should develop relevant strategies to encourage proper use or employ people who can help them.
5. Customers should be encouraged to seek robust support contracts with suppliers.

11. After my study tour

As someone who has been involved in the development, support and sales of technical systems to farmers, I will confess to having had several theories prior to beginning my Nuffield Farming study as to why technology utilisation was unsatisfactory. Fortunately, I realised early on in my travels that the fundamental issue revolved around the fact that our conceptualisation of a farmer was incorrect. Therefore, armed with this understanding:

- I have already encouraged many of my clients to approach their systems differently.
- I am also engaging with specialists - veterinarians, nutritionists, consultants and retailers to understand:
    - How we can better collaborate on-site.
    - How we can reconfigure or develop systems to better match their requirements.
- On projects where I am actively involved in system development, we are reconsidering the nature of the metrics we present to the operator.

Additionally, I've made a number of presentations to farmers and have begun discussing my findings to the Global Dairy Farmer network via a bi-monthly blog.

Tom Allison

12. Acknowledgement and Thanks

12a. Financial support

It has been my good fortune to have received wonderful financial support, without which my Nuffield Farming experience would not have been possible:

I would like to thank the **Trehane Trust,** for their generous sponsorship that enabled my Nuffield Farming Scholarship. I am particularly grateful to the Trehane chair, Professor Wynn Jones, for his considered commentary and support throughout my Nuffield Farming process.

As a recipient of the "**Richard Chantler Memorial Nuffield Farming Bursary"** my sincere thanks to Mrs Penny Chantler. As a self-employed contractor working in agriculture, this was a welcome addition to my travel funds.

Wynnstay for their very generous contribution towards my travel.

Dr Aidan Connolly, Chief Innovation Officer at **Alltech** for their generous support.

Jon Thornes, MBE for both hosting me in London and allowing me to observe several investor-developer meetings

12b. Encouragement

I would like to thank **The Nuffield Farming Scholarships Trust** for the training, organisation, encouragement and administration they supplied. As someone whose natural state is disorganised, I stand in awe of the way that I was organised.

To **Nuffield Wales** I say "Diolch yn fawr" for organising the Royal Welsh Show social and for the valuable "mock interview."

I am also one of the first Nuffield Farming Scholars to have had a personal mentor. **Mark Tripney NSch,** thank you for your patience, cups of coffee, cakes and calm advice. We got there in the end.

VES Environmental Solutions have been a transformative influence on my professional career. Thank you for your patience as I took time to travel and write my report. And again, thank you for the awesome contacts in the USA, Australia, Japan and Israel. My Nuffield Farming journey would have been much, much poorer without you.

To my loyal customers, whom have had almost 2 years of patchy service and to **Gareth Howells, Terry Wilson and John Phillips** who stepped in when needed. Diolch.

A big thank you to **Mum and Dad**. I would have never had the experiences I have enjoyed had it not been for your inspiration, support and love.

To **my wife, Lisa.** We met shortly before my interview and ever since, you have been both my sounding board and guiding light - thank you.

Finally, the Nuffield experience would not be possible without the larger Nuffield Farming Network and the farmers, business, politicians and academics who freely share your thoughts, time and contacts. To everyone who has helped me in the pursuit of my study - thank you.

13. Technical terms and abbreviations

Hyberbolic discounting	Selecting smaller, immediate rewards rather than larger, later ones.
SOP	Standard Operating Procedure

Please see next page for Appendix

14. Appendix

14a. Erwin Schrödinger

In 1935 the Austrian quantum physicist Erwin Schrödinger, devised a hypothetical experiment to highlight flaws of the 'Copenhagen interpretation' of quantum mechanics which stated "that a particle exists in all states at once until observed."

In the experiment, a cat is placed in a sealed box along with a radioactive sample, a Geiger counter and a bottle of poison. Should the Geiger counter detect that the radioactive material has decayed, the poison is released and the cat will be killed.

The Copenhagen interpretation suggests the radioactive material can have simultaneously decayed and not decayed in the sealed environment, ergo the cat is both alive and dead until the box is opened.

Clearly this is not the case, and Schrödinger used this to highlight the limits of the Copenhagen interpretation (when applied to practical situations).

Regardless of observation, the cat is either dead or alive.