final report

Northern Beef

Project code: B.NBP.0597

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Date published: April 2010

ISBN: 9781741915112

PUBLISHED BY
Meat & Livestock Australia Limited
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NORTH SYDNEY NSW 2059

The business case for Precision Livestock Management technologies and applications

Abstract

Precision Livestock Management technologies are defined by a capacity to monitor and control livestock remotely and provide producers with management capabilities that better link and control the biological and physical processes surrounding livestock production. Implicitly, these technologies facilitate more rapid, frequent and objective monitoring of animal performance. Against the background of such potential, the project was aimed at establishing the absolute and relative economic merit of several PLM technologies currently under development, but not yet commercialised. In general terms, the commercial potential of the technologies examined was found to be modest. Notwithstanding this generalisation, the most promising opportunity for immediate investment was found to be unmanned aerial surveillance. The technical capabilities of this technology have already been proven but applications specific to the northern pastoral industry have not yet been refined or made known to producers. Less attractive was a bundle of technologies that can be effectively and efficiently applied at enclosed waters. Thus limited additional investment in the so-called Remote Livestock Management System that combines walk over weighing with electronic identification, automatic drafting and telemetry is justified. Investment by MLA in automated management systems, where all the input and output data (including control of herd behaviour) are physically linked to the individual animal, is not recommended until the economic relationship between remote control of herd movements and pasture utilisation has been positively demonstrated and the cost per animal of achieving effective herd control has been significantly reduced.

Executive Summary

Project rationale

The project was undertaken to provide Meat and Livestock Australia with an objective basis for allocating R&D dollars among competing investment opportunities found to have ‘good prospects’. To this end, the project assessed and identified ‘new and substantial’ Precision Livestock Management technologies (PLMs) that offer the most attractive investment potential from the perspective of the northern beef industry. ‘Expected enterprise and industry-wide economic performance’ was the primary criteria used to determine the relative merit of the various PLMs assessed. It was assumed that the ‘expected economic performance’ of a new technology will have the most influence on PLM uptake rates but ‘the quantum of additional R&D investment needed’ and various non-economic factors were also taken into account.

Description of the process

The first step of the assessment process was identification of new and substantial PLMs with potential application to the physical, economic and social environments applying to the northern beef industry. While the PLMs assessed for ‘investment prospects’ are still new, several established PLMs were included in the early stages of our analysis. This was done for demonstration purposes and because most PLMs are in fact a combination of several components – some new and some existing. PLMs considered to have particular application to the northern beef industry were those that address the spatial challenges associated with general management, performance measurement, mustering and movement of cattle. While lot feeding does not face the same spatial challenges as breeding and growing operations, it was included because it is an integral part of the northern beef production system. The quantitative assessment commenced by determining the likely economics of each PLM at an enterprise level assuming in each case that the technology is developed and immediately available for adoption. Once the enterprise economics had been established for each PLM, the whole of industry application was determined by aggregating the available opportunity gains across all properties with a technical capacity to adopt the technology. The industry up-take of each PLM was defined relative to expected financial performance and the adoption behaviour of producers after taking into account various constraints to adoption and the investment of time and money still needed to make each PLM market-ready. To arrive at ‘expected financial performance’ the assessment also took into account the probability of each particular PLM being offered to the market with the capabilities and functionality prescribed by proponents at the beginning of the R&D phase.

Project achievements

While all of the PLMs examined were found to have technical merit, there was substantial variation in terms of expected economics and hence ‘likely practical application’. This finding was based in the first instance on potential enterprise and whole-of-industry financial performance, but was then adjusted to take into account the probability of successful development, the time and money still needed to make the particular PLM market-ready and various non-financial factors that affect uptake and application in practice. In terms of primary results, the PLMs examined generated a potential net present value of $5.3m when developed to the stage of being adoptable. While this is a modest total, performance among the PLMs assessed was highly variable meaning that scope exists to persevere with investment in selected technologies. The best prospect for MLA investment was found to be unmanned aerial surveillance. Limited scope also existed to support unmanned aerial mustering and remote livestock management systems that combine walk-over-weighing, auto drafting, telemetry and individual animal identification. A general finding was that PLM performance is highly dependent on how particular technologies are combined to capitalise on the investment in data collection capacity. In terms of the four regions making up the northern beef industry, it was found that the Central and North Queensland region would benefit most from unmanned aerial surveillance (with 64% of the total benefit). Southern Queensland would benefit most from adoption of unmanned aerial mustering while the Gulf, Top End and Kimberley region would benefit most from the remote livestock management system (71% of the total benefit) with the balance going to the Arid Zone.

Context and methodology for comparing different PLMs

The likely economic performance of each PLM at an enterprise level was determined by applying cost benefit analysis. The costs and benefits were assumed to be those likely to apply at an enterprise level once the technology option is fully developed and commercialised. The investment in R&D and commercialisation needed to take the PLMs to the market place was not included in the primary cost benefit analysis. However, each PLM proponent was asked to estimate the cost and time needed to take their technology to the market and the probability of it being successful. Qualitative probability estimates were quantified by the consultants and all these inputs were included in the final evaluation of each option. This approach allowed us to determine the short and longer term investment prospects of each PLM based on commercial potential once in the 'market' and the investment of R&D required to get to the 'market'. For the PLMs examined, the comparison of options was complicated by them having very different cost and benefit profiles in terms of timing, size, risk, substitutability and complementarity. Despite the need to develop assumptions (because we were uncertain about how the future will unfold) this did not prevent identification of the relative economic prospects for MLA investment. Within the limitations of the methodology, the assessment is deemed to have been objective and capable of providing MLA with a sound basis for going forward.

How the industry will benefit

The Australian beef industry must be constantly on the lookout for technologies that will raise its productivity and in the process protect its international competitiveness. Although some good examples of PLMs are already being applied (eg telemetry) most are still in the development phase, implying a need for further R&D before commercialisation is attempted or achieved. The issue on this occasion is whether the beef industry should positively assist with commercialisation of PLMs by investing levy monies in the R&D phase. After all, most PLMs are being developed by commercial firms and when the technologies have been fully developed and proven, they will be marketed to producers for the purposes of generating company profits.

The standard justification for market intervention is 'market failure'. For the northern beef industry, evidence of market failure could take several forms. Thus an absence of investment by commercial firms in areas of demonstrative producer need and preparedness to pay (such as mustering, fencing, surveillance, etc) could be taken as evidence of market failure. Or reticence on the part of producers to apply a particular PLM, because of perceived risk or lack of awareness regarding the PLM's competitive advantages in a commercial context, could also be construed as market failure. In all such cases, investment of industry funds would be justified if there was a high probability that the source of failure could be removed. In all likelihood, removal of market failure associated with PLMs would give producers access to new technologies quicker, and in the process generate significant opportunity savings, relative to reliance on prevailing systems and technologies.

Based on this rationale, the project's challenge was to identify those PLMs likely to benefit the beef industry and then recommend investment strategies aimed at minimising the lead-time to full development and adoption. Thus a two-step process was used; in the first instance the 'best prospects' were identified and then (depending on the actual findings) recommendations were made regarding the most efficient and equitable way of dispensing and administering assistance to PLM developers. The end result was substantiated business cases for MLA investment. Investment in unmanned aerial vehicles (for both surveillance and mustering support) was found to be the most attractive short term option while investment in remote livestock management systems at enclosed waters was found to be the best longer term investment option.

Contents

1 Background

1.1 Innovation in the northern beef industry

While the reliance of productivity gains on innovation is fairly obvious, the linkages between particular technologies and the efficiency and viability of enterprises are less well understood. In this study we are concerned with the relative rate at which beef enterprises (cattle producers and lot feeders) convert inputs into products when they have access to different technologies.

In practice, the beef industry has available to it two main productivity drivers:

- Cost productivity drivers (that bring about lower costs per unit of output); and
- Value productivity drivers (that bring about higher prices per unit of output)

For the purposes of this study, technical efficiency leading to greater cost competitiveness is usually the most important productivity driver with value productivity less important but still significant. Cost productivity is usually the most important driver because in highly competitive industries, as typified by the Australian beef industry, delivered prices tend to be comparable after accounting for quality differences. Therefore beef enterprises can exercise more influence over costs on-farm than they can over prices in the final market place. Some technologies, however, are aimed at raising the average price received by monitoring weight gain so that ultimately a higher proportion of total turnoff is sold at premium rates.

Over the past 40 years, Australia's northern beef industry has experienced periodic surges in innovation that have allowed it to become a more integral part of the national beef industry. As it turns out, most of these surges were forced on the industry. Thus the national Brucellosis and Tuberculosis Eradication Campaign (BTEC) that commenced in 1970 brought about many intensive management practices that had previously been missing from the northern industry. The BTEC campaign also led to improved market access and freer movement of cattle throughout the nation. In the early 1970s, a large and sustained collapse in beef prices led to the closure of virtually all the abattoirs across northern Australia (that specialised in supplying grinding beef to the US) and forced northern producers to seek-out new markets. Northern beef producers are now participants in long-distance and relatively complex supply chains that include quality specifications with potential for higher returns. Also, ongoing competition from the mining and infrastructure industries for workers has forced the northern beef industry to adopt many labour-saving measures. While northern cattle producers were not forced to switch to Brahman cattle, they did this *en mass* from the early 1970s as the breed's superior adaptation to harsh climatic conditions and tick resistance became apparent. Perhaps the most recent innovation imposed on the whole industry was individual animal identification (via the National Livestock Identification Scheme) which attaches to every beast its own unique number. This number can be associated with performance data specific to the individual animal thereby giving producers the potential to make comparisons and associated decisions across the herd and through time. Barriers to the widespread application of this technology (beyond biosecurity) are discussed later in the report.

It will be apparent from the above outline that significant innovation has occurred in many key areas affecting productivity including animal health, genetics, mustering and transport, market recognition and individual animal identification. Within each of these areas there will be significant variation in uptake from one enterprise to another depending on scale of operation, capacity and preparedness to master electronics and the proficiency of management. Implicitly, therefore, management always plays a key role in determining the dividend stemming from innovations.

This study considers the comparative economics of a defined set of Precision Livestock Management technologies that have been partially developed. Going forward, these technologies could be adopted and applied to cattle operations according to how individual managers perceive the contiguous benefits. In practice, PLMs will give rise to benefits depending on how well they integrate with, and complement, existing operations and management systems. The background influences that determine the commerciality of new technologies are discussed further under 'methodology'.

1.2 The emergence of PLMs

PLMs exhibit several characteristics that help to define and set them apart from other technologies. To start with there is a strong emphasis on electronics for the purpose of sensing or reading variations and interpreting data (using algorithms) and transmitting data across time and space as well as analysing data for the purpose of providing management with recommendations. Another defining feature of PLMs is a capacity to perform tasks automatically and remotely. Telemetry, for example can be used to send signals that control water pumps and gates. PLMs such as walk over weighing and machine recognition, combined with automatic drafting, allow selection or culling 'decisions' to be made remotely and automatically.

In some cases, the development of PLM technologies has been driven by a new paradigm – one that transcends the simple imperatives that apply to farm viability. The new paradigm seeks to observe and respond to all the interactions between the natural environment and imposed production systems. Thus the rationale for "…transforming agriculture through pervasive wireless sensor networks" (see Wark et al, 2007) is explained in terms of "…challenges associated with climate change, water shortages, labour shortages and increased societal concerns about issues such as animal welfare, food safety and environmental impacts" (p50). The public interest associated with a more holistic and sensitive agriculture has helped to attract public funding for PLMs seen to deliver outcomes that acknowledge and include the natural environment. Indeed Virtual Fencing has attracted considerable public sector funding (via the federal government) for testing the technology's capacity to protect riparian land from over-grazing. This study is more interested in whether or not the technology will prove to be economic from a private sector perspective.

1.3 PLMs under consideration

For the purpose of this study, PLMs have been defined thus:

> "….technologies that automatically recognise, interpret and report quantitative interactions between livestock and their production environment for the purpose of improving productive efficiency, profitability and sustainability"

From an economic perspective, the use of electronics to capture, transmit and translate data is aimed at conquering 'the tyranny of distance' that is a defining characteristic of much of pastoral Australia. To emphasise this point, each PLM has a particular spatial dimension making it possible to differentiate PLMs in terms of the space they occupy and perform in. Thus virtual fencing (VF), once implemented, would apply at ground level and control the movement of cattle according to pasture conditions (monitored for either conservation or utilisation) or an activity such as mustering. Unmanned Aerial Vehicles (or systems) operate in the air space above the land surface for the purpose of rapid surveillance of livestock, the environment and critical infrastructure. 'Enclosed water technologies' apply to cattle concentrated at paddock waters or in feed lots. Indeed several PLMs can be used once cattle are concentrated in one place eg automatic weighing, animal recognition, monitoring and selection. Enclosed water in the pastoral context allows cattle to be observed and managed remotely when they come in to drink. The enclosed space that is a feed lot can apply similar technologies. But because the space includes a feeding activity and the livestock are more numerous and higher value, scope exists in feed lots to apply more intensive management systems. For both enclosed waters and feed lots it is necessary to put in place sensors and data transmission technology to automate the management decisions associated with species, health and liveweight monitoring.

For the purposes of describing and analysing the different PLMs, they are grouped according to what they do, eg mustering and movement versus measurement and management. Looking ahead, however, it is apparent that some PLMs will be clustered or bundled for the purpose of performing multiple functions. Thus a bundle of technologies might be applied at enclosed waters that allow cattle to be individually monitored, measured, managed and mustered. Also Unmanned Aerial Vehicles (UAV) and virtual fencing (VF) might interact with sensors that monitor the cattle as well as contain them and muster them. The capacity of PLMs to perform multiple tasks means that they cannot be easily categorised according to a uni-dimensional function. Table 1.1 provides an introduction to how the PLMs under examination can be grouped and applied.

Table 1.1: PLMs grouped according to where and when they apply

Where & When	PLMs required	Outcomes + Key Strengths & Weaknesses
1. Enclosed space at either remote locations, when the livestock visit for water; OR in a feedlot as cattle visit feed and water stations	EID, WOW, ART, AD, T, software including GrowSafe	Afford a capacity to monitor the performance of individual animals and apply management decisions according to pre-determined 'rules' but minimal interaction with the environment. Needs to incorporate several complementary PLMs to realise full economic benefit. Biggest challenge would appear to be technical complexity and hence suitability for the average producer.
2. Aerial surveillance where and when required. Could apply to cattle or pest animals, condition of natural resources especially exceptional circumstances such as fire, pests, flood, weeds, etc.	UAV, sensors, cameras, communications network, algorithms	Afford a capacity to rapidly monitor and assess the status of sparse physical resources. Also lend a capacity to supplement helicopter mustering. But little capacity at this time to assist with, or contribute to, individual animal management. Immediate challenge might be finding clear-cut commercial applications.
3. Automated rangeland management of cattle via individual control and monitoring devices	VF, sensors EID, T, communications network, animal behaviour	Capacity to control cattle movement using sensory cues with potential to extend to monitoring individual animal health and state of the environment. High capacity to connect to individual animal but still expensive. Biggest challenge seen to be quantification of claims regarding superior pasture utilisation.

EID: Electronic Identification
WOW: Walk over weighing
T: Telemetry
ART: Animal recognition technology
AD: Automatic drafting
UAV: Unmanned aerial vehicle
VF: Virtual fencing

2 Project objectives

2.1 Objectives

The project was guided by close adherence to the nine directions outlined below. The wording used below corresponds to that provided in the project's terms of reference.

2.1.1 Workshop

Organise, facilitate and document outcomes from a technical information gathering and scoping workshop with relevant researchers, manufacturers and producers. This will be undertaken in collaboration with MLA. (Details of the workshop were reported to MLA in Milestone report 2.1 'Outcome of scoping workshop' dated 31 May 2009. The project's milestone reports can be found in Appendices 9.1 and 9.2. Brief mention of the workshop is also made in section 3 of this report).

2.1.2 On-farm applications of PLMs and associated technologies

Document in detail the range of potential on-farm applications of PLM and describe how various technology and innovation components underpin each application. This may require identifying and evaluating different technology components and innovation approaches being developed for the same application eg walk-over weighing and auto-drafting. (This objective is dealt with in section 4).

2.1.3 Source of production benefits

Document in detail how the production benefits from potential PLM applications could be achieved on-farm in relation to genetics and breeding, nutrition and supplement management, reproduction and fertility, animal health, animal husbandry, animal handling and mustering, marketing or meeting market specifications. (This objective is delivered in large part in section 5; most PLMs examined are aimed at generating opportunity savings in the areas of grazing management, handling and mustering).

2.1.4 Quantification of economic benefits

Document in detail and provide quantitative estimates of potential economic benefits for enterprises and the northern beef industry for PLM applications and approaches in terms of cost of production, animal productivity, labour efficiency and annual net benefits. Rank potential application according to their benefits, strengths and weaknesses. (The expected enterprise level performance of each PLM and region is quantified in section 5).

2.1.5 Commercialisation potential

Document and provide quantitative estimates of investment, development and commercialisation costs, resource requirements, constraints and challenges, risks, complexity and expected delivery horizons for research and development, commercialisation and industry adoption phases for each PLM application. Rank potential applications and approaches according to costs, constraints, complexity, risks and expected delivery horizon. (The adoption and ranking analysis is provided in section 6).

2.1.6 Likely adoption by industry

Evaluate the likely adoption and acceptance of each PLM application and approach to industry segments based on an appraisal of implementation cost, relative advantage, compatibility, trialability, observability and simplicity. Rank applications according to their on-farm implementation costs and likely adoption and acceptance. Rank applications and technology approaches in terms of their general strengths and weaknesses to the measures listed above. (The likely adoption on a whole of northern industry scale is provided in section 6).

2.1.7 Ranking

Rank applications and technology approaches in term of their general strengths and weaknesses to the above measures (ie 2.1.2 – 2.1.6).

2.1.8 Selection of most promising PLMs

Identify and provide detail for two promising PLM applications and their component technologies for MLA investment over short (1-5 years) and medium (5-10 years) time frames in terms of Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (BCR), R&D leverage ratios and risk indicators.

2.1.9 Business case

Document a brief business case and investment strategy for the two best-bet short, medium and longer term PLM applications. (The business cases for or against investment in each PLM are made throughout the report. Section 7 provides suggested terms of reference for those PLMs found to have sound investment prospects).

3 Workshop and method

3.1 Scoping workshop and data collection

The PLM workshop was held on 27 April 2009 in the Primary Industries Building, Brisbane. It was attended by PLM developers, PLM manufacturers / suppliers and existing or potential end-users. The workshop was designed, primarily, to help MLA and the project team identify a broad range of R&D investment opportunities that might deliver significant positive benefits to the northern beef industry. The workshop was judged successful in terms of the following:

- The participants represented a reasonable cross-section of PLM technologies with potential application to the northern beef industry and were given the opportunity to talk about their progress and opinions to an informed audience.
- This process provided the project with a useful introduction to relevant PLMs and the people behind them.
- During the workshop it was possible to establish probable linkages between various PLM technologies and their application to cattle production.

The workshop stopped short of nominating particular technologies for investment, leaving it to the ensuing project to place the options in context and objectively assess their prospects going forward. During the project, several PLM proponents were asked to complete the questionnaire shown in Table 3.1. The responses were used throughout the study for analysis and reporting.

Table 3.1: Data sought directly from each PLM proponents

Issue	Information sought
A. Status of technology	1. Proof of concept attained?
	2. Component technologies tested?
	3. Target market of producers identified?
	4. Pilot testing of total package proven successful?
	5. Business plan developed including definition of benefits to beef producers?
	6. Any commercial users at present?
B. Constraints currently faced	1. Scientific? Describe the key scientific constraint (e.g battery life, adaptation of other equipment, lack of software etc)
	2. Funding? Are your plans being constrained by access to financial resources?
	3. Market knowledge? Do you have sufficient knowledge of the potential market?
	4. Competition? Are other firms or technologies entering the market and likely to compete with your products and services?
	5. Risk? Are the major development risks you face technical, financial, markets or competition?
C. Target markets and benefits	1. How will a producer benefit?
	2. Will there be particular attributes of producers, their properties or production systems that will be targeted, such as size, location, breeding etc?
D. Likely schedule for delivery of benefits to industry	1. What is your current outlook for the future of the technology, without any involvement by MLA? See questions below?
	2. Year in which initial industry benefits will occur?
	3. Year in which maximum benefits will be captured?
	4. Total cost of developing the technology up to the year of initial benefits?
	5. Probability of success in development of technology and industry capturing benefits?
E. Form of assistance that would be most helpful?	Which of the following forms of assistance from MLA would be the most helpful? a. Funding/joint ventures in packaging, trialling etc b. Facilitating connections to industry c. Funding of outside scientific expertise to address technical component constraints d. Support in assisting with demonstrations e. e. Other
F. Impact of assistance	1. Would such assistance be critical to attaining the benefits, bringing the benefits forward or increasing the chances of success?
	2. If considered critical, why?
	3. If the assistance would hasten delivery of benefits to industry, estimate by how many years?
	4. If the assistance would increase the chances of success, what would be the probability of success compared to that estimated in question D4 above?
	5. Would the answers to F1 to F4 above depend on the level of assistance offered? What level of assistance have you assumed in answering F1 to 4?

3.2 Method

The comparative economic prospects of the PLM technologies and systems were estimated using cost benefit methodology applied at the individual beef enterprise level and across four regions. Steps in the application of this methodology included the following:

1. *Identification of the candidates*: In the context of the project, this was a comparatively easy step since it was a matter of identifying technologies applicable to the northern beef industry that are currently being researched or are almost market-ready with perceived commercialisation potential. Some technologies have not yet been accepted or adopted by the 'market' and might never be while others have been adopted (such as EID and telemetry) but have not yet been fully adopted. Thus the project was aimed at assessing each technology's applications (once fully developed) and their commercial prospects. For the purposes of 'identification' some PLM technologies are intended to generate benefits on their own while others are only effective in combination with other PLMs. Thus it was possible to develop a list of stand-alone technologies and combinations of technologies (systems), each of which can be subject to an enterprise / industry cost benefit analysis.

2. *Bridging the gap being development and commercialisation*: Some of the PLMs considered are still being researched and developed. In the first instance, this means that 'some other party' – as yet unknown – will undertake the commercialisation phase. While the PLM developer can be expected to have a good grasp of the product's capabilities, they might have little idea of the cost to users or the sort of commercial model that might have to be developed to take the PLM technology to the market. As such, the project included various forms of commercialisation as possible MLA investment options. On the other hand, it should not be assumed that beef producers will buy and apply all the PLM technologies that affect beef production. Virtual Fencing R&D, for example, is presently being supported by government agencies as a means of protecting riparian areas from overgrazing. Despite the possibility of a PLM generating public interest benefits, the focus of our analysis was on producer usage of PLMs.

3. *Quantification of costs and benefits*: Net benefit streams were developed for each PLM technology or system based on expected implications for each component on the profit equation. These implications were derived in the first instance at an enterprise level. With and without methodology was applied at an enterprise level to ensure that whole-of-enterprise impacts were captured. Cost and income assumptions were developed based on consultations with PLM developers and the consultant's own knowledge of beef production in northern Australia[1]. To determine the industry-wide relevance of each particular technology it was necessary to extrapolate its expected enterprise-level impact to the whole of the northern beef industry. This was a difficult step requiring formulation of assumptions regarding where, when and how the technology would be taken-up. It was found, for example, that some technologies will have limited industry-wide application despite being quite profitable at the enterprise level. Those PLMs reliant on enclosed waters, for example, have limited scope for application in areas not traditionally having enclosed waters. At both the enterprise and industry level, the benefit attributable to a PLM was the 'with versus without' difference. Thus a PLM would only generate a positive benefit if it was likely to improve on the 'without scenario'.

[1] Details of the assumptions applied to the enterprise-level analysis are revealed in section 5.

4. *Specification of the time frame*: Most of the PLMs compared are at different stages of development or application. In addition, they differed in terms of scale; large scale, costly investments normally have long lives and are recouped over long time periods compared to small scale investments. The analysis attempted to capture variations of this nature by discounting the expected net benefit stream to a single present value. For the enterprise-level analysis, the cost and benefit streams of each PLM were projected forward 10 years and discounted to the present using a rate of 10%.

5. *Significance of the results*: In most cases positive investment criteria at the industry level suggest that the technology should be successfully developed by the private sector without industry (MLA) assistance. The main reasons the industry would want to supplement the investment in a PLM, predicted by objective analysis to be profitable, would be: a) to expedite the PLM's entry into the market place by either assisting the R&D effort or assisting with the extension effort[2]; b) to reap complementary gains (e.g from combining with other PLMs) not yet apparent to the market place; c) to reduce the risks associated with accessing a particularly attractive benefit; or d) to allow application by MLA of a lower discount rate than is appropriate to the private sector. As a permanent institution that is responsible for protecting and enhancing the future of Australia's red meat industries, it is appropriate that MLA adopt a relatively long planning horizon and give explicit recognition to emerging technologies that might take many years to bring to commercial fruition.

3.3 Drivers of PLM development and uptake

Figure 3.1 shows the full array of influences and interactions that apply to the development, transition and final adoption and establishment of new technologies. Implicitly, our analysis endeavours to capture all these influences and interactions in the process of determining the relative investment prospects of each particular PLM.

[2] MLA is particularly well placed to assist with the extension of innovations to producers. In addition to MLA programs, there exist complementary programs funded and staffed by State departments of agriculture. Programs that MLA already have in place for popularising technical information include Producer Demonstration Sites, the EDGEnetwork programs, BeefUp and the Feedback and Frontier magazines, to mention but a few.

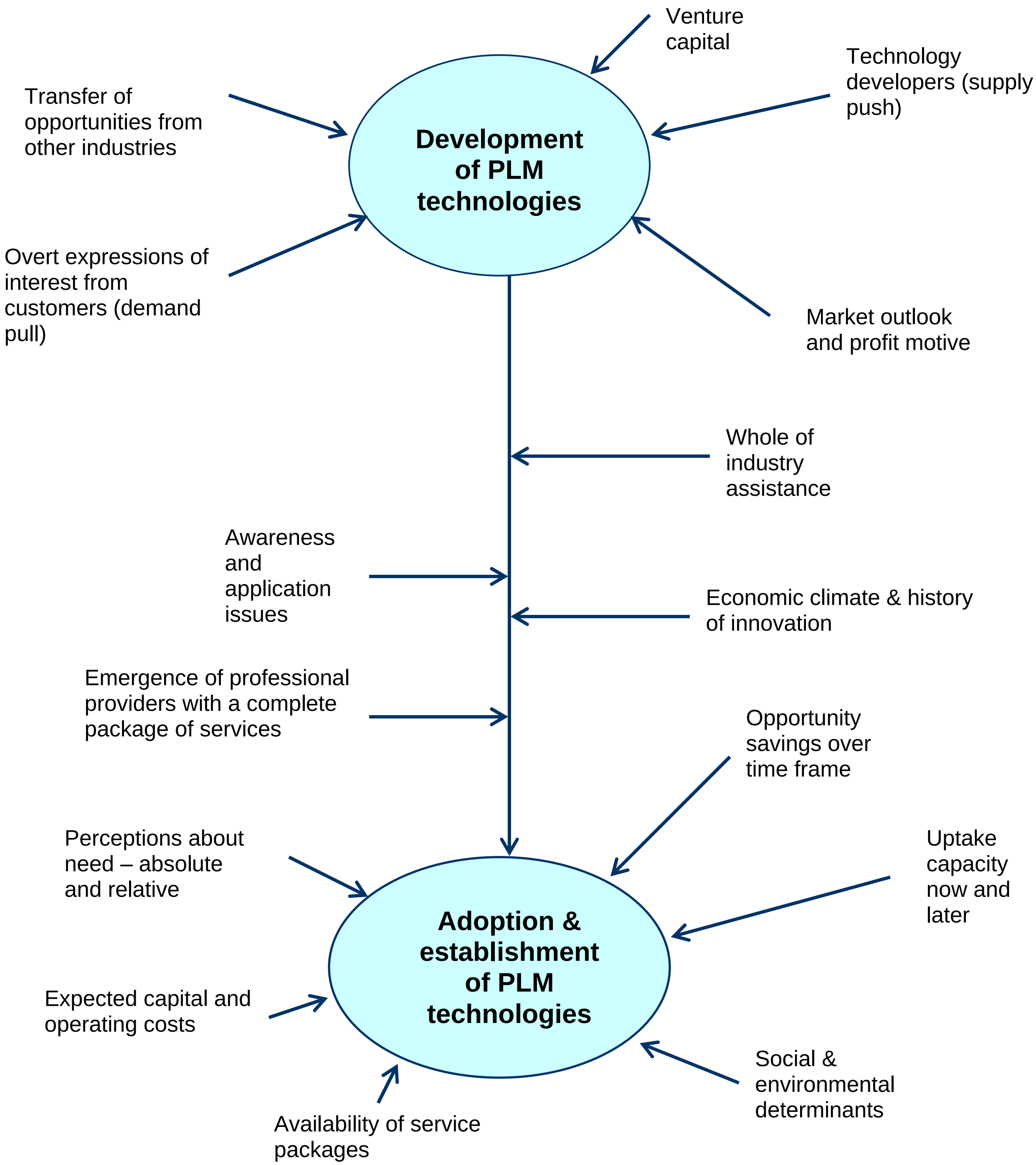


Figure 3-1: Factors driving the development and application of PLMs

4 Application of PLMs and associated technologies

This section addresses objective 2.1.2 by documenting the likely on-farm application of each PLM. The approach is deliberately qualitative for the purpose of providing context and perspective. The quantitative analysis of each PLM in terms of enterprise-level impacts is undertaken in section 5.

4.1 Cattle mustering and movement

The helicopter in combination with ground support is seen to be the 'contemporary method' of mustering cattle in extensive parts of northern Australia. PLMs exist that might complement helicopter mustering. Alternatives or complements to helicopter mustering would be attractive if they could reduce costs, do the job better (eg less stress) or perform additional tasks.

4.1.1 Unmanned aerial vehicles and systems

Background: UAVs were developed in the first instance for military applications with little regard to cost or civilian applications. Since 2005, however, there has been a concerted effort to apply the UAV concept to a range of civilian uses including perceived needs within the pastoral industry. The UAV configuration most likely to find a niche in civilian applications is a relatively small vehicle and is multi-functional. There is a substantial institutional and private sector involvement with UAV technology. Indeed the operational capabilities of UAVs are already well proven, leaving only the problem of finding commercial applications. A Brisbane based company (V-TOL Aerospace) is currently developing and marketing UAV services to a range of customers and assisted this project by demonstrating system capabilities (see below).

V-TOL is developing two machines that might prove useful in the pastoral industry. The fixed wing Warrigal (see figure 4.1) is the most advanced and is the primary focus of this preview. But also under development is a small unmanned helicopter that potentially has a range of applications. Thus a cattle producer who acquired a 'small unmanned helicopter' could use it for supplementary mustering and basic surveillance although the latter task would have to be appropriately 'scaled' to the slower speed of the helicopter relative to the Warrigal. Despite the advanced state of the UAV technology, there is still a role for R&D in bridging the gap between system capabilities and field applications according to specific needs. The Centre for Field Robotics, University of Sydney, for example, has a large staff devoted to developing practical applications for UAV technology – see for example: "Aquatic weed surveillance using robotic aircraft" by Salah Sukkarieh (LWA project code USY13, 2009)[3].

The concept: Fixed wing UAVs potentially allow farm managers to remotely view, monitor and control assets on the ground via an integrated suite of sensors, cameras and switching systems. This means they can be programmed from the ground to fly a pre-determined route and capture data which can be 'translated' into useful information. Thus there are two key elements of the UAV technology; the vehicle itself (ie an air component comprising the vehicle, sensor suite, and flight software systems and communications module) and the ground component comprising the control station and communications network. The combination allows data to be collected, translated into

[3] Dr Sukkarieh advised that the Centre for Field Robotics was not qualified to assist with consideration of UAV commercial issues and suggested that we make contact with V-TOL Aerospace.

useful information and published for accessing by client. The fixed wing UAVs already available for commercial applications have the following specifications:

- Runway independent and autonomous in the air
- 2.5 to 5 kg weight
- Up to 1.25 hours per flight and six hours per day or night. The addition of solar boosters will eventually increase flight duration
- Warrigal model can observe 40 square kilometres per hour
- Silent electric power plant
- Speed 30 – 70 knots
- Tolerate winds to 40 knots and moderate rain
- Auto land and take-off
- Five bays for carrying payload
- Durable airframe system
- Low operating costs

UAVs should be especially suitable for surveillance in the outback where distances are great and it is expensive to provide men and equipment for checking the condition of the natural environment and the state of repair of public and private infrastructure.

Figure 4-1: V-TOL's Warrigal model UAV resting in its cradle

Applications: With a competitive advantage in rapid and low cost aerial surveillance, UAV systems would appear to have many applications to Australian agriculture. In the case of the northern beef industry, the applications are likely to include fence monitoring, location of livestock including feral and pest animals, identification of weeds and soil erosion and monitoring of any ground activity and ancillary mustering activities. Beyond their physical capabilities, UAV applications will be determined in large part by the business model which will make it economic for a business entity to own and operate a UAV fleet. Only relatively large-scale cattle producers are expected to purchase and operate their own UAV. Most producers who use the technology are likely to purchase 'surveillance services' from a UAV operator who holds the franchise to service a given region of the continent. As the real cost of UAVs comes down they are likely to find on-property applications. Small unmanned helicopters have obvious potential for such activities as weed spraying and mustering. The ability of UAVs to identify and spray aquatic weeds has already been demonstrated in the Land and Water project mentioned above.

Stage of development: The UAV technology has a strong commercial partner in V-TOL Aerospace, a firm based at Rocklea in Brisbane but with demonstration and training facilities[4] at Woodlands, a semi-rural site west of Ipswich. V-TOL is in the process of developing and demonstrating fully integrated systems with a view to forging commercial partnerships with industry and agencies. The Smart Farm Project developed by V-TOL "…aims to add value to farming resources, reduce costs and enhance productivity by providing a range of benefits to farm operators and owners via user-friendly, real time integrated management systems for agricultural assets".

Potential economic advantage: The economic advantage stemming from application of UAV technology will arise from opportunity savings and/or gains relative to the technology that it would replace or supplement. Opportunity savings arise when a particular activity can be completed at a lower cost – with the same outcome. Opportunity gains arise when the quality of the product is enhanced – this might occur if cattle could be mustered with less stress and less weight loss. Apart from identifying the source of economic advantage, the assessment will depend on the business model. Where beef producers can purchase highly specified UAV products (eg cattle mustering, weed spotting and treatment) on a fee for service basis, there will be no upfront ownership costs and it should be relatively easy to establish the relationship between costs and benefits. Thus simple comparisons of cost effectiveness might be all the analysis needed to determine whether UAVs have an economic application at the enterprise level. Large scale enterprises (including integrated pastoral companies) might see a role for UAV ownership and in this case the economics will be more complex. In either case, UAV benefits would be realised through opportunity savings on surveillance and mustering costs.

4.1.2 Virtual fencing (VF)

Background: The inherent appeal of virtual fencing is such that researchers have been attempting to prove it has practical applications for some 20 years. As pointed out by Anderson (2007) "… the most useful practical modification of GPS technology for locating objects was the elimination of selective availability (SA) … in May 2000. This allowed civilian users to pinpoint locations up to 10 times more accurately than previously…" (p66). The ability to 'track' animals was the first step towards automating control of their movements. As reported by Anderson the first recorded control

[4] The Australia & International Training Institute and the University of Queensland are affiliated with V-TOL for the purpose of facilitating the training function.

of a free-ranging cow using GPS technology combined with autonomously-applied sensory audio and electric stimulation, occurred in April 2001. The discovery that cattle respond in a predictable manner to audio and electronic cues was a major breakthrough for VF technology. However, the capacity to replicate this response on a commercial scale has not yet been proven and additional research will be required if the technology is to ever have widespread commercial application.

The ability to control animals using electronic cues has focused more recently on the efficacy of the hardware and the limits of animal 'training'. The R&D currently underway in Australia is being directed by CSIRO staff with funding to date provided by the Commonwealth Department of Agriculture, Forestry and Fisheries. DAFF's interest in the technology stems chiefly from the (public sector) need to protect riparian vegetation from over-grazing that would normally give rise to stream-bank erosion and sediment outflows that damage marine environments. However, VF also has the potential to generate private benefits by substituting for conventional fencing and moving cattle strategically – whether for more uniformly grazing of the existing pasture resources or mustering into yards. It is the nature and extent of these two benefits that is the focus of the current analysis.

<u>The concept</u>: The virtual fence research aims to discourage cattle from crossing a non-physical barrier that is delineated by GPS coordinates. The cattle are discouraged from crossing the invisible barrier by a combination of auditory and tactile stimuli that emanate from a device worn around the animal's neck. In effect, the cattle carry the barrier component of the 'fence' around with them, while the (virtual) fence posts that determine the location of the barrier are established electronically and remotely. Unlike a physical fence that the cattle can see and feel, the virtual fence discourages movement outside the designated area by a combination of auditory and tactile stimuli. As an animal approaches the exclusion zone, it is alerted by a sound from the device. If it proceeds into the exclusion zone, it receives a tactile stimulus. Numerous research studies (see Handcock et al 2009) have found that cattle quickly learn to leave the exclusion zone with minimal cuing, ie audio stimulus. Moreover, the degree and direction of the audio cuing can be regulated to enhance the accuracy of the animal response. While this control still needs to be demonstrated in 'larger commercial environments' proof of concept has been achieved.

It is apparent that automatic and continuous control of cattle herd movements is the attraction of 'virtual fencing' rather than substitution for a traditional fence that is permanently fixed in the landscape. But the question remains: can artificial manipulation of herd movements (using VF) bring about better utilisation of pastures than natural grazing behaviour where the herd decides the pattern of movement within the constraints imposed by waters? In this context, VF can be compared to cell-grazing where the aim is to control grazing effort through time and space to maximise the potential of the property's feed resources. If cell-grazing and VF were equally effective at 'maximising the potential of a property's feed resources', the choice of system (used to control grazing effort) would come down to a comparison of costs. Since both systems are 'high cost' it is unlikely that either would have an obvious application to extensive areas, with relatively poor pastures.

The collars that facilitate VF can also be used to carry data loggers that allow behaviour and performance monitoring. Thus it is possible to connect the collars via 'static nodes' to the web and receive real time data about individual cattle. Performance criteria that might be monitored include oestrous in cows (useful in intensive regimes for facilitating AI), time of calving and health indicators that can be related to biosecurity[5].

The R&D effort is currently focused on making the technology more cost effective. Trials have already demonstrated that VF will work satisfactorily with only a proportion of the herd collared. The analysis in section 5 assumes that 25% of the herd needs to be equipped with a collar that incorporates GPS. The collars are bulky and relatively expensive. The balance of the herd would be equipped with ear tags that maintain radio contact with the collared animals but still have the ability to signal animals when they approach the virtual fence. As the ear tags are cheap by comparison to the collars (about $60 each for tags versus $300 each for collars) it is possible to lower the average cost per beast in a 'controlled' herd to about $120 per head (pers. comm. Greg Bishop-Hurley)[6].

Longer term, the collars must be robust enough to withstand a long paddock life. Also the battery must store enough energy to drive the GPS over a 'commercial' life. Thus the economics of the concept are likely to be highly dependent on the time interval between battery replacements. The hope is that solar power will eventually enhance the collar's battery life.

<u>Applications</u>: While virtual fencing would have a competitive edge in areas that are difficult to fence conventionally, such as stream banks, flood out country and sensitive alpine slopes, it would be wrong to think of the technology as nothing more than substitute for a conventional fence. Because it is effectively carried around by the cattle, the virtual fence can be easily moved to direct the herd to where it is wanted. This might be done to:

- Promote better utilisation of pasture resources,
- Re-locate cattle to where the feed is most abundant (analogous to cell-grazing),
- Avoid trouble spots such as those with toxic plants or no feed – following a recent fire,
- Drift the herd to where it can be yarded for intensive husbandry.

The application of VF could be extended to 'individual animal monitoring' by linking the collar devices to the individual animal's EID and a sensory node. This would make it possible to sample such things as animal temperature and feed intake and in this way closely monitor the physical environment and the health of the whole herd. Application of this technology, however, would necessitate integration with third party systems to manipulate the data and apply various decision making guidelines.

<u>Stage of development</u>: Sufficient R&D has been carried out to prove that virtual fencing is conceptually feasible. Moreover, it has practical and novel applications that extend well beyond conventional fencing, giving the technology a unique capacity to deliver environmental and ethical outcomes, considered by the industry as strategically important. However, the concept in its present (R&D) form cannot be transferred directly into the marketplace – represented on this occasion by northern cattle producers. Anderson (2007) believes there are three outstanding areas that need to be addressed. First the size, mass and cost of the equipment platform and electronic hardware

[5] Biosecurity is necessarily related to surveillance, which is costly and ineffective if reliant on human intervention. Automated systems, such as collars or UAVs connected to sensors appear a credible alternative.
[6] The cost of manufacturing the experimental collars was in the order of $800 but this figure is clearly not applicable to this analysis. The experimental collars were 'hand-made' for the job and included many 'add-ons' that would not be included with a commercial collar.

needs to be reduced; secondly a better source of power generation and storage must be found and thirdly an optimal suite of sensory cues for eliciting consistent behaviour from collared cattle needs to be found. But overcoming the technical challenges faced by VF will not guarantee it success in the marketplace – this will only come from delivery of clear-cut benefits – a facet of the R&D that has not yet been attempted. Furthermore, the 'optimal suite of sensory cues' referred to by Anderson will have to be deemed acceptable from an animal welfare perspective since welfare is one of the criteria by which the Australian beef industry now rates its performance. Confronted with a paucity of commercial data, our assessment has had to derive synthetic costs and returns for the purpose of arriving at enterprise-level economics. The analysis performed in section 5 assumes that the benefits offered by VF are confined at this stage to better pasture utilisation and lower mustering costs.

<u>Potential economic advantage</u>: As with UAV technology, the economics of VF will rest with whether it can offer opportunity savings and gains relative to the existing technology associated with monitoring, containing and moving cattle. Because VF is still locked in the R&D mode and is more than a straightforward substitute for conventional fencing, its economics are difficult to demonstrate. Conceptually, the net gain from VF is given by its capacity to increase whole of property performance and replace existing costs after netting out new costs associated with adoption. Depending on the number and extent of applications, benefits could include:

- Introduction of 'fencing' to areas currently unfenced or sub-optimally fenced
- Elimination of existing internal fencing
- More uniform grazing distribution and therefore more efficient utilisation of pasture resources
- Reduction in mustering costs
- Improved cattle monitoring via static sensors.

The overhead costs associated with adoption of VF should be relatively small, being confined to the establishment of a sensor network and a data management system that might have multiple uses in any event. However, the low fixed costs are likely to be overwhelmed by high variable costs since the VF system relies on equipping a proportion of the herd with collars that read GPS coordinates and emit signals to control the host animal. At this stage the collars are expensive to manufacture, fit and maintain, making the short term chances of VF adoption slim indeed. Despite this, we can see advantages in controlling and monitoring cattle using devices that are integral to the individual animal. If total control and monitor can be attached directly to the animal, via a collar or similar mechanism, it will make redundant the infrastructure and control systems currently used to manage cattle.

4.2 Advanced cattle measurement and management

In extensive areas characterised by long distances between grazing precincts and yards, there should be merit in systems that automatically identify, measure and manage cattle *in situ* so that traditional mustering (to central yards) is minimised. As it turns out, automatic measurement and consequent management is possible where waters can be enclosed and their access controlled via a single-file race. With such infrastructure in place, cattle accessing water are forced to present in a manner that allows critical data (such as tag number, species, size and body weight) to be collected and transmitted as a basis for making continuous management decisions. Thus enclosed waters can serve as the foundation stone for a range of automated practices that can be used singularly or in combination depending on the nature of the operation and needs of the producer. Taken to its logical extreme, enclosed water could allow for application of multi-functional and fully integrated systems that replace manpower, assist with decision making and ultimately improve profitability.

The proponents of Walk over Weighing have taken the logic step of bundling a suite of complementary technologies to arrive at a system for facilitating whole-of-herd management. Key elements of the system include regular measurement of individual animal performance (as in body weight), transmission and interpretation of the data and automatic drafting – to allow the system to function remotely. Packaged as such this is known as the Remote Livestock Management System.

Technology can also serve to enhance the integrity of the enclosure itself. Thus telemetry can be used to monitor the status of water supplies within the enclosure and in the process help to justify the technology afforded by creation of enclosed waters. Telemetry can also be used to transmit data to headquarters where it is analysed and decision-rules applied, which are then actioned at ground level via automatic drafting. The key elements of the system are shown in Figure 4.1.

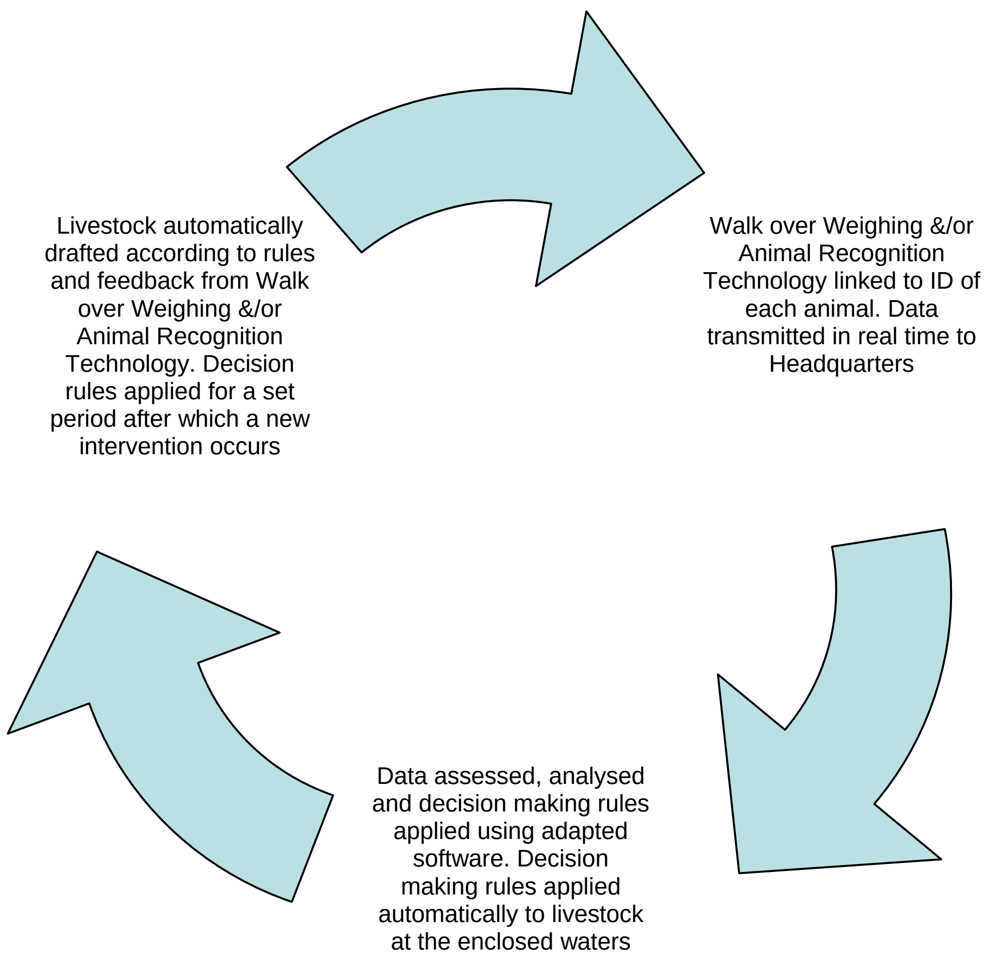


Figure 4-2: Connectivity between data collection, decision rules and management

Below we examine in detail the various PLMs that are linked in the first instance with enclosed waters. The technologies are introduced individually but the significance of ‘integrated systems’ is noted where appropriate.

4.2.1 Animal recognition technology (ART)

Background: What is now referred to as ‘animal recognition technology’ derived from ‘machine vision technology’ and had its first applications in fruit and vegetable grading almost 20 years ago. Machine vision technology uses computer based camera equipment to capture and interpret images in real time. This capability has been used for automatic grading and sorting in many agricultural industries over the past 20 years. However, the technology is only now being investigated in the pastoral industry. The ongoing problem of vertebrate pests (that compete with domestic livestock for feed and water) and the relatively recent introduction of the bore capping program (that has led to an expanded capacity to control watering points) have combined to provide the opportunity to apply machine vision technology. This opportunity was identified by Neal Finch (while a PhD student at the University of Queensland) and the analysis presented below is mostly based on information supplied by Neal. Commercial partners (including RPM Rural and Observant) have already expressed interest in manufacturing and retailing ART, both singularly and in combination with other PLMs such as walk-over-weighing. Furthermore, the South West Queensland NRM based at Charleville has expressed considerable interest in field-trialling ART for the purpose of discovering the circumstance under which it is likely to prove economic for cattle producers. This organisation already has access to field demonstration sites at Quilpie, Wyandra and Thargomindah.

The concept: Once a stock water supply has been enclosed (by fencing it for the purposes of controlling entry to and exit from the water) it becomes possible to apply several PLMs of which ART is one. While the economics of enclosing waters will be enhanced by bundling of PLMs, the focus for the moment will remain with ART. The ART software is designed to identify and classify animals as they enter a race leading to the water source. A webcam is positioned 1 metre high and 3 metres back pointing at a blue background on the far side of the laneway, through which the animals pass on their way to the water. Colour separation is used to develop a binary image of the animal and this is matched against a library of templates to determine the image’s species and size. The species best identified by ART to date include sheep, goats, cattle, horses, pigs, kangaroos and emus. The most basic application of ART requires that it be combined with automatic drafting so that animals can be separated by species once they have passed the webcam and been ‘recognised’.

Applications: ART is seen to have two and maybe three main applications. First, ART can be used to trap feral animals when their numbers are seen to be economic for harvesting. Thus goats might be accumulated at one or more waters (provided feed is made available within the enclosure) until there are sufficient numbers to fill a truck. Secondly, ART can be used for drafting within and among species. Weanable calves for example can be automatically drafted from their mothers according to size and seasonal conditions. This task could be refined by combining ART with walk over weighing and telemetry – for conveying data back to headquarters. Thus automatic weaning might occur when ART sees calves that WOW says have achieved 160 kg. But for ART to generate a positive additional benefit (over WOW) it would have to be low-cost and capable of inferring some additional benefit such as condition scoring or differentiation among species falling within the target weight range. Thirdly, ART could be combined with auto-drafting to exclude pest animals from waters installed for use by domestic species. The value of this application would be greatest during drought when all herbivores compete for the same plants. Implicitly, ART would force wildlife to abandon a particular water (protected by ART) and go to others that are either natural or unprotected. However, this application might have weaknesses. In the first place it might simply transfer 'the problem' from one location to another with very little overall benefit. Secondly, there are probably cheaper, more socially acceptable and more effective means of exercising control over excess kangaroos and other feral animals.

Stage of development: The viability of ART as a workable concept has already been proven. It is unlikely, however, that ART will find its way into the marketplace without field demonstration of how it would integrate with and benefit an extensive livestock management system. To this end, ART could be demonstrated on a property scale – possibly at a Producer Demonstration Site. Telemetry would complement ART and auto-drafting by transmitting data to headquarters and making possible computer-assisted decisions based on critical species, the number at the enclosed water, weights, prices, etc. Other data that might enter the decision making processes are pasture conditions at the target area versus conditions at other enclosed waters.

Potential economic advantage: ART is most likely to apply in relatively arid areas with enclosed waters but high pest animal populations. In this environment, the ART unit could be moved from one enclosed water to another in the process of rotating pastures. While this strategy would reduce the capital outlay, the economics of ART will still depend on the extent to which it can support decision making rules associated with the applications nominated above, eg trapping harvestable animals and assisting with automatically drafting cull animals. While ART could be applied as a stand-alone technology (eg identify the species composition using particular enclosed waters) we imagine its economics would be improved by high-level complementarity between a bundle of technologies including telemetry.

4.2.2 Walk-over weighing (WOW)

Background: The technology associated with weighing cattle as they enter or leave enclosed waters was developed more than 20 years ago. However, the impetus to apply this technology gained momentum with the introduction of telemetry and advances in data capture and transmission, computer-based analysis and remote application of decision rules. Thus WOW combined with telemetry and auto drafting only became 'useful' following its integration with data capture and analysis that allowed individual animal weight data to be used as a basis for 'decision making'. The Desert Knowledge CRC is actively involved in researching WOW for the purposes of arriving at an integrated system (viz, RLMS referred to page 23) with commercial scale application. The questionnaire shown in Table 3.1 was completed by Dr Andy Bubb from the Desert Knowledge CRC and his feedback is used from this point where appropriate.

The concept: This PLM technology allows individual body weight to be captured remotely, linked to the animal's tag number and automatically transmitted to headquarters. WOW and data transmission is best applied at enclosed waters where cattle can be trained to 'use' the system on a regular basis – as they access water. 'Trained' cattle will enter and leave the water slowly and in a single line to facilitate accurate data capture and auto drafting. The training process will be assisted by yard construction that recognises the fundamentals of livestock behaviour (pers. comm. John Lapworth). Time series data captured under these circumstances has been found to be more accurate than the once off weighing with yard scales (pers. comm. Tim Driver). It is possible to monitor individual and group weights through time and use the resulting data to assist any decision making that is weight-dependent. In the future it might be beneficial to use weight data in combination with ART. The WOW hardware has already been successfully demonstrated at Napperby Station but the software is still being refined.

Applications: Walk over weighing can provide the producer with a reasonably accurate knowledge of individual animal weight. The issue is whether this information can be used to increase profitability. The economic opportunities available include:

- Monitoring the weight of cattle destined for market for the purpose of applying a decision-rule. Thus bullocks might be mustered when 80% had achieved a live weight of 570 kg, assuming a target carcass weight of 300 kg and a dress-out of 54%. The same sort of process could be applied to cull cows that have to dress at least 250 kg to achieve the highest offer price. If all cattle mustered are sold, information provided via WOW should govern the timing of mustering and thereby reduce the opportunity costs associated with selling under-weight cattle.
- Monitoring the weight of growing cattle to determine when they need to be supplemented or transferred to another paddock. For example, if the average weight-gain of growing cattle at a particular enclosure/paddock falls to below 400 gm per day, they would get moved to a fresh paddock or sold, etc. This application assumes that weight monitoring provides a better basis for decision making than direct monitoring of pasture condition.
- Monitoring the weight of calves or their mothers to determine when the calves should be weaned – this re-action might be facilitated by automatic drafting.
- Monitoring when pregnant cows have calved. This will allow the intensity of management to be regulated according to the income generating capacity of sub-groups.

Potential economic advantage: Like ART, WOW has the potential to generate benefits on both sides of the profit equation ie, by increasing income and reducing costs. Income will be increased by reducing opportunity losses associated with variability while costs will be reduced by less monitoring and mustering. WOW could be used as a standalone technology but its economics are likely to be enhanced by combining it with complementary technologies such as telemetry, decision making software and automatic drafting. Assuming WOW incorporates automatic data capture and decision-making, the package should allow weight-related management practices to be virtually optimised. In practical terms this means reducing variability around key production targets. The marginal gains associated with optimal weight management are demonstrated for a range of assumptions in the section 5.

Recent research at Napperby Station, located north of Alice Springs, suggests that WOW could serve as the platform for many benefits, additional to those quantified later in section 5. Table 4.1 identifies several of these 'additional' benefits and gives them a priority rating (pers. comm. Steve Petty and Andy Bubb).

Table 4.1: Potential impacts and benefits of walk over weighing and auto drafting

Area of Impact & Priority rating	Specific information	Practice	Benefits
Animal Management: Sale of Heifers / Steers / Cows Priority: HIGH	Performance recording: Tracking animals growth to improve sale weights	- Target specific markets most suited to animals being sold: - Mustering when 'the most' animals are making the weight'	- Higher prices per kg; - More efficient handling and lower transport costs per kg
Animal Management: Breeders Priority: HIGH	Timing of supplementation: Drafting individuals into supplement pen	- Effective segregated supplementation based on time of calving or intended time of joining; - Spike feeding to bring on cycling: - Getting heifers up to joining weight	Reduced supplementation cost and increased calving %
Animal Management: Weaners/Breeders Priority: HIGH	Automated weaning	Wean group (truck load etc) of calves based on weight/age/cow condition	- Weaner specific paddock (high quality feed) *Weaner only supplement feeding - Improved cow condition - Increased cows cycling - Increased calving %
Animal Management: Breeders Priority: HIGH	Performance recording: Time of calving	Using weight to identify when cows tested pregnant have calved	Increased herd fertility – single most important determinant of profitability
Animal Management: Breeders Priority: MEDIUM	Controlling mating (ie non continuous mating)	Tighter calving pattern	Increased weaning % Targeted genetic improvement
Sustainable stocking Priority: LOW	Accurate grazing pressure (kg feed : kg cattle LW)	Using animal performance for indication of quality/quantity of pasture	Maintaining/improving land condition
Feral animal management Priority: LOW	Feral animal and non production animal control	Exclude or trap non production animals from water	Increasing available feed for production animals

4.2.3 Auto drafting

Automatic drafting is needed to realise the potential of other PLMs such as WOW and ART, placed at controlled waters. Using solar power and pneumatics, in combination with EID, it is possible to draft for such characteristics as sex, weight and age with high accuracy rates. In addition to the 'turn-off related' decisions noted above, automatic drafting married to NLIS tags and telemetry can be used to control mating by drafting either heifers or bulls according to pre-determined decision rules or monitor breeder weights before and after calving. Due to its reliance on complementary technologies, auto drafting is not treated here as a separate technology. Because the ART and WOW technologies outlined above rely on auto drafting to realise their full potential, its cost is included in the enterprise-level evaluations undertaken in section 5.

4.2.4 Telemetry

Background: Telemetry is in the early stages of being commercialised for automatic monitoring of remote waters. Despite its progress towards ‘full commercialisation’ telemetry features throughout this study because it is a perfect example of PLM technology and it has ‘high relevance’ to several other PLMs still under development. Thus telemetry can be used independently or linked with other PLM applications such as water medication, walk over weighing and machine recognition. The significance of automated water monitoring has increased in parallel with the intensification of northern cattle production through additional water points and increased use of paddock resting and rotations. Telemetry solutions are now commercially available to pastoral stations, through a range of providers, with the main pastoral industry providers being Observant Pty Ltd, Stockman Electronics, Blackmores Power and Water and uSee Remote Monitoring.

On a typical station, the boreman has to check each watering point (particularly ground waters equipped with a pump) 2 or 3 times a week to ensure the animals have continuous access to a water supply. In many cases the boreman will simply confirm that water is available and move on to the next site. Key maintenance and recharging of the fuel supply is usually done once per week. The combined cost of running a vehicle over the rough terrain and paying wages is significant. With ongoing intensification of cattle stations in north Australia, resulting in additional water points to be checked and more gates to open and close, the cost of ‘water checking’ will continue to increase.

Telemetry has a role to play in reducing manual monitoring of water points and helping to manage or reduce the associated operating costs. Most water points require fuel or maintenance at least once per week and this ‘run’ is often used concurrently to check the location, condition and health of the animals.

The Concept: With telemetry, ultra-high frequency (UHF) radio is used to send and receive water depth data and to control pumping operations remotely while water depth data are recorded and displayed on a computer at the homestead or base. UHF transmission range can be extended by either installing repeater networks or by transmitting the data between each water point, back to the homestead.

Applications: There are many applications for telemetry beyond remote water monitoring. The company, Observant, has developed a self-contained, solar powered and radio equipped telemetry unit that provides an integrated approach to managing all aspects of bore control and monitoring. The self-contained unit performs the following functions remotely:

- Checks water levels in storage facilities (turkey nest dams, tanks, troughs, in-flow dams)
- Accurately measures water usage at very high resolution (by minute, hour, day etc)
- Automatically starts and stops pumping equipment used to manage water supplies, including engine management systems
- Provides regular still photography of points of interest at sufficient resolution to make out important detail
- Monitors electric fences
- Accurately measures rainfall at very high resolution (by minute, hour, day etc)

- Interfaces with power monitoring equipment to help manage remote power generation facilities
- Manages livestock performance systems such as NLIS tag readers and animal walk-over-weigh and auto-draft facilities.

Potential economic advantage: The economics of telemetry can be tested using partial budgeting that compares the relative costs and benefits of conventional water monitoring versus telemetry. If telemetry can be shown to be more cost effective after ensuring a valid comparison (that might include risk factors and manager preferences) then a basis for choosing among systems exists. The appropriate budgeting exercise is undertaken in section 5 and the whole-of-property implications are incorporated into the baseline property for the purposes of arriving at whole-of-industry implications. Because it is already available in the market-place, telemetry is not considered for 'further MLA investment' by this study.

4.2.5 Data management and decision making

Background: Several of the above PLMs gather data that only become useful when subject to analysis and decision making rules and actions. The actions associated with enclosed waters technologies, for example, rely on capturing the animal's weight or shape data, storing or transmitting these data and subjecting it to some pre-determined decision rules. For all these things to happen there must be various 'complementary' technologies and systems in place. The integrated system reviewed on this occasion includes individual animal EID, data management and computer-based decision making as portrayed in Figure 4.1. This analysis is as interested in identifying weaknesses in the application of the 'complementary' technologies as it is in finding useful commercial applications.

The concept: Adoption of the National Livestock Identification System commenced in the cattle industry in mid 2004 and became nation-wide in July 2005[7]. NLIS was introduced to enhance the biosecurity of the national herd by delivering a capacity to track and trace the location of every beast. While the system has a capacity to identify and trace individual animals, the issue is whether cattle producers should find it worthwhile to apply this capacity at a property level to assist with management. This might be done by linking the animal's unique number to inputs and outputs such as fertility status, age, weight gain, treatments, sale weight, place of origin, progeny, etc. Data belonging to an individual animal can be accumulated throughout its life (in a computer) with the common link being the animal's EID. From this point, the data could be managed and subject to various decision making rules. But experience to date has revealed flaws in some applications. While it might seem worthwhile, for example, to estimate weight gain per day over a steer's life by relating final carcass weight (obtained from the abattoir's feedback sheet) to age (in days) and birth weight (a standard estimate) there is a high probability that the results will prove too inaccurate to be useful (pers. comm. Alan Laing, QDPI Ayr). The need, for example, to estimate birth weight and age combined with differences in gut fill between cohorts is likely to render the data highly unreliable. On the other hand, there are several aspects of individual breeding cow performance that can be

[7] New generation EID systems are already under development. A company called Sirion Global claims to be developing the world's first real time GPS global satellite tracking system for livestock. This technology would allow regular audits of the national herd at the 'press of a button', without reliance on producer and service provider data input. In the event of an exotic disease being reported, satellite GPS technology could provide real time tracking, traceback and quarantine capabilities (Reported at the 'Spatial Livestock Futures: outcomes of the GPS Livestock Tracking Workshop and Discussion Forum', 11 Sept 2009, University of New England).

monitored (via the animal's EID) and actions taken with significant implications for profitability. Section 5 considers the specific example of culling breeders on the basis of historical performance – made possible by linking performance to the cow's EID.

<u>Applications</u>: The obvious application of EID is statistical profiling for the purpose of raising the average performance of the herd through time. Thus individual animals can be sorted, culled or kept, supplemented, selectively joined, etc once the primary measurement systems are in place. Closely aligned to individual animal ID is the technology of proximity loggers where 'receivers' worn by a pair of animals allow collection of information on social encounters and affiliations. Thus contact or proximity loggers can record the date, time and duration of close encounters. As the frequency and duration of contact is a reliable indicator of which calf belongs to which cow, proximity loggers provide a means of positively relating animals to one-another. Ultimately, mother-offspring data can be linked via the animal's EID and used as a basis for accurate selection. While this might be justified for stud breeding purposes, it is not seen as applicable to the wider industry at this time.

<u>Stage of development</u>: Technologies that make use of EID (beyond biosecurity) already exist but uptake is likely to remain slow and variable for a host of reasons including the following:
Cost of setting up: Acquisition of tag readers and a crush side computer, etc amounts to a significant cost that has to be recouped via gains related to 'superior selection pressure'. Apart from hardware, there are significant 'learning' costs associated with 'how the whole system works' and how best to exploit its potential. Producers with an aptitude for computers will enjoy relatively low entry costs.
Obsolescence: The 'essential electronics' for using EID are not necessarily a once-only cost. Obsolescence and wear-and-tear are inevitable and add to the average fixed costs of using the system.

Incompatibility: Lack of compatibility between systems and abattoir feedback is also inevitable and amounts to another cost that has to be met before meaningful results can be accessed.
Maintenance of skills: Maintenance of systems and personal computer skills depends on frequency of use. This is not a problem for large operations that will have frequent and multiple computer-based applications but the average northern beef operation is too small to facilitate the natural accumulation of computer skills that comes with frequent use. If crush-side e-data are only collected 2-3 times a year, adoption will confront a learning barrier on every occasion (pers. comm. Mike Sullivan, QDPI Rockhampton).

For all of the above reasons, smaller-scale operators are likely to perceive that they cannot justify the overhead costs of implementing objective measurement systems. In this case we are inclined to think that NLIS/EID will remain a whole-of-industry tool with little individual application to the average beef property in northern Australia. The more general point to make is that PLMs with universal application are likely to be those that function automatically and deliver clear-cut results without placing significant additional demands on the operator's time or skills base. Several of the PLMs investigated in the study tend to fall into this category but high-level usage of EID is not one of them. Thus intensive usage of EID is likely to be confined to larger producers who can better absorb the requisite overheads, have more scope to employ specialist staff (with computer skills) and can benefit most from applying selection pressure to the herd.

<u>Potential economic advantage</u>: Data capture, management and manipulation are integral to maximising the use of technologies such as WOW, ART and auto-drafting. Without inclusion of the data management function (including capture, transmission and analysis) some PLMs are merely

data capture devices. Implicitly, therefore, the economics of WOW, ART and similar technologies should incorporate all the costs and gains associated with achieving the system's full potential. Certainly this is the approach taken in section 5 where we test the enterprise-level economics of each PLM.

4.3 Feedlot performance and management

4.3.1 Individual animal monitoring and management

<u>Background</u>: The precision technologies applicable to the lot feeding sector are similar in nature to those applying to enclosed waters because they permit automatic identification and management of individual animals for the purpose of maximising the production opportunities available to the system. Automatic identification of animals has become possible with the introduction of NLIS in combination with data reading and transmission technology. Several performance monitoring systems are under development but those coming out of North America are considered the most advanced and most relevant to this study. The GrowSafe system, under development in Canada since 2002, has the capacity to monitor liveweight, and water and feed intake[8]. GrowSafe software has the ability to track individual-animal performance and apply pre-determined decision rules based on feed intake, costs of production, prices and estimated carcass weight. It is possible to think of this system as 'automated decision making' for the purpose of profit maximisation.

However, it is not a foregone conclusion that such a clever system will be universally economic. As a general principle, the economics of monitoring and decision making systems will improve as the variability between the cattle making up a mob increases. Thus mobs that are 'homogenised' at the backgrounding stage of production, for the purposes of reducing variability, will provide relatively little scope for generating gains during the intensive lot feeding phase[9]. On the other hand, mobs that are not subject to deliberate 'homogenisation' (through selection pressure) prior to entering the feed lot will afford monitoring systems such as GrowSafe the potential to generate significant opportunity savings. With this caveat in mind, it is possible to explain the concept and its application further.

<u>The concept</u>: Regardless of whether we are monitoring the health or weight of individual animals, the rationale is much the same – the aim is to avoid opportunity losses to the point where further avoidance becomes uneconomic. In the case of animal health, feed and water intake are used as proxies for health and performance potential. In the case of weight, the cattle are sold direct to works with the unit price based on carcass weight and condition; price penalties (that give rise to opportunity losses) apply when carcasses fall outside the optimal specification. The probability of carcasses falling within the weight band that attracts the highest unit price can be maximised by monitoring individual animal liveweight and drafting off individuals as threshold weights are achieved. Clearly the system must be able to relate liveweight to carcass weight and it will be helpful to predict when optimal sale weight will be achieved.

[8] The GrowSafe system was chosen for scrutiny after discussions with the Dr Heather Burrow at the Beef CRC. After extensive investigation of competing systems, the Beef CRC chose GrowSafe for adoption at its Tullimba feedlot.

[9] Integrated beef production operations that breed, grow, background and finish their own cattle are well placed to apply selection pressures throughout the supply chain. If heavy selection pressure is applied at the backgrounding phase, mobs entering the feedlot will be relatively homogeneous (in terms of sex, age, weight and fat cover) and this will minimise the scope for performance drafting during finishing in the feedlot – when the opportunity costs of under-performance will be relatively high. However the application of selection pressures during the growing stages also carries a cost with culled cattle being sold prematurely or finished outside the feedlot channel for a lower-value end market.

Early identification of sick or under-performing animals affords the opportunity to take pre-emptive action that minimises weight loss relative to whole-of-mob performance and reduces cross infection. Traditionally it was the stockman's duty to visually identify sick and under-performing animals and separate them from the mob so that they could be treated and eventually returned. Access to stockman with such skills is becoming more difficult and costly, making it imperative to look for automatic means of finding and separating the sick animals. Based on performance profiling, GrowSafe can positively identify those animals likely to be sick or under-performing and provide an easy means of separating them so that they can receive treatment and convalesce before being returned to their mob. The payoff to early detection of sickness is given by the savings gap between an automated system (in this case GrowSafe) and a manual system that relies on visual detection.

<u>Applications</u>: The overall aim of automated decision making is profit maximisation. As intimated above this is achieved via two applications, firstly more accurate prediction of the optimal turnoff weight and secondly more accurate prediction of ill thrift in individuals – so that associated opportunity losses can be minimised.

<u>Stage of development</u>: GrowSafe will shortly be installed in the Beef CRC feedlot at Tullimba on the New England Tablelands. The Tullimba installation cannot be considered a commercial application but it might identify the local conditions under which GrowSafe would be economic.

<u>Potential economic advantage</u>: As suggested above, the economics of automated feedlot decision making will depend on the variability within the mobs entering the feedlot; in practice, the scope for generating benefits from automated decision-making will be directly related to the variability between animals within the mob. Anecdotally, vertically integrated operations that apply a lot of selection pressure at the growing and backgrounding phases of production are likely to have least need for an automated decision making system such as GrowSafe. The decision as to which feedlots should implement 'automated decision making' will obviously depend on the cost of implementing the system relative to the opportunity costs it can avoid.

The GrowSafe system is licensed to users and charged on a per head basis – estimated at about $10 per head by the time it is made commercially available in Australia. The likely economics of the system are tested quantitatively in the next section of the report.

5 Enterprise level economics of each PLM

5.1 Methodology

New technologies follow a pathway that typically commences with an idea and hopefully ends with commercialisation – signifying a successful 'journey'. The full gamut of stages that a technology can progress through includes the following:

1. Idea
2. Proof of concept / prototype
3. Full-scale trial
4. Market research and development
5. Commercialisation

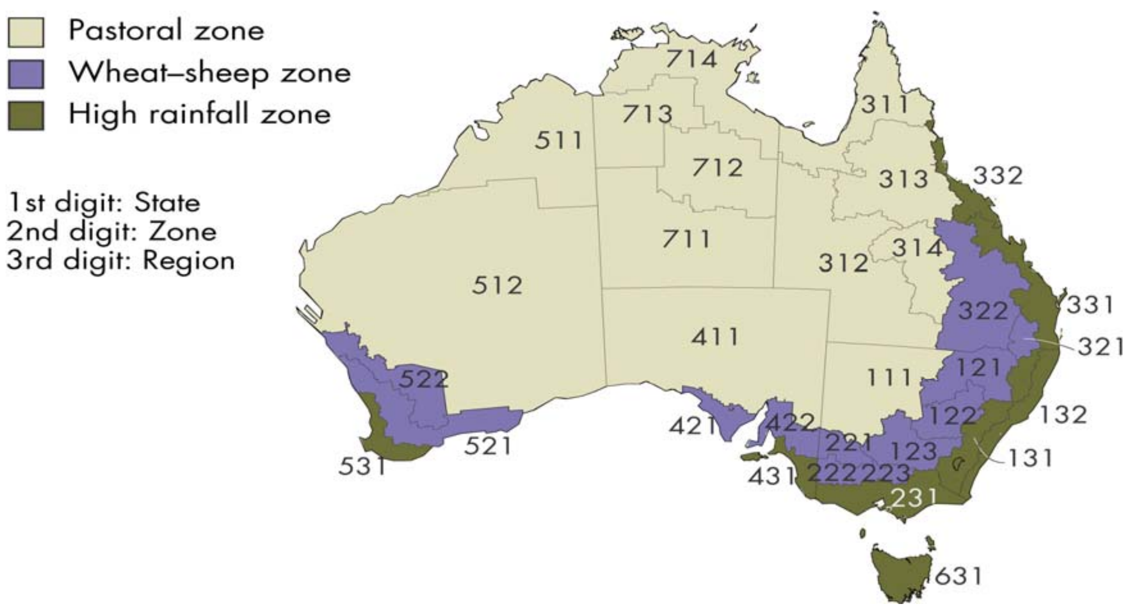
The analysis performed in this section assumes that all of the PLMs profiled in section 4 have completed the journey and 'made it into the market place'. Thus it was assumed for this analysis that any difficulties currently being experienced with development and commercialisation have been addressed. This is done for the purpose of determining the economics of each particular PLM at an enterprise level and at the industry level, assuming they can clear all the hurdles between where they are now and the real 'market'. It is then the task of later sections to assess each PLM after taking into account real-world considerations such as:

- The investment of time and money in R&D to take the PLM from where it is currently to the actual market
- The chances of the R&D overcoming any remaining technical obstacles
- The likely rate of adoption by producers when the PLM is presented to the market.

The potential benefit of each PLM technology at the enterprise level was assessed as the incremental gain from the introduction of the technology over a defined period. The investment performance of each PLM, based on annual net gain, was arrived at using cost benefit methodology. In each instance, the base case was derived from the Beef CRC templates "Regional Representative Herds" prepared by Bill Holmes from the Department of Employment, Economic Development and Innovation (DEEDI). Cost benefit methodology was used as most of the PLM technologies impact upon the operating costs, capital costs and value of sale cattle. As a rule, the PLM technologies examined did not significantly improve herd fertility, mortality or liveweight gain and therefore a more transparent and straight forward cost benefit analysis was used for the majority of the analysis. But 'Breedcow', was used to 'inform' the cost benefit analysis of Virtual Fencing regarding the impact of reducing the stocking rate on whole herd productivity.

The additional capital costs, operating costs and gross benefits were estimated for each of the prospective PLM technologies for each of the four regions. The assumptions behind these cost and benefit estimates were based on 'best available information' provided by the PLM developers, informed producers and the project team. The analysis in this section assumes the technologies are applied 'as envisaged' when developed. This approach was critical for establishing the potential economics of each technology. All of the assumptions used by the enterprise-level analysis are listed below the budget provided for each individual PLM. The analysis was aimed at providing a general estimate of the costs and benefits expected to apply to each PLM on the typical station located in each of the four regions as shown in Figure 1. It will be appreciated that our findings will not be applicable to all stations; actual results will always vary throughout depending on differences in scale of operation and the management system applying on individual cattle stations.

Australian broadacre zones and regions



The regional herd models represent the typical property in terms of scale, herd size, level of production and economic parameters for pastoral businesses in each of the regions. A summary of the data pertinent to northern cattle industry properties is presented in Table 5.1.

Table 5.1: Herd parameters for the typical station within each of the four regions based on Beef CRC templates "Regional Representative Herds" (AE: Adult Equivalent)

Herd parameters	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313a, b, c, d & 314)
Production data				
Weaning percentage	61%	79%	57%	63%
Bull percentage	4.5%	3.0%	3.8%	3.5%
Female deaths	3.4%	2.7%	4.7%	4.1%
Male deaths	2.0%	1.5%	2.0%	2.1%
Animal Numbers per property				
Breeders	2,212	420	4,264	1,021
Spay Cows	-	-	268	-
Heifers retained	678	166	1,210	319
Bulls	100	13	163	36
Steers/Bullocks	1,980	487	2,977	1,144
Total Numbers	4,969	1,086	8,882	2,520
AE's	4,237	1,025	6,766	2,211
Sale price				
Heifers/Cows	$414	$656	$458	$501
Spay females	$0	$0	$412	$484
Steers/Bullocks	$591	$1,022	$502	$821
Bulls	$727	$1,053	$739	$782
Economics per property				
Sales income	$616,178	$261,318	$982,879	$375,377
Husbandry costs	$78,766	$17,242	$140,874	$58,532
Bull costs	$47,411	$10,480	$56,056	$14,702
Gross Margin ($)	$490,001	$233,597	$785,956	$302,142
Gross Margin ($/AE)	$116	$228	$116	$137
Capital value	$1,826,427	$59,876	$3,335,679	$1,131,465
Regional data				
Average herd size (AE's)	5,537	1,081	8,482	2,476
Number businesses	52	3,166	273	1,197
Total Numbers (AE's)	287,924	3,422,446	2,315,598	2,963,409

5.2 Benefits and costs of the PLMs at the enterprise level

5.2.1 Unmanned aerial vehicles for surveillance

Unmanned aerial vehicles have been successfully applied by the military for some years but have not yet been commercially used in the pastoral industry; nor has there been any significant R&D on their application to the pastoral industry. Although there has been little research in this field the authors and UAV developers believe the technology has application to the northern pastoral industry – chiefly for surveillance – but also for supplementing mustering activities. Establishing the economic potential of UAVs is difficult at this stage given the lack of commercial data. The economic analysis presented below is therefore based on data sourced from the UAV suppliers, the authors' own experience and input from beef producers in the four regions.

For this analysis it was assumed that UAVs are used to check all fences pre and post muster, check flood crossings during the wet season and check the water points once a week. The most logical UAV for this application would be a fixed wing UAV as they are cheap, reliable and fast and have the load carrying capacity for surveillance equipment. Surveillance by this means would reduce vehicle travel (valued at $1.20 per km) and labour costs (assumed to be $20 per hour) associated with fence maintenance and reduce the cost of the bore run. Any faults would still need to be fixed on the ground, but the associated trips would be focused and linked to the remaining infrastructure. The only savings considered in this economic analysis were those resulting from the reduced cost of monitoring the fences.

The analysis assumed that the larger stations in the Arid Zone and Gulf, Kimberley and Top End would lease a UAV unit worth in the order of $30,000 and would train a staff member to operate the unit. We assumed these stations budget $5,000 per year to fix major breakdowns. Flying and maintenance costs are estimated by the manufacturer to be in the order of $30 per hour.

For the Southern, North and Central Queensland regions it was assumed the stations would contract the UAV supply and management out to a commercial group, who would provide the UAV on an hourly basis and operate the unit on site. This would be based on a number of producers in an area using the UAV to justify a commercial group offering a service. Commercial rates for operating in the pastoral industry are not yet available so an assumed rate of $130 per hour was used, based on the value of the unit, hours used and estimated operating costs. The distance travelled, number of hours used, and time frame would significantly influence this rate. A summary analysis is provided in Table 5.2.

Table 5.2: Opportunity gains attributable to UAV application for monitoring by region

	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313 & 314)
Costs				
Operating hours (assumed hrs/yr) (a)	67	15	80	27
Staff Training & set up in year 1 (b)	$10,000	$5,000	$15,000	$8,000
Operating costs (c)	$2,000	0	$2,400	0
Annual fixed lease and Repairs cost ($/yr) (d)	$13,000	$2,450	$15,000	$4,310
Total annual operating costs	**$15,000**	**$2,450**	**$17,400**	**$4,310**
Benefits				
Check fencing (prep & post muster, routine & flood crossings in wet)				
Reduction in vehicle travel ($) (e)	$2,400	$528	$2,880	$960
Reduction in labour ($)	$2,667	$587	$3,200	$1,067
Reduce water monitoring by 1 run per week (f)				
Reduced bore run lenght (km/week)	250	55	300	100
Reduced bore run lenght (km/yr)	7,500	1,650	9,000	3,000
Reduction vehicle costs	$9,000	$1,815	$10,800	$3,300
Reduction in labour costs	$2,500	$550	$3,000	$1,000
Total savings per year	**$16,567**	**$3,480**	**$19,880**	**$6,327**
NPV (Discount rate 10%, 10 yrs)	**$536**	**$1,781**	**$1,602**	**$5,119**
IRR	**12%**	**21%**	**13%**	**31%**

Assumptions:

(a) Operating hours based on the distance to be flown on each station and the speed of the UAV (30 km/hr)
(b) Staff training is based on sending one staff member to Brisbane to learn about the applications and for the larger properties how to fly and maintain the UAV
(c) The operating costs are the hourly costs to operate the UAV ($30/hr)
(d) The lease costs are based on a commercial lease for a $30,000 unit plus a profit margin for a commercial UAV lease company on the arid zone and Gulf, Top End and Kimberley (assumed to be a four year equipment lease). The lease costs in central, north and southern Queensland is the commercial lease per hour (assumed $130/hr)
(e) The reduced vehicle travel for checking fences is based on a saving of two station runs around property fences per year and a vehicle running costs of $1.20/km and a labour cost of $20/hr
(f) The reduced bore run costs are based on a vehicle running cost of $1.20/km and a labour cost of $20/hr

The analysis in Table 5.2 suggests that the UAV's have surveillance potential in all of the regions but especially in Southern and Central and North Queensland. This result is likely to be a function of the smaller paddocks in these areas as well as the economics of contracting the operation of the UAV equipment from a commercial group. The lease option is dependent on a contractor offering the required services for the assumed price, or lower, when and where required. It was assumed that the contractor does not charge relocation costs, which would be expected if there is significant demand in a region.

5.2.2 Small unmanned helicopter for mustering

UAVs could also supplementing mustering activities and potentially reduce the cost of helicopter mustering. Using UAVs for mustering has not yet been demonstrated, but radio controlled aircraft have already been used to assist mustering (tested by authors). V-TOL, a commercial UAV provider, also believes that mustering would be technically feasible. They suggest the UAV could be controlled by a trained person on the ground, with live video feed back. The unit could be used, to muster and move cattle within smaller paddocks and work in conjunction with other mustering systems.

For this analysis it was assumed that the UAV would be primarily used for mustering. It was assumed the UAV operates at 30 km per hour and costs approximately $30 per hour to operate. It was also assumed the units would only be used in the smaller paddocks (< 30 km^2) and standard mustering techniques would be used in the larger paddocks.

The analysis assumed that the larger stations in the Arid Zone and Gulf, Kimberley and Top End would lease a UAV unit worth in the order of $30,000 and would each train a staff member to operate the unit. In addition they would budget $5,000 per year to fix major breakdowns while the flying and maintenance cost would be in the order of $30 per hour.

On the Arid zone properties and Gulf, Kimberley and Top End stations it was assumed that the UAV would also be used to check fences and other surveillance requirements as proposed in the analysis under 5.2.1. A summary analysis of the investment criteria is provided in Table 5.3.

Table 5.3: Opportunity gains attributable to UAV helicopter for mustering and checking fences and waters

	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313 & 314)
Costs				
Operating hours (assumed hrs/yr) (a)	127	15	173	94
Staff training & set up in year 1 (b)	$10,000	$5,000	$15,000	$8,000
Operating (c)	$3,818	$0	$5,186	$0
Annual fixed lease, training and R&M cost ($/yr) (d)	$17,000	$2,450	$20,000	$13,075
Total annual operating costs	**$20,818**	**$2,450**	**$25,186**	**$13,075**
Benefits				
Check fencing (prep & post muster, routine & flood crossings in wet)				
Reduction in vehicle travel ($) (e)	$2,400	$528	$2,880	$960
Reduction in labour ($)	$2,667	$587	$3,200	$1,067
Reduction in helicopter mustering costs (%)	10%	0%	10%	25%
Helicopter costs (f)	$57,585	$0	$88,213	$25,747
Hours	152	-	232	68
Reduction in helicopter costs ($)	$5,758	$0	$8,821	$6,437
Reduce water monitoring by 1 run per week (g)				
Reduction vehicle costs	$9,000	$1,815	$10,800	$3,300
Reduction in labour costs	$2,500	$550	$3,000	$1,000
Total savings per year	**$22,325**	**$3,480**	**$28,701**	**$12,763**
NPV (Discount rate 10%, 10 yrs)	**$167**	**$1,781**	**$7,966**	**-$9,186**
IRR	**11%**	**21%**	**27%**	**0%**

Assumptions:

(a) Operating hours based on the distance to be flown on each station and the speed of the UAV (30 km/hr)
(b) Staff training is based on sending one staff member to Brisbane to learn about the applications and for the larger properties how to fly and maintain the UAV
(c) The operating costs are the hourly costs to operate the UAV ($30/hr)
(d) The lease costs are based on a commercial lease for a $30,000 unit plus a profit margin for a commercial UAV lease company on the arid zone and Gulf, Top End and Kimberley (assumed to be a 4 year equipment lease). The lease costs in central, north and southern Queensland is the commercial lease per hour (assumed $130/hr)
(e) The reduced vehicle travel for checking fences is based on a saving of two station runs around property fences per year and a vehicle running costs of $1.20/km and a Labour cost of $20/hr
(f) The Helicopter cost and hours are based on regional commercial costs
(g) The reduced bore run costs are based on a vehicle running cost of $1.20/km and a labour cost of $20/hr

The analysis in Table 5.3 shows the additional benefit from a reduction in mustering cost on top of the surveillance advantages. These results suggest that UAV’s have potential to assist with mustering and surveillance on Gulf, Top End and Kimberley properties and to a slightly lesser extent on the properties in the Southern Queensland region.

5.2.3 Virtual fencing

For the purposes of understanding the expected economic benefits of VF, we assumed the technology would be used to increase pasture utilisation within existing paddocks[10]. The VF system

[10] VF is assessed on this occasion without inclusion of any of the supplementary technologies (mentioned in section 4) that might eventually make it a far more powerful and holistic technology.

would be used to rotationally graze the pastures and force cattle to access 100% of the area of the paddocks, thus minimising selective grazing and more uniformly graze the existing pasture. Implicitly, this assumes cattle can access water points from 100% of the paddock area. In this analysis it was assumed that more uniform and complete grazing would lead to a 5% increase in the station's carrying capacity. This is clearly a critical assumption but it was based on the consultant's first-hand experience with patch grazing studies at Pigeon Hole (see *Optimal Utilisation Rates – The Pigeon Hole Project 2002-2007* a joint MLA and Heytesbury joint project) and other sites. We do not believe that there exists any basis for adopting a more favourable assumption at this time. It was also assumed that VF could be used to manage the location of the cattle sufficiently to place them near yards prior to muster thereby reducing mustering costs by 50%.

As explained in section 4, Virtual Fencing uses a combination of devices to provide real time control over a herd's movements. The devices include collars and ear tags that are effectively linked; while both have the ability to send movement cues, only the collars carry the GPS readers, which have relatively high power needs. The herd can be effectively controlled by a combination of collars and tags yet the two devices have vastly different costs. So the average cost of a controlled beast within a herd depends on the proportion equipped with collars versus the proportion equipped with complementary ear tags. For the purposes of this study, it was assumed that 25% of the controlled herd is equipped with a collar while the balance is equipped with a linked ear tag.

Virtual Fencing collars have not yet been produced under commercial conditions. However, the researchers have suggested that this study should assume a current 'commercial' cost in the order of $300 per collar. The cost per animal within a controlled mob will depend on the proportion that is collared versus ear tagged. Assuming a 25:75 ratio and respective costs of $300 and $60, the average weighted cost for a 'controlled herd' would be $120 per head. The cost of the sensor network to communicate with these collars has been assumed to be $100 per unit, with each unit covering a 750 m range. Given there is an existing network of paddocks, we assumed that 50% of the station would need to be covered by sensors, thereby allowing the analysis to be completed on a whole-of-station basis. These sensors are needed to send signals back to a central computer at the homestead. The outcome of the cost benefit analysis for VF is presented in Table 5.4.

Table 5.4: Opportunity gains attributable to Virtual Fencing application by region

	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313 & 314)
costs				
Number of breeders	2,212	420	4,264	1,021
Average cost of control device per animal	$120	$120	$120	$120
Cost for tags (@ $120 each) (a)	$265,405	$50,411	$511,637	$122,503
Area (km2) (b)	923	54	1060	165
Number sensor units (50% stn x $100/unit)	98	6	112	18
Cost network ($)	$9,792	$573	$11,250	$1,751
Total Capital Cost	**$275,197**	**$50,985**	**$522,887**	**$124,254**
Annual Maintenence costs	**$11,059**	**$2,100**	**$21,318**	**$5,104**
Benefits				
Increases income due to 2.5% increased carrying capacity (fn regional models) (c)	$15,990	$6,153	$25,382	$8,637
Assumed mustering cost	$57,585	$11,242	$88,213	$25,747
Reduction in mustering cost by 50% (d)	$28,792	$5,621	$44,107	$12,874
Total savings/yr	**$44,782**	**$11,774**	**$69,488**	**$21,511**
NPV (Discount rate 10%)	**-$192,775**	**-$15,368**	**-$468,172**	**-$81,298**
IRR	**0%**	**-2%**	**0%**	**0%**

Assumptions:

(a) Control devices cost $120 per head
(b) The area refers to the average station in this region derived from the ABS data
(c) The increase in carrying capacity derived from better utilisation of the pasture through better grazing distribution.
(d) Reduced mustering cost by 50%

Based on a collar cost of $300 per animal and the other assumptions used by the analysis, it would not be economic to establish virtual fencing in any of the four pastoral regions.

5.2.4 Animal recognition technology + auto drafting and telemetry

The application of animal recognition technology (ART) plus auto drafting and telemetry is currently being researched and demonstrated. As suggested in section 4.2.1, the key benefits for ART are the capacity to separate feral animals from a mob of cattle and to draft cattle on the basis of size or shape (ie without the need to weigh or reference an EID). To estimate the economic value of ART it was assumed units were established on water points near the perimeter of the station. Trap yards and a holding paddock were then established at key water points and the animal recognition and auto drafting system placed in the yards. We assumed that any additional waters were fenced off to ensure the cattle utilised the established waters and the system had a 10 year life, with the yards and fencing having a residual value at the end of 10 years.

The aim of establishing these units is to capture feral animals including unbranded cattle and other uncontrolled species. On many places, these feral animals are missed in the standard musters but a trapping system may capture them late in the dry season. Installing these units would also avoid the second round muster with 20% of the breeders that utilised the water points. The second round muster is avoided on these waters by drafting the weaners from the cows and drafting the cleanskin calves from the cows as they come in to water, so they can be branded and/or weaned. The opportunity saving was assumed to be a $7 per head per year reduction in mustering costs on the second round. This mustering cost was used across all stations as the larger, more extensive stations, are able to dilute the cost with helicopters and large numbers. The smaller stations do not have to muster such extensive areas but do not have the numbers to dilute overhead costs. Our estimates of the opportunity savings for each region are shown in Table 5.5.

Table 5.5: Opportunity gains attributable to ART + AD + T by region

	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313 & 314)
Costs				
Units established to achieve benefits	4	1	6	4
Capital Cost ($67,600 per site) (a) + (b)	$270,400	$67,600	$405,600	$270,400
Annual Maintenance costs	**$6,000**	**$1,500**	**$9,000**	**$6,000**
Benefits				
Number of feral animals captured and sold cattle (2% herd) (c)	99	-	135	50
Sale value of ferals and cleanskins (@ net $250 each) (d)	$24,844	-	$33,829	$12,599
Number of breeders (e)	2,212	420	4,264	1,021
Reduction in cost 2nd round muster for 20% breeders (@ $7/hd) (f)	$3,096	$588	$5,969	$1,429
Total savings/yr	**$27,941**	**$588**	**$39,798**	**$14,029**
NPV (Discount rate 10%)	**-$76,704**	**-$58,483**	**-$128,038**	**-$162,188**
IRR	**2%**	**-20%**	**1%**	**-6%**

Assumptions:

(a) Cost of the Animal recognition unit and auto drafting unit = $17,000, This Animal Recognition Technology equipment has a 10 year life
(b) Cost of the trap yards is $25,000 and the cost of the holding paddock is $25,600
(c) This unit would capture feral animals, which are assumed to occur at 2% of the total herd numbers
(d) The sale value of feral animals or cleanskins was assumed to be a net value of $250/head
(e) Average number of breeders on a station in this region.
(f) The unit would be used to draft calves from 20% of the breeder paddocks late in the dry season, saving the cost of the 2nd round muster on these paddocks.

The high capital costs of establishing the trap and holding paddocks equipped with ART and auto draft, restricts the potential return from this technology, especially on smaller more developed stations[11]. In extensive regions there is more opportunity to capture and sell feral animals, particularly in the Arid Zone where trapping is more widely used. In the Gulf, Top End and Kimberley regions this system will have application in paddocks where there is no surface water and in areas where trapping can be practiced effectively. Although feral animals are more prevalent in the Kimberley and Top End, natural surface water is widespread, thus restricting the ability to apply a trapping system with water as the attractant. In the more developed regions, there is generally less

[11] While making the ART unit mobile and shifting it between waters would act to reduce unit capital costs, total capital costs are dominated by the permanent yards that have to be constructed at each watering point. These yards are necessarily robust and need to hold relatively large numbers. In addition, the holding yards would need to be equipped for feeding facilities if animals are accumulated at the waters before bulk removal.

advantage to be gained from the capture of feral animals as there is likely to be less feral animals on the property.

ART may have application outside the ‘northern beef industry, most particularly in the Goldfields and Gascoyne regions of Western Australia. Certainly this will be the case on properties where the controlled waters are already substantially fenced, thus avoiding the biggest single barrier to making ART an economic proposition.

5.2.5 Walk over Weighing (WOW) + Auto drafting (AD) + Telemetry (T) + Electronic identification (EID)

Walk over weighing is still in the research phase but a prototype unit has been developed in central Australia allowing collection of daily weights and demonstration of auto-drafting. The ‘remote livestock management system’ was described in the WOW section in section 4. This system involves routine weighing of growing cattle post drinking from an enclosed watering point over a period of time and then finally drafting according to weight or EID. The major benefit of this application is daily performance recording that can be used to more effectively market the cattle, ie virtually ensuring all sale cattle fall within premium specifications. The application of this technology is expected to result in a marginally higher overall sale weight as a result of selling the cattle before they start losing weight at the end of the growing season as well as a possible price premium as a result of having all of the animals within specification. Additional economic advantages can accrue through a reduction in mustering costs and avoidance of weight loss due to traditional mustering and drafting.

The potential value of this technology depends on the region to which it is applied. In the Arid zone, trapping is an effective tool and the addition of WOW to the trapping system provides the capacity to target appropriate weight specifications or some other sale specification (eg sex, age, etc). In the economic evaluation, we have assumed that the ability to more effectively target sale cattle will result in a 2.5% premium on sale price. This is based on research conducted at Napperby station in central Australia. In this region the seasonal conditions have a significant impact on weight gain and timely decisions on the time of sale can have a major impact on sale weight. This analysis also assumes the capacity to sell cattle before they start to losing weight will increase the average sale weight by 5%.

In Central, North and Southern Queensland the lower incidence of grower paddocks with enclosed water may limit the application of this technology. In paddocks with controlled water there would be some potential to target the timing of sales and attract a premium. In the Gulf, Top End and Kimberley there are not likely to be many paddocks where the waters are enclosed, thereby restricting the ability to apply the technology. Assuming a station in this region did identify these paddocks for growers (eg, open black soil paddocks) the WOW system may deliver an improvement in sale weight by ensuring turnoff cattle are sold at the optimal time and minimise weight loss due to mustering, weighing and drafting. In the economic evaluation we assumed a 5% increase in sale weight based on the Napperby experience. As these regions primarily target the live export market and sell on the basis of a flat unit price, there would be limited capacity to attract a premium by drafting into tighter specification. The exception to this would be those stations that turn off growers to be value added ‘down south’.

The expected benefits from WOW+AD+T, assuming a system life of 10 years, are shown in Table 5.6.

Table 5.6: Opportunity gains attributable to WOW+AD+T by region

	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313 & 314)
costs				
Units established to achieve benefits	3	1	3	2
Capital Cost (&, $77,600 per site) (a)+ (b)	$232,800	$77,600	$232,800	$155,200
Annual Maintenence costs	**$12,000**	**$4,000**	**$12,000**	**$8,000**
Benefits				
Number of sale cattle per year	1,274	249	1,951	569
Average sale value ($0) (c)	$483	$807	$480	$660
Improved sale value ($/hd) (d)	$37	$49	$24	$47
Total addtional gross income (e)	$46,902	$12,139	$46,821	$26,683
Reduction in labour costs (f)	$2,547	$497	$3,902	$1,139
Total savings/yr	**$49,449**	**$12,636**	**$50,723**	**$27,821**
NPV (Discount rate 10%)	**$26,111**	**-$13,585**	**$33,969**	**-$12,435**
IRR	**13%**	**5%**	**14%**	**8%**

Assumptions:

(a) The walk over weighing, auto drafting and Telemetry systems combined costs $27,000
(b) The cost of the trap yards = Portable panels ($25,000) + holding paddock (8km*$3200 = $25,600) & the units have a 10 year life.
(c) This is the average regional sale price based on ACR data
(d) Increase sale weight by 5% through selecting the optimum time of sale and reduced weight loss and Increase sale price by 2.5% due to targeting the right market
(e) This is the number of sale cattle by the total additional gross income
(f) Assumed reduction in weighing cost (labour and weight loss)

The results suggest that WOW has modest prospects. Beyond this, the technology's best application would be in the Arid Zone and in the Gulf, Top End, Kimberley region where many properties have paddocks with controlled waters. The high capital cost of establishing the Remote Livestock Management System at waters is likely to limit its application in the Central and North Queensland region and in the Southern Queensland region although there might be some pockets within these regions where the technology could be profitably applied.

5.2.6 Telemetry and water monitoring

The economics of telemetry can be tested using partial budgeting that compares its costs and benefits relative to those for conventional water monitoring. Telemetry units can be established on one or a number of water points across a station. On this occasion it was assumed that telemetry units are established on 50% of the more difficult to monitor water points, resulting in a reduction of one bore run per week per station. The assumed reductions in distance travelled and labour hours saved for each region are listed in Table 5.7. A maintenance cost of $500 per unit per year was used to allow for consistent upgrades of the units. It was assumed the units have a 10 year life. It was also assumed the telemetry units were used primarily to monitor water levels. The potential to value-add these units by monitoring water medicators, automatically start and stop bores, etc are significant but were not considered in this analysis.

Table 5.7: Opportunity savings attributable to telemetry by region

	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313 & 314)
Costs				
Units established to achieve benefits (a)	9	2	14	4
Purchase price (@ $3,000/unit)	$27,000	$6,000	$42,000	$12,000
Annual Maintenance costs	**$5,400**	**$1,200**	**$8,400**	**$2,400**
Benefits				
Reduced bore run length (km/week) (b)	250	55	300	100
Reduced bore run length (km/yr)	7,500	1,650	9,000	3,000
Reduction vehicle costs (c)	$9,000	$1,980	$10,800	$3,600
Reduction in labour costs (d)	$2,500	$550	$3,000	$1,000
Total savings/yr	**$11,500**	**$2,530**	**$13,800**	**$4,600**
NPV (Discount rate 10%)	**$17,845**	**$3,809**	**$2,635**	**$4,791**
IRR	**37%**	**36%**	**13%**	**26%**

Assumptions:

(a) There are 300 head on average at each water point and telemetry units are established on 50% of the waters
(b) This is the estimated length of a bore run on this 'typical' station
(c) The running cost of a vehicle is assumed to be $1.20/km
(d) The labour cost of $20/hr

This basic telemetry system examined was found to be economic for beef producers in all regions. The potential economic benefit for an individual station will depend on distance to water points, capacity to check the waters on a regular basis and the terrain separating waters.

5.2.7 Data management systems

Compliance with the NLIS system requiring cattle to be tagged with electronic devices incorporating a unique identification number is widespread throughout Australia. Electronic identification (EID) provides the opportunity to collect data for individual animals and use this information to make more informed management decisions as suggested in section 4.2.5. Some producers are starting to capitalise on this opportunity but it remains difficult to analyse individual animal data and make timely decisions based on statistical principles. While costly, potential exists to contract the data analysis to a third party, thereby allowing the producer to be provided with timely advice, based on statistically valid data analysis. But as pointed out in section 4, 'data analysis' is not the only barrier to greater utilisation of EID.

In this example it was assumed that the producer commissions a technical group to regularly analyse the weight and fertility data collected for individual animals. Equipped with these data, the analyst would generate two key outputs within two years. First, they would identify the less productive breeders in the herd. These are breeders that consistently conceive but rarely return to the yard with a calf at foot. Herds in the VRD and Barkly region have 5-10% of the breeders in this group (Petty pers comm.) In this analysis we have assumed 5% of the breeding herd were in this category and could be identified through the EIDs and analysis. It was assumed that the non performing breeders are sold (for $400 each) and replaced with fertile breeders (costing $550 each).

It was assumed there would be on-station capital costs to set-up the system and there would be a net capital cost for the additional breeders. The charge rate from the technical support group was assumed to be $0.50 per head for larger stations and $1.00 per head for smaller stations based on provision of a similar commercial service. The results of the analysis are shown in Table 5.8.

Table 5.8: Opportunity gains from decision making based on analysis of individual animal data

	Arid Zone - Alice Springs region (Zone 711)	Southern Queensland (Zone 322)	Gulf, Top End and Kimberley (Zones 511, 713, 714, 712 & 311)	Central & North Queensland (Zone 313 & 314)
costs				
Capital cost to set up (a)	$10,000	$6,000	$10,000	$8,000
Capital for additional breeders minus sale culls (b)	$55,370	$10,810	$84,820	$24,757
Total herd numbers	5537	1081	8482	2476
Service agreement (cost per head) (c)	$0.65	$1.20	$0.55	$0.80
Annual service costs	$3,599	$1,297	$4,665	$1,981
On station cost to collect data ($2/hd) (d)	$11,074	$2,162	$16,964	$4,951
Total annual costs	**$14,673**	**$3,459**	**$21,629**	**$6,932**
Benefits				
Cull 5% non performing breeders				
Total Breeders	2,212	420	4,264	1,021
Increased net profit due cull of non performers (e)	$32,038	$8,614	$50,764	$17,289
Total savings/yr	**$32,038**	**$8,614**	**$50,764**	**$17,289**
NPV (Discount rate 10%)	**-$20,366**	**-$1,796**	**-$14,352**	**-$2,640**
IRR	**5%**	**8%**	**8%**	**9%**

Assumptions:

(a) Capital cost to set up includes equipment on station, upgraded internet, upgraded computing and data recording equipment
(b) Sell poor performing cows for $400 and purchase chance mated breeders for $550 plus transport costs
(c) Support cost per head for the stations range from $0.55/head on the more extensive stations to $1.20/head for smaller stations, based on complexity of analysis and level of interaction
(d) On station labour costs to collect the data at $2/head
(e) Utilise the NLIS system to cull the 5% of the breeders that are not performing and replace them with fertile cows. The economic benefit from culling the 5% non performing cows was derived from Breedcow modelling of the typical herd in each region. Assumed the infertile cows are sold for $400 and chance mated cows are purchased for $500 plus transport.

This simple cost benefit analysis suggests there is some potential in all four regions to make greater use of individual animal data tied in the first instance to the nation-wide EID system but particular note should be made of the limitations outlined in section 4.

5.3 Southern Queensland feedlots

5.3.1 Quantitative assessment of benefits

GrowSafe is an animal selection technology that is currently being tested in Australian feedlots. An economic analysis (non- specific to a region) was carried out to assess whether the benefits from applying the technology in a representative feedlot would outweigh the costs involved.

This was achieved through analysing 48,604 records of beef animals that passed through a Case Study feed lot between August 2005 and June 2009. The animals were analysed to assess the potential savings that could be made from turning all animals off at a premium weight – determined in relation to the market's price schedule. In the first instance, the analysis examined the weight performance of steers in the 2-tooth and 6-22 mm fatness range. This class of animal made up 18,338 or 38% of the total throughput over the four years.

In order to attract the premium price (the highest price on offer) steers in this class had to have a carcass weight of at least 320 kg. In this case we estimated the opportunity loss (or additional gross revenue) that would have been obtained if animals in the category had equalled or exceeded the premium weight (320 kg). The opportunity loss suffered by carcasses failing to achieve the premium weight was estimated in two parts: 1) the actual weight times the applicable price discount; and 2) the weight shortfall times the premium price.

The nature of the calculations can be demonstrated for one animal using the following assumptions:

Premium price	345 c/kg (paid for carcasses exceeding 320 kg)
Example carcass weight	305 kg (15 kg below premium weight)
Price for 305 kg carcass	340 c/kg (5c/kg discount on the premium price)

Opportunity loss = (305 kg x 5c) + (15 kg x 345 c) = $15.25 + $51.75 = $67.00

About 10% or 1,820 of the 18,338 steers with less than 2 teeth and 6-22 mm of fat were sold at less than the premium weight. The value of weight loss averaged $49.35 per animal for those animals not achieving the premium weight. This translated to about $4.90 per animal across all animals in the category.

The opportunity on offer of $4.90 per animal does not account for the cost of additional feed that would be needed to achieve the premium carcass weight of 320 kg. For the sample used, the additional average weight gain required was 9.8 kg per head or 17,854 kg across 1,820 animals. At a feed conversion ratio of 9.6 kg of mixed feed per one kg of carcase weight, we would need about 171,000 kilograms of feed to add the required carcass weight. Assuming 20 cents per kg of feed, the additional gain would cost $34,200. This would be equivalent to $18.80 per affected animal, or $1.87 per head across the whole category.

Assuming there would be no additional labour or holding costs (eg infrastructure or capital) the net gain over feed from identifying and ensuring the lower weight gain animals reached 320 kg was $4.90 less $1.87 ie just over $3 per animal.

This $3 per head across the pen would be insufficient to cover the estimated $10 per animal cost for all animals enrolled in the GrowSafe system. Apart from the issue of the system's cost effectiveness, there are other considerations that would work against selecting turnoff cattle on the basis of individual weight. In practice, feedlot cattle tend to enter, stay and leave in lots. This is done for both economic and behavioural reasons. From an economic perspective, average fixed costs per beast are minimised by utilising the holding capacity of the facility to the maximum extent possible. This economic principle favours an 'all in all out' approach as does the desirability of not splitting or mixing mobs within the feedlot – because of the tendency for mobs to become internally socialised. These two considerations, added together, work against the notion of 'drafting off the top'.

In addition to informing management regarding the optimal turnoff weight, GrowSafe might identify more quickly those animals that get sick and thereby provide quicker pre-emptive treatment. The same feedlot, for example, treated about 1% of its annual throughput of animals (300/35,000) for some form of sickness. But because many of the identified animals could be underweight due to sickness, it was decided that assigning another benefit to the GrowSafe technology could result in double counting and over-estimation of potential savings.

In addition to morbidity, the feedlot suffers annual mortalities of about 0.2% (60 - 100 out of 35,000 annual throughput). It should not be unreasonable to assume that an ‘automated pre-emptor’ could detect morbidity much more rapidly than a (possibly inexperienced) yard-rider. Assuming that pre-emptive action (afforded by GrowSafe) could save 50% of the mortalities across 18,338 animals and they had a value of $1,200 per head, the opportunity saving would have been $44,000 per annum or $2.40 per animal across the entire category.

The total benefit from the technology therefore is estimated at $5.40 per head (ie $4.90 - $1.86 + $2.40) for all animals in the category. This opportunity can be compared directly with the $10 per head charge for using a technology such as GrowSafe.

The turnoff weights used in this analysis were drawn from a ‘cattle management system’ that homogenises the cattle entering its feedlot at the weaning, growing and backgrounding stages of production. Thus selection pressure in the early stages of production has the effect of reducing variability in entry weight to the feedlot.

The estimated costs and benefits are summarised in Table 5.9.

Table 5.9: Opportunity gains from applying selection technology in a feedlot

Cost	Value
Cost per head per annum	$10
Cattle throughput per annum	30,000
Total annual cost of applying the technology	$300,000
Benefits	
Gain in value due to animals identified now reaching the premium weight	$4.90 per animal average
Gain due to lower mortality	$2.40 per animal
Less cost of additional feed	$1.87 per animal
Net gain due to technology	$5.43 per animal
Total annual gain across 30,000 head before costs	$162,900
Net result from applying the technology	-$137,100

Thus it is possible to conclude that adoption of automatic selection and optimisation technology (such a GrowSafe) would not provide a worthwhile benefit to feedlot business that apply heavy selection pressure to cattle prior to them entering the feedlot. Specifically, the costs of using the technology would exceed the benefits it could generate.

However there might be other circumstances under which GrowSafe (or some similar technology) could prove to be economic. These circumstances are likely to exist where the inherent cost of variability is high because the feeder cattle have been subject to relatively little selection pressure prior to going into the feedlot. If, for example, the feedlot buys its feeder steers out of saleyards or accumulates them haphazardly from independent backgrounding operations, there is likely to be a lot of variability between entry weights (and other determinants of performance) and this in turn will build potential for profitable application of automated selection technology. The opportunity cost of such variability would have to exceed $10 per head across the particular feedlot before adoption of GrowSafe would be economic.

The overall conclusion is that the economics of selection technologies (such as GrowSafe) will depend on the management and operating systems employed by the individual feedlot. Thus the application of GrowSafe should be determined on a case-by-case basis.

A summary of the enterprise-level results for all PLMs and regions is shown in Table 5.10.

Table 5.10: Summary of enterprise-level results for PLM and region

PLM		Arid zone	Southern Qld	Gulf, Top End & Kimberley	CQ and NQ
UAV – surveillance	NPV	$536	$1,781	$1,602	$5,119
	IRR	12%	21%	13%	31%
UAV – mustering	NPV	$167	$1,781	$7,966	-$9,186
	IRR	11%	21%	27%	0%
VF	NPV	-$192,775	$15,368	$468,172	-$81,298
	IRR	0%	-2%	0%	0%
ART+AD+T+ED	NPV	-$76,704	-$58,483	$128,038	$162,188
	IRR	2%	-20%	1%	-6%
WOW+AD+T+ED	NPV	$26,111	-$13,585	$33,969	-$12,435
	IRR	13%	5%	14%	8%
Telemetry x water monitoring	NPV	$17,845	$3,809	$2,635	$4,791
	IRR	37%	36%	13%	26%
Data management system	NPV	-$20,366	-$1,796	-$14,352	-$2,640
	IRR	5%	8%	8%	9%
Feedlot monitoring (a)	NPV	-$137,100			

(a) As there was no up-front capital investment for this technology, the results are presented as an annual gross margin for a 30,000 head feedlot.

6 Potential industry benefits, likely adoption and investment criteria for further investment

6.1 Introduction

The analysis to this point has investigated PLMs from two perspectives. Section 4 introduced each PLM in terms of background, parties involved, the underlying concept, applications and the basic determinants of economics. This work identified how and where economic benefits might be realised on-farm – usually in the form of opportunity savings relative to existing management and production systems.

Section 5 provided a quantitative analysis of each PLM at an enterprise level, for each region, assuming that the PLM was already fully developed and could be put into practice immediately. However, the analysis did not consider the likely adoption rates expected in practice or the remaining investment (of time and money) needed to take each PLM to the market place.

Hence this section presents:

(i) The potential industry net benefits for each PLM and for each of the four regions

(ii) A method for determining likely adoption rates

(iii) The industry net benefits for the most likely adoption rates

(iv) The investment required to address the remaining constraints (mostly identified by the proponents)

(v) A cost benefit analysis of the investment required to make each PLM technically viable and ready for adoption.

6.2 Potential industry net benefits

This section estimates the potential importance of each PLM to the whole of the northern beef industry. This was achieved by taking into account the following:

- The number of cattle and beef enterprises in each of the four zones making up the northern beef industry (see Table 5.1).
- The maximum on-ground potential to apply PLMs; the application of WOW and ART for example depends in the first instance on the existence of enclosed waters, whereas others, such as UAV surveillance could, theoretically, be applied throughout the northern beef industry. In Table 6.1 we provide estimates of the maximum theoretical adoption rates applying to each PLM and region.

Table 6.1: Maximum theoretical adoption rate for each PLM and region (consultant's estimates)

PLM	Arid zone	Southern Qld	Gulf, Top End, Kimberley	CQ and NQ
	%	%	%	%
UAV – surveillance	100	100	100	100
UAV – muster	30	80	30	50
VF	50	80	40	70
ART+AD+T+ED	80	50	30	40
WOW+AD+T+ED	90	50	30	40
Telemetry x water monitoring	100	80	100	90
Data management system (DMS)	100	100	100	100
Feedlot monitoring	100	100	100	100

UAV muster - Many of the paddocks would be too big to use UAVs effectively. VF – low level of stock control and large scale will always be a challenge. ART – Controlled waters will always be a challenge.

An aggregate NPV for each PLM in each of the four regions was estimated using a) the enterprise NPVs from section 5; b) the maximum theoretical adoption rates in Table 6.1; and c) the ratio of total animal unit numbers in each region to the animal unit numbers on each representative enterprise. It should be appreciated that at some critical stage, differences in the theoretical adoption rate (b) and the total animal units in a region (c) can overwhelm the order of the enterprise IRR results derived in section 5. Thus Table 6.2 shows the total NPV according to region and PLM assuming maximum adoption of each positive PLM, after taking into account the maximum theoretical application rates in Table 6.1. The assumption of 'maximum theoretical adoption' is made for the purpose of providing a platform for later estimating the most likely adoption rates.

Table 6.2: Total industry NPV by PLM and region assuming adoption to the maximum extent possible

PLM	Arid zone	Southern Qld	Gulf, Top End & Kimberley	CQ and NQ	Total
	$'000	$'000	$'000	$'000	$'000
UAV – surveillance	36	5,948	548	6,861	13,394
UAV – mustering	3	4,758	818	0	5,580
VF	0	0	0	0	0
ART+AD+T+ED	0	0	0	0	0
WOW+AD+T+ED	1,597	0	3,488	0	5,084
Telemetry x water monitoring	1,213	10,174	902	5,779	18,067
Data management system	0	0	0	0	0
Total	2,849	20,880	5,756	12,640	42,125
Feedlot monitoring (a)			36		

(a) As there was no up-front capital investment for this technology, the results are presented as an annual gross margin for a 30,000 head feedlot; this number is not included in the totals in Table 6.2.

The results in Table 6.2 assume all 'eligible' enterprises adopt PLMs found to be profitable (by our analysis in section 5). Despite this assumption, the result is a total NPV of $42.1 million including telemetry and EID and only $24.1 million excluding telemetry and EID. This is not an encouraging result considering that not all producers will uptake PLMs, even if they can be shown to be profitable for the average property.

6.3 Derivation of likely adoption rates

Despite the difficulties, it is necessary to estimate adoption rates in order to establish the value of PLMs to the northern been industry. In this case, likely adoption rates for each PLM were estimated by taking into account the following:

- The enterprise level NPV and IRR for each PLM - estimated in section 5. These results are indicators of likely financial performance and are considered to be the dominant determinant of adoption behaviour by producers.
- Non-financial factors for each PLM also likely to influence the decision making behaviour of producers.

Base Adoption Rates Assumptions

Pannell et al (2006) highlighted the crucial role of 'relative advantage' as a driver of adoption and the importance of expected profit as a driver of farmers' behaviour. Accordingly, Table 6.3 shows the IRRs for each PLM and region as derived in section 5. Any PLMs found to have with a negative IRR in section 5 were assigned a zero IRR in Table 6.3.

Table 6.3: Expected enterprise IRR by PLM and region

PLM	Arid zone	Southern Qld	Gulf, Top End & Kimberley	CQ and NQ
	%	%	%	%
UAV – surveillance	12	21	13	31
UAV – mustering	11	21	27	0
VF	0	0	0	0
ART+AD+T+ED	2	0	1	0
WOW+AD+T+ED	13	5	14	8
Telemetry x water monitoring	37	36	13	26
Data management system	5	8	8	9

Assumptions regarding 'return on investment as a driver of adoption' developed by the consultants were as follows:

- An internal rate of return (IRR) of zero or less than zero would result in a nil adoption rate (AR).
- A positive and increasing IRR would result in a positive and increasing adoption rate.
- An IRR above 70% would be associated with the same adoption rate as an IRR of 70%. In other words, the adoption rate would plateau beyond an IRR of 70%
- The relationship between IRR and AR for 0<IRR<70 was assumed to be (approximately): **AR = -5.14 + 0.8 times IRR** (This equation was developed from the assumed relationship following):

Hypothesised Relationship between IRR and Adoption Rate

IRR (%)	Adoption Rate (%)
0	0
10	1
20	10
30	20
40	35
50	40
60	45
70	50
>70	50

Adjustment to Derived Adoption Rate

The four non-financial criteria believed to be most relevant to technology adoption by producers, once it has reached the market place, are explained in Table 6.4. Each criterion was applied to each technology and region (scored out of 5) with an equal weighting. When added together, each criterion had a total score out of 20; this score was divided by 10 to provide a relative rating that ranged from 0 to 2. The IRR driven adoption rate was then multiplied by the resultant final factor for each PLM. However, if the IRR-driven adoption rate was zero, the score on the other factors was also set to zero. These 'rules' mean that the adjusted IRR remained the critical driver of PLM adoption, irrespective of the apparent merit of 'other adoption influences'.

Table 6.4: Criteria used to adjust IRR driven adoption rates

Criteria	Basis for scoring each characteristic (maximum score per cell as nominated)
Availability & support	Is the technology readily available in the market and does it have a commercial partner who will support users when things go wrong? The more available or timely and better supported, the higher the score assigned out of 5. Obviously each PLM has to be given an inferred value for this criterion.
Credibility & relevance	Would the PLM be perceived by producers as a credible aid to the operation of their business and relevant to their overall objectives and strategy? If so a high score out of 5 should be assigned.
Risk & uncertainty	What is the perceived risk associated with the projected returns from the PLM and how well can the risks be managed? A low risk of payoff should be recognised by assigning a high score out of 5.
Ease of use	Would the PLM be easy of use by staff on the average enterprise in the region with or without training? Positive ease of use should be recognised by assigning a high score out of 5.

The assigned points were based on the qualitative assessment in section 4 and are shown in Table 6.5.

Table 6.5: Non-financial points assigned to each PLM

PLM	Arid zone	Southern Qld	Gulf, Top End, Kimberley	CQ and NQ	Total (out of 20)	Final (total divided by 10)
UAV – surveillance	5	2	5	5	17	1.7
UAV - muster	4	2	4	4	14	1.4
VF	0	1	2	2	5	0.5
ART+AD+T	3	2	4	2	11	1.1
WOW+AD+T	4	4	2	2	12	1.2
Telemetry x water monitoring	5	4	4	2	15	1.5
Data management system	4	4	4	2	14	1.4

The resulting annual adoption rates by producers for each PLM technology and region are shown in Tables 6.6. For example, based on the profitability findings from section 5 and the 'adoption assumptions' in Table 6.5, 8% of producers in the Arid Zone would adopt UAV surveillance each year over the next five years. To sum-up, differences between the 'most likely' adoption rates are mostly affected by differences in the expected IRR levels and to a lesser extent by differences in non-financial considerations.

Table 6.6: Most likely adoption rates according to PLM and region over next five years

PLM	Arid zone	Southern Qld	Gulf, Top End, Kimberley	CQ and NQ
	% per year	% per year	% per year	% per year
UAV – surveillance	8	22	11	35
UAV muster	5	18	25	0
VF	0	0	0	0
ART+AD+T+ED	0	0	0	0
WOW+AD+T+ED	7	0	9	2
Telemetry x water monitoring	39	38	8	25
Data management system	0	3	2	3
Feedlot monitoring	0			

6.4 Industry net present value with most likely adoption

The most likely adoption rates were applied directly to the NPV figures in Table 6.2 to arrive at the most likely total industry NPV for each PLM and region. The expected total NPVs for each PLM x region combination are shown in Table 6.7, together with whole of PLM and whole of region totals.

Table 6.7: Expected total industry net present value (NPV) after adoption of PLMs

PLM	Arid zone	Southern Qld	Gulf, Top End, Kimberley	CQ and NQ	Total
	$'000	$'000	$'000	$'000	$'000
UAV – surveillance	3	1,313	58	2,428	3,802
UAV – muster	0	865	203	0	1,068
VF	0	0	0	0	0
ART+AD+T+EID	0	0	0	0	0
WOW+AD+T+EID	120	0	298	0	418
Telemetry x water monitoring	477	3,853	74	1,464	5,868
Data management system	0	0	0	0	0
Feedlot monitoring	0				
Total	600	6,031	634	3,892	11,156

The results shown in Table 6.7 provide an objective basis for ranking 'expected net benefits' in terms of PLM technology and region after taking into account the assumptions applying to 'likely adoption'. It should be noted that the total benefits in Table 6.7 are what could be expected if all PLMs were fully developed and available for adoption.

The total NPV for expected adoption in all regions and for all PLMs is $11.2 million. If telemetry is taken out of the total, the balance is $5.3 million with the two UAV technologies contributing $4.9 million and the remote livestock management system (WOW) a marginal $0.42 million. The region with most potential to benefit from unmanned aerial surveillance is Central and North Queensland (64% of the total), followed by Southern Queensland (35%) and Gulf, Top End and Kimberley (2%). With the unmanned aerial mustering and remote livestock management system benefits added in, the distribution of gains are shared among the Southern Queensland (41%) and the Central and North Queensland (46%). The results in Table 6.7 show that most of the unmanned aerial mustering benefit would accrue in Southern Queensland.

Although telemetry is the PLM with the highest expected returns, it is no longer a candidate for 'industry development assistance' because it is already established in the market place.

Considering the time and money already invested in the PLMs, $5.3 million might not seem like a prize worth pursuing. However, the historical investment is irrelevant. Additional investment in PLMs still in the R&D phase will be justified provided it seems likely they will generate a positive net present value, once made ready for adoption. It is therefore necessary to assess the R&D investment in removing the constraints to adoption for those PLMs found to have 'sound prospects'.

Based on the assumptions adopted, several of the PLMs were found not to be profitable at the industry level. These included Virtual Fencing, Animal Recognition Technology and Data Management Systems. VF was the only PLM not to have a positive IRR at the enterprise level.

6.5 Status of the PLM technologies

The status of each PLM technology analysed above is shown in Table 6.8. This detail was provided by the technology proponents (refer to the questionnaire in Table 3.1).

Table 6.8: Status of each PLM technology (Source: Proponent feedback)

PLM	Proof of concept attained	Field tested under semi commercial conditions	Market research completed	Commercial; partner negotiations held	Commercialis ation achieved	Adoption occurring
UAV – surveillance only	Yes	No	No	No	No	No
UAV – muster + surveillance	No	No	No	No	No	No
VF	Yes	No	No	No	No	No
ART+AD+T+ED	Yes	Yes (part)	No	Yes	No	No
WOW+AD+T+ED	Yes	Yes (part)	No	Yes	No	No
Telemetry x water monitoring	Yes	Yes	Yes	Yes	Yes	Yes
Data management system	Yes	Yes	Yes	Yes	Very limited	No
Feedlot monitoring	Yes	Yes	Yes	Maybe	Not locally	No

As commercialisation and adoption are the goals sought by industry, the aim is to convert the status assessments in Table 6.8 from ‘no’ or ‘maybe’ to ‘yes’. Accordingly, Table 6.9 identifies the principal constraints to the further development of the technology and the next step towards full commercialisation. Implicitly, the constraints and way forward shown in Table 6.9 for a given PLM should be incorporated in any R&D project that aims to go forward to commercialisation.

Table 6.9: Immediate constraints, next step and potential investment option

PLM	Immediate constraints	Next step and potential investment option
UAV – surveillance	Need for training and demonstration of applications, raise awareness by producers	Market research and industry involvement in proving applications followed by live demonstration
UAV – muster	Identification of applications, limited field testing, lack of producer awareness	Market research and industry involvement in defining applications followed by live demonstration
VF	Cost of collars combined with short battery life. Proof of marginal benefit via improved pasture utilisation	Scientific challenges: Reducing cost, extending battery life, adding to functionality of the collars, proving the marginal gain from ‘improved pasture utilisation’
ART+AD+T+ED	Functionality of software and integration of components	Field testing with naïve cattle and demonstration of integrated system. Accommodation of animal behaviour patterns
WOW+AD+T+ED	Functionality of software and integration of components	Field demonstration, integrated of systems, accommodation of animal behaviour patterns
Telemetry x water monitoring	Producer acceptance of PLM technology	Field demonstration and other forms of promotion
Data management system	Costs and steep learning curve for the average size producer - see detail in section 4	Harmonisation of systems, make software more user friendly and demonstrate under field conditions
Feedlot monitoring	Opportunity cost of variability between feeder steers introduced to the feedlot	Identification and demonstration of the critical tipping point – according to inherent variability within mobs

Most of the PLMs have been developed as stand-alone technologies but few of them have much capacity to generate benefits if applied on their own. On the other hand, particular combinations of PLMs can generate demonstrative benefits (eg WOW plus auto drafting). Table 6.10 shows how the PLMs are likely to be combined in practice and details the current stage of development and the investment of time and money still needed to take each of the technologies to the market place. This information was provided by the PLM proponents. They also provided details of the ‘next step’ and the ‘probability of success’ but their qualitative rating was quantified by the consultants in terms of our background knowledge and experience. The consultant’s probability estimate is shown in parenthesis.

Table 6.10: Stage of development and remaining investment to take each PLM to the market

PLM	Current stage of development	Proponent's next step, estimated investment requirements
UAV – surveillance	V-TOL trials	To test this technology in the pastoral industry on a commercial scale (eg demonstration site). With an estimated investment of $380,000 over three years, the technology can be ready for adoption in the fourth year. The probability of success is rated as 'high' (70%)
UAV – muster + basic surveillance	V-TOL are working on a proof of Concept	To determine the potential of this technology to assist with mustering under a range of circumstances. With an estimated investment of $200,000 over two years, the technology can be ready for adoption in the third year. The probability of success is rated as 'high' (50%)
VF	Prototype	Additional R&D to find a longer-lasting power source and reduce the cost of collars as well as scale up the research into a commercial environment. With an estimated investment of $7 - $12 million maximum benefits can be achieved in 5 – 10 years. For this level of investment, the probability of success in terms of effective animal control through time and space is rated by the proponent as '100%' (100%)
ART+AD+T+EID	Full scale trial	Develop a system with commercial outcomes and demonstrate these in a number of environments. With an estimated investment of $150,000 over three years, the technology can be ready for adoption in the fourth year. The probability of success is rated as 'high' (50%)
WOW+AD+T+EID	Full scale trial	Develop a system with commercial outcomes and demonstrate these in a number of environments. With an estimated investment of $150,000 over three years (consultant's estimate) the technology can be ready for adoption in the fourth year. The probability of success is rated as 'high' (60%)
Telemetry x water monitoring	Commercialised as a standalone PLM but telemetry being integrated into other PLMs yet to be commercialised	Commercial drivers already in place considered adequate to take standalone telemetry to those producers best equipped to exploit the technology. Relevance to other PLMs such as WOW already apparent and will require relatively little additional R&D effort. Probability of successful application not relevant.
Decision support software	An integral component to other PLMs – constantly being refined and adapted	Demonstration occurring at a number of PDS sites across north Australia. Expect firms will undertake additional R&D to value-add the data and facilitate better decision-making. Current investment via PDS considered sufficient for taking the opportunities to those producers who are best placed to exploit the technology. Probability of successful application not relevant.
Feedlot monitoring	Full scale trial	Collect data in trials, prove commercial outcomes and publicise results. Investment opportunities and needs should be kept under review. Under ideal circumstances, the probability of successful application of the GrowSafe is rated as 'high' (90%)

6.6 Investment analysis for further investment

This last part of section 6 assesses the potential of future R&D investment in each PLM from an MLA viewpoint. Thus the sunk-cost of getting each PLM to its current state of development can be ignored. What is important going forward is the time and money needed to reach the market place, the probability that the PLM will function as intended and the expected economic impact of the PLM once taken to the market place.

The assumptions used in the following R&D investment analysis are based on those in Table 6.10 and are summarised in Table 6.11.

Table 6.11: Assumptions for analysing investment in removing constraint for each PLM

	Total investment required to achieve next step (MLA plus others)	Adoption commences/most likely adoption reached	Expected total benefit generated by investment (a)	Probability of success (in overcoming the major constraints)
PLM	($)	Year	Aggregate Industry NPV ($)	%
UAV – surveillance	180,000 year 1 100,000 year 2 100,000 year 3	Year 4/Year 8	3,801,875	70
UAV – mustering	100,000 year 1 100,000 year 2	Year 3/Year 7	1,068,398	50
VF	1,000,000 per annum for 7 years	Year 8/Year 12	0	100
ART+AD+T+EID	50,000 year 1 50,000 year 2 50,000 year 3	Year 4/Year 8	0	50
WOW+AD+T+EID	50,000 year 1 50,000 year 2 50,000 year 3	Year 4/Year 8	417,769	60
Telemetry x water monitoring	Already happening via Producer Demonstration Site investment			
Data management system	Already happening via Producer Demonstration Site investment			

(a) Expected total enterprise NPV at most likely adoption with 100% success

The performance of those PLMs expected to generate positive returns from the nominated investment stream are shown in Table 6.12. It has been assumed, implicitly, that without MLA investment, none of the gains shown in Table 6.12 would be made.

Table 6.12: Expected return from prescribed R&D investment*

	Investment criteria				
	PV of benefits	PV of costs	Net PV	B/C ratio	IRR
PLM	$	$	$		%
UAV surveillance	1,667,515	353,554	1,313,962	4.7	65
UAV muster	368,188	190,909	177,279	1.9	35
WOW+AD+T+ED	157,059	136,777	20,282	1.1	14

*Based on a discount rate 10% and analysis period 15 years with year of first investment being year 1

The above results provide a structured basis for formulation of investment priorities. Given the assumptions made regarding the R&D costs and the probability of success, the analysis indicates some potential for further investment in UAV surveillance, UAV mustering and Remote Livestock Management System (based primarily on walk over weighing). This potential is explored further in section 7.

7 Business case for MLA investment

7.1 Basis for MLA investment in PLM technology

With a sound knowledge of the investment potential of each PLM now in place, it is possible to turn our attention to the 'appropriate MLA response'. In the first instance this will take the form of an investment strategy shaped by MLA policy and industry needs as well as the absolute and relative potential of contending PLMs.

MLA is funded by both industry and government and as a consequence is obliged to respond to demands for applied results with special interest applications (usually coming from industry) and for basic knowledge with more general applicability (usually coming from government). Against this background it is necessary for MLA to allocate funding to both applied and strategic research. In terms of this dichotomy, PLM technology is difficult to place. While most PLMs should be applied for the exclusive benefit of producers, several have public-interest benefits in such areas as natural resources monitoring and management, worker safety, animal welfare and general surveillance. Thus a PLM thought likely to generate multi-sector and enduring benefits, should have a superior capacity to attract longer term funding relative to a highly focused project, and in this sense all PLMs might not be direct competitors for the R&D dollars commanded by MLA.

7.2 Key elements of investment strategy

High expected returns to producers should do two things: first they should encourage developers to persist with commercialisation plans and secondly, they should encourage producers to seek out the particular technology. Thus high expected rates of return suggest that adoption will occur without the need for any intervention by MLA. In practice, however, adoption rates might be low despite the prospect of high rates of returns – implying market failure. Possible explanations for market failure of this type include the following:

- *Non-availability*: Some of the PLMs assessed are not yet available commercially. For PLMs with very long planning horizons (eg VF) this 'problem' contributed to low expected returns whereas those close to commerciality gained an implicit advantage (eg unmanned aerial surveillance). Some PLMs might be slow getting to the market because they must be packaged with another technology that is also struggling to reach commercial status. The results generated in section 5 for bundled PLMs provide strong anecdotal support for investment since bundling was clearly a significant contributor to financial performance.

- *Lack of awareness*: Making producers aware of options, choices and solutions is an ongoing problem for developers of technologies and innovation. This is particularly the case for small-scale innovators with no recognition factor in the market place and limited resources for extension. V-TOL Aerospace, for example, is facing the daunting task of taking UAV technology to the pastoral industry but is practically unknown outside the UAV industry and is presently funded by the company's founders and employees. It would seem, therefore, that success in getting UAV technology to the marketplace might depend on some third party stakeholder, such as MLA, lending support to the effort in terms of increasing awareness among producers.

- *Perceptions of risk or imposition of a high risk premium by individuals*: Producers struggling to keep up with their existing workloads might be loath to invest the time, money and effort into a system that would take them months to implement and refine without any certainty that it will work as intended. To exploit the advantages of enclosed waters, for example, a producer should install a bundle of sophisticated technologies. To overcome their fear of adoption and generate confidence regarding a quick return on their investment, the average producer will want to be convinced by access to demonstration trials. Under such circumstances there would be a case of MLA investment in such demonstrations – once the total package of PLMs has been field tested and stabilised.

7.3 The business case for MLA investment

The business case for MLA investment is implicit in the results presented in Table 6.12. Accordingly MLA is now positioned to make an informed decision with respect to two priority PLM applications; one that can be pursued in the short term and a second that is better suited to longer term investment. It is proposed that unmanned aerial surveillance and unmanned aerial mustering be adopted as the short term priority and that the remote livestock management systems be adopted as the longer term priority. These choices stem directly from the proposed investments (Table 6.11) and the subsequent results (Table 6.12).

If MLA invested $380,000 in unmanned aerial surveillance technology over three years, it could expect a benefit cost ratio (via industry benefits) of 4.7 and an IRR of 65%. Somewhat less attractive but still worthwhile would be an investment of $200,000 over two years in unmanned aerial mustering technology. This would generate a benefit cost ratio of 1.9 and an IRR of 35%. As a longer term investment, MLA could invest modestly in walk over weighing via the remote livestock management system. Investment of $150,000 over three years would generate a benefit cost ratio of 1.1 and an IRR of 14%. While these returns are close to the industry's lower bounds of acceptability, the net present value is positive after applying a discount rate of 10%. In addition, any improvement in sale weight beyond the rate assumed in section 5 (viz, 5%) would bring about a vast improvement in financial performance. If, for example, WOW could increase sale weight by 7.5% (ie a 50% improvement) the benefit cost ratio would increase to 33 and the IRR would increase to 209%. In other words, any improvement in performance beyond that assumed in our primary analysis would make WOW highly attractive for the northern beef industry.

For the purpose of translating the findings of the investment analysis into research proposals and ultimately projects, the next section sets out detailed terms of reference for the short and longer term projects.

7.4 Terms of reference for priority investments

7.4.1 Short term priority

Table 7.1: Short term priority for MLA investment in PLM technology

Project Title	**Short title: Cost effective aerial surveillance of biophysical factors critical to efficient livestock production.** Long title: Identify and demonstrate up to four applications for UAV technology with demonstrative benefits for producers and NRM agencies represented in the northern beef industry.
Purpose and description	The project would identify, test and demonstrate UAV applications relevant to cattle production and NRM monitoring and management across northern Australia. UAV surveillance and mustering could be treated as separate projects. The applications might complement other PLMs including EID and telemetry but might exhibit competitive strengths as a stand-along technology. The project should be commissioned by late calendar 2010 and allowed three years to meet all deliverables.
Objectives	• Combine UAV developers with appropriate researchers to identify and test applications in a practical setting. • Locate the systems at demonstration sites within regions most likely to adopt the systems and generate data to prove that the associated practices are beneficial. • Prove at field days and workshops that the applications are operationally robust and capable of making producers better off. • Report at six-monthly intervals on progress generally and produce materials for public distribution that support the operation of the UAV applications and indicative economics.
Additional Detail	The project is likely to be conducted by a consortium of UAV technology developers, interested producers, regional NRM agencies and specialist researchers. It is expected the project will run over three years and for some of this time would be located on a collaborator property. The project should combine systems design and development with practical demonstration. Projects inputs would be selected and applied in terms of their capacity to generate practical outcomes.
Milestones	By the end of year 1: Identify the UAV applications and establish a demonstration site on a collaborator property with a technical demonstration capacity. Prepare and make available partial budgets showing how the system can increase profits. By the end of Year 2: Have hosted at least three public field days and developed a detailed report on the associated inputs and outcomes. Also keep a record of producer interest in the applications and indicate the history of on-farm adoption and financial results. By the end of Year 3: Undertake more demonstrations of proven UAV applications and look to establishing commercial models that will foster uptake of applications throughout the northern beef industry. Generate an overarching report that assesses the success of the project in terms of its original goals and objectives. Make recommendations on how the project might have been strengthened and indicate if any further work is needed.
Budget	MLA will contribute $380,000 over three years (year 1 = $180,000; year 2 = $100,000; year 3 = $100,000). It is expected that collaborators will make material contributions of a similar magnitude. Evidence of third party involvement and commitment will be viewed favourably.
Assessment criteria	The winning bid is likely to come from a formally constituted consortium with complementary skills in the areas of PLM technology development and commercialisation, design and delivery of high quality R&D with particular relevance to the beef industry,

Table 7.2: Longer term priority for MLA investment in PLM technology

Project Title	**Short title: Automated management of cattle at enclosed waters**. Long title: Refine and demonstrate Remote Livestock Management Systems at enclosed waters that automate the monitoring and management of cattle in the northern beef industry for the purpose of making cattle producers better off
Purpose and description	The project would be aimed at proving and demonstrating the practical application of appropriate combinations of PLMs relevant to cattle monitoring and management at enclosed waters. Thus several PLMs should be bundled into systems to achieve critical outcomes. Apart from WOW and possibly ART, components parts might include EID and decision making software, telemetry, automatic drafting and UAV surveillance. Systems should be designed to generate economic outcomes such as selection of cattle according to liveweight, pregnancy status, age, or identification of pest species such as feral goats, kangaroos or pigs. The projects should commence by mid calendar 2011 and be allowed three years to meet all deliverables.
Objectives	• Combine PLM components into systems that facilitate monitoring and management of cattle at enclosed waters to facilitate more effective and efficient application of practices that reduce costs and/or increase average prices. • Locate the systems at demonstration sites within regions most likely to adopt the systems and generate data to prove that the associated practices are beneficial. • Prove at field days and workshops that the systems are operationally robust and capable of making producers better off. • Develop highly prescriptive extension kits that would assist producers to adopt and profit from automated management systems at enclosed waters. • Report at six-monthly intervals on progress generally and produce materials for public distribution that support the operation of the systems and their economics.
Additional Detail	The project is likely to be conducted by a consortium comprising 1) specialist researchers, 2) interested producers, 3) regional NRM agencies and 4) technology developers and sellers. It is expected that sub-projects will run from 2-3 years and for most of the time allowed would be located on one or two collaborator properties. The projects should combine systems design and development with practical demonstration. Project inputs would be selected and applied in terms of their capacity to generate outcomes that will clearly benefit beef producers and fit within the strategic focus of the industry. Thus the project should not be driven by the technical capacity of gadgets.
Milestones	By the end of year 1: Design of at least two PLM systems with a demonstrative capacity to deliver profitable outcomes for producers who have enclosed waters By the end of Year 1: Establish demonstration sites on at least two collaborator properties with a technical demonstration capacity and hand-out partial budgets showing how the system can increase profits By the end of Year 3: Host at least three public field days and at least six special invitation workshops and report in detail on the associated inputs and outcomes. Also keep a record of producer interest in the systems and indicate the history of on-farm adoption and financial results. By the end of Year 3: Generate an overarching report that assesses the success of the project in terms of its original goals and objectives. Make recommendations on how the project might have been strengthened and indicate whether any further work is needed.
Budget	MLA will contribute $150,000 over 3 years. It is expected that collaborators will make material contributions of a similar magnitude. Evidence of third party involvement and commitment will be viewed favourably.

Assessment criteria	The winning bid is likely to come from a formally constituted consortium with complementary skills in the areas of PLM technology development and commercialisation, design and delivery of high quality R&D with particular relevance to the beef industry, NRM credentials with a strong interest in the nexus between beef production and NRM and serious beef producers with a strong commitment to the vision of a more efficient, socially responsible and productive industry

7.5 Concluding comments

This project was aimed at establishing the absolute and relative merit of several PLM technologies (currently under development, but not yet commercialised) from the perspective of the northern beef producers. The PLMs assessed were Virtual Fencing, Remote Livestock Management Systems (that included combinations of WOW, ART, EID, telemetry and automatic drafting) and unmanned aerial vehicles. The future absolute and relative merit of the PLMs was established using economic principles and methodologies.

Given the assumptions adopted, the combined potential of the technologies examined was found to be modest. Notwithstanding this generalisation, the most promising opportunity for immediate investment was found to be unmanned aerial surveillance. The technical capabilities of this technology have already been proven but applications specific to the northern pastoral industry have not yet been identified and refined. Less attractive was a bundle of technologies that can be effectively and efficiently applied at enclosed waters. Thus limited additional investment in the Remote Livestock Management System that combines walk over weighing with electronic identification, automatic drafting and telemetry is justified. Investment by MLA in automated management systems, where all the input and output data (including control of herd behaviour) are physically linked to the individual animal, is not recommended – at least not until the relationship between remote control of herd movements and improved pasture utilisation has been demonstrated and the cost per animal of achieving effective herd control has been significantly reduced.

Apart from identifying those options most worthy of industry support, the assessment process has provided some insights into the nature of innovation itself. It is apparent that innovations, such as those embedded in PLM technologies, are often driven more by supply-side forces (that want to find novel applications for existing technologies) than they are by demand-side forces expressed overtly or covertly by the potential customer (in this case beef producers). This is not necessarily a bad thing – because innovators often pre-empt market preferences and beef producers are often not adept at foreseeing and articulating their areas of greatest need. But it seems to us that the investment in beef industry innovations could be made more efficient through regular and intense scrutiny of customer needs and preferences. Thus all of the PLMs assessed by this project could have benefited, we believe, from some form of early-stage modelling of the target market. This would not only indicate whether or not a market is ‘ready and waiting’ but could also assist the direction of development for those PLMs found to have real market prospects.

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9 Appendices

9.1 Milestone 1: Details of the workshop

The PLM workshop was held on 27 April 2009 in the Primary Industries Building, Brisbane. It was attended by PLM developers, PLM manufacturers/suppliers and existing or potential end-users (see list attached). The workshop was designed, primarily, to help MLA and the project team identify RD&E investment opportunities that can deliver significant positive benefits to the northern beef industry. For the purposes of the workshop and the ensuing project, Precision Livestock Management was defined as "…technologies that automatically recognise, interpret and report quantitative interactions between livestock and their production environment for the purpose of improving productive efficiency, profitability and sustainability".

The workshop was enthusiastically attended by PLM developers (11), manufacturers and distributors (6) and end users (5). In addition there were four MLA staff members, three consultants (comprising the project team) and Janine King (for the purposes of recording proceedings). Des Rinehart from MLA also represented the feedlot sector while Rodd Dyer acted as workshop coordinator throughout the event. The workshop was judged to successful in terms of the following:

- The participants represented a reasonable cross-section of the PLM technologies, with potential application to the northern beef industry, and were given the opportunity to talk about their progress to an informed audience.
- This provided the project with a useful introduction to both the PLMs and the people behind them. During the workshop it was possible to develop cross-tabulations between various technologies and their application to cattle production.
- The workshop stopped short of nominating particular technologies for adoption, leaving it to the project itself to place the options in context and assess their prospects going forward.

A complete record of the workshop proceedings is attached. This comprises two parts:

- An introduction by each of the PLM researchers/developer/businesses/end users
- Details of Workshop discussions surrounding how each PLM technology might be applied in practice. Several PLMs will be used in combinations to represent a PLM system.

Introductions by PLM workshop participants

1.	Peter Chudleigh	- Overviewed the economic process to be used in the project.
2.	Sean Starling	- Off-farm R&D group with MLA.
3.	John Billingsley	- Developer: National Centre for Engineering and Agriculture within USQ. - Need interesting problems for researchers to work from – primary output is doctorates. - Needs advice from economists. - Concerned at supplying technology that's needs based. - Working on Machine-Vision (analyses images to make decisions). - Take various sensors (ultrasonic, infrared, straight forward vision, GPS) and uses software to integrate with actuators that perform tasks. - Urge of end users to buy expensive equipment cited tractor guidance control device – economic failure – too cheap!
4.	Libby Homer	- Labour problems. - Uses RF technology. - Opportunities for tags to hold more info. - EU market specific specifications – must be monitored closely to maximize income. - Biosecurity and animal security is important – recognition and ownership. - Weeds issues – recognizing large outbreaks in specific areas would be useful to enable quicker effective treatment.
5.	Pat Gunston	- Manufacturer and developer. - Provides cattle tags for NLIS. - Involved in sheep CRC.
6.	Geoff Niethe	- Issues in quality of research. - Pressure on research stations – existence threatened. - Need tool to locate cattle for mustering and identify mortalities. Working on this for biosecurity reasons. Grazing behaviours, what cattle are eating and their locations. - Technologies to address/measure methane emissions.
7.	Tim Driver	- Developer and manufacture/sales. - Focus on automatic drafting systems and data collection systems – focusing on production systems for production animals. - Increased production through measurement and increased marketability. Using walk over weighing and laser measurement. - Gather info in the paddock and target marketing to each animal rather than groups – will attract a premium. - Still in research stage – sold two units this year to NT DPI. Have Generation 1 available on market for cattle – data collection of weight and auto drafting. 3 units used in R&D on station. - Question for later – differences in approaches between using machine vision vs laser approach for measurement issues.
8.	Tom Newsome	- Focus is distribution of data management systems – working in saleyards and producer areas. - Looking at comparative analysis – measuring performance of cattle to date in historic sense – collect data crush side and predict animal performance in the future. Can't make profitable management decisions with comparative analysis. - Key projects working on – MLA Cash Cow project. - Collecting historical data on animals to predict future eg growth. - Manage opportunity costs of each animal while working on variability within the herd. - Pedigree matchmaking active in sheep industry: not currently seen as commercially viable in cattle industry – focus currently on the environmental aspects.
9.	Salah Sukkarieh	- Working in mining, defence and stevedoring industries. - Unmanned vehicle applications – working off defence work. - Wide scale sensor networks – fusing info from many sensors. - New to this area. - Working on a woody weeds spraying project for MLA. Animal nutrition program work with Princeton Uni. Work with chemical plants.
10.	John Lapworth	- Involved with electronic side of animal management. - Problems: have electronics; know we can record weights – lot of work from animal

	behaviour viewpoint to ensure these technologies will work well. Commercial companies tell you technologies do things but they don't. - Interested in technologies that make life easier for producers, is affordable and efficient. Needs to be failsafe. - He knows how technologies need to work in a practical sense. Involved since first walk over weighing in early 80s.
11. Les Zeller	- Works in engineering and technology field and adoption of technology (30 years experience). - Worked with a range of technologies.
12. Mark Copeland	- Sheep CRC – focus of precision sheep management ID top performing management and develop strategies to market these and reduce production costs. - Range of information with sheep to determine which animals are the most productive and most valuable – developed selection indexes. - Capacity on farm to collect data is good – good support from hardware and tag companies. Greatest challenge is using data to make decisions. - Software products CRC has are commercialized – talking to farm management software companies to incorporate products into their software products – finalizing license agreements. Products available in 6-12 months depending on development timeframe. - Farmers get excited about technology but don't think why they need technology or to collect data. Their approach is ensuring farmers think about where they want to take business forward, what data is needed then what technology required. - SP asked: How many sites using this approach of collecting range of info and making decisions – is this common? About 2,500 farms started to use this at various levels – some more sophisticated in application and using for decision-making. Others collect and use basic data – depends on producers goals and capacity. - Other area getting interest in sheep industry is seedstock sector – data accuracy is critical to their business. Need to easily capture data. Flock variation is an issue. - Gaps for additional work – extension. CRC don't have a charter for extension – groups like ALLFLEX try to promote technologies. - Developing range of training products and linking technologies and how they work. Focus for next while is Webinars and internet based forums - *Roy Chisholm (good point): issue for producers is managing data, analysing it and getting useful information producers can use*. Mark: include analysis in software to make use by producers easier. Cited Pedigree software – report available for approx $50-60 –easier than producers learning software and analysing it themselves.
13. Gary Edwards	- NLIS. - Working with Consolidated Pastoral 8 years. - Data collection and management system – used by stock camps. - Developing own specific software - crush side data collection system which runs across multiple stock camps – sent to a central data processing point. - Speed and type of data collected crush side is an issue – standardization of decision making tools and templates. Issue continually facing in pastoral is greater number of staff with less practical experience – this software gives standardization of decision making. - Animals drafted on a range of performance criteria – info is centralized. - Key component is tracking animals to end destination (many in NT end up in Indonesia) issue is getting info back from end destination. - Significant profitability outcomes. - Commercial release of software scheduled at Beef09. Stage 2 of a 4 stage process. - Will empower decision-making across all levels.
14. John Finlayson	- NLIS, RFID. Specialty is manufacturing reader equipment. They research, develop, manufacture and market – 20 years on-farm experience. - All equipment tested on farm prior to release. - Sees a future need for greater software integration into equipment. - Significant hole in market for producer to get simple accurate info. 20% of producers use data entry product of these 5% actually use it for what its made for. Software is too complicated (too technical) for some producers to get the info they need. They have technicians plus people with on-farm production experience to provide input into products before it reaches producers.
15. Tony Searle	- Producer from the Top End.

	- Difficult country to manage as property under water for half the year. - Not much of what he's heard is practical for him. - Can't use remote sensing equipment due to surface water. Don't use supplement as high phosphorus content in land. Don't have supplementary feeding regimes other producers have. Hence no control over cattle for remote sensing technology. - Each year have to re-erect fences due to flood waters. Needs a virtual fencing system to negate having to put up fences each year before mustering – annual fencing cost $50k. - Capacity ranges from 2,000 cow herd to 8,000 in dry season (growing season) – opposite to most northern cattle producers. Pasture runs at 14% in dry season. - Low infrastructure because it gets washed away – need to double up management of animals. - Utilise tag that gives control over cattle so can sell on weight rather than end of season. - Pasture and weed control high priority – big cost.
16. Roy Chisholm	- Extensive dry land production producer north of Alice Springs. - EU producer, RFID tag on all animals. - Wants to maximize technology he has. - Uptake and adaptation of RFID technology can benefit his operation. Biosecurity reasons drive need for this. - Vested interest in measurement and production performance. Long term vision is production efficiencies eg preg testing technologies. - Would like a visual real time remote sensing for on property infrastructure and environment conditions of land eg feed availability, dryness of country – measure this effective and stock accordingly. - Outsource management and reporting of data.
17. Craig James	- DKCRC – integration of all components into a system purchasable off-the-shelf that works well. - Synthesise all parts so they work together and provide management decisions. - If re-bid successful will continue to look at systems approach to technologies and remote sensing technology on large cattle and sheep properties.
18. Tony Thompson	- Mixed farmer from Bourke – sheep based grazing operation. - Started PLM in 2002 – measure variation in animals (up to 500% variation). Systems to measure and manage variability. - Change to an objective approach to farming – looking for tools and systems to enable this. Important combination is animal management and decision approach to resource management – trying to use Paddock Grass system. Currently difficult to get support for continuation of work he's undertaken. - The issue from walk through weighing perspective is hardware and animal behaviour. He uses water as the attractant. - Software – lot of work required. He wants software that uses information to analyse individual animals. Upside in productivity to be gained. - Need support to manage data.
19. Kim Bryceson	- Involved in these technologies since 1982. - Working on whole-chain approach. Strong focus on technologies that add value to producers. - Young labour force is technologically savvy and interested in developing technology and using it on farms. Very little info easily available for education resources for young people to learn – they'll be driving industry in future and this is an issue.
20. Andy Bubb	- Project Leader 21st Century Pastoralism project – DKCRC - In the desert problem is having opportunity to manage animals. - Use technology to assist labour issues. Potential upside to production system is huge. - Producers are more tech savvy – good opportunity to integrate interested in creating a remote livestock management system.
21. Matthew Pryor	- Observant - Remote monitoring systems which deliver timely relevant and reliable info about status of production oriented equipment. - Solutions started with water management focus – scope of solutions needs to include all labour equipment. - Bringing all data together to provide a more holistic approach to animal management.

	- Observant's role is to gather as much info as possible and work with developers and manufacturers of as much equipment as possible. Much of existing equipment being monitored is not theirs. Worked with many groups at today's workshop. - Very commercially focused. Saw a big problem with this area as reliability, serviceability, warrantability – especially with regional resellers – need to design and build products which can handle the commercial environment. - 50 commercial implementations of their systems over the years. - Good mix of exposure to commercially focused research and on-farm customers.
22. Des Rinehart	- Manage MLA's Feedlot R&D program. - Feedlot industry readily adopt of technology to reduce costs and increase production. - Interest in ID of sick animals in the feedlot based on work from USA and Canada which shows 4 days advance warning can be gained from using technologies to detect sick animals before a pen rider finds them.
23. Geoff Cornford	- Biggest opportunity as industry is to integrate existing technology, package them for producers as more cost-effective than developing new technologies. - From a producer's perspective they want to adopt technologies that increase profitability.
24. Neal Finch	- Applications in animal industry – how far has machine vision progressed linking to other technologies. Interested in vertebrae pests. - Production improvements also improve the environment. - Machine Vision identifies animals at species level. Technology is now licensed and on the cusp of commercialization. Monitors pest species, can also trap animals. - Scope for managing the whole ecology. - Technology is compliant with other technologies and complimentary to say walk-over-weighing technology. Anywhere walk-over-weighing technology works, animal ID technology will work.
25. Greg Bishop-Hurley	- CSIRO – works with behavioural monitoring of livestock and automated animal control work, environmental monitoring using low cost low powered networks.
26. Dave Swain	- CSIRO – using technology on animals as opposed to eg a watering point. Focus on virtual fencing or automated animal control. - Trying to better understand social aspects of animal behaviour. - Long way from commercialisation. Have number of patents re virtual fencing – discussions underway re commercialisation. - Attention focused on application areas important to the industry. - Environmental protection is an area of increasing importance and government funding is supporting CSIRO's work in this area. - Challenge is getting a practical device with longevity. - Looking at cow calf behaviour and maternal variance. Other work uses social indices of getting date of conception – use ovarian scanning – see huge value with this work. - On animal devices have challenges different to devices located at eg watering points.
27. Steve Petty	- Consultant based in northern Australia. - Interested in converting technology into strategies and how technology can be applied in a practical environment.

Themes

Discussion	**Theme: Cattle mustering and movement** (covered Virtual Fencing and UAVs)
Describe and discuss component technologies	**Virtual Fencing** • Separate animal location from where you want them to go. • GPS becoming cheap with single chip solutions. Power consideration is an issue for on-animal systems. Re mustering – how do you make animals go where you want. o CSIRO's GPS product is part of a sensor-platform in-house for their research work to define where the industry application is. Range is an issue – need to store data on-device. Network picks up info when back in range. Level of tracking is not commercially viable. These devices include a radio to allow communication to deliver instructions. Can also retrieve info from the device. Battery life depends on time GPS switched on – can last 6-12 months if say 4 hourly sample interval – higher sample

	rate battery lasts 4 days. Intervals can be from 1 sec to 1 day. o Animals are stimulated audibly then electrical shock if they "cross the line". Use smart technologies to deploy different virtual fencing to shift cattle. o Onboard technology: GPS, Radio, Battery, CPU, Stimulus – audio and electrical, o USA group trialling electrical shock on different side of the neck to direct movement. • Distance is a critical factor with technology. Power is an issue. Passive versus active technology. Wireless radio and satellite options. • Greg BH: Could move the fence-line. GPS uses more power. • John: instead of GPS include a beacon. For mustering need two-way communication. Set up network from a range of components that cover various distances – short vs long haul. Important differences in power characteristics. What can be attached to animal impacts on this? Consider amount data to be recorded, transmitted and processed. • Matthew: need to define paddock scale. • Les: how far away is this technology from being economic? • J Lapworth queried animal behaviour when stimulus applied – queried stimulus level. DS: proportion of animals stop on audible sound and back off when electrical stimulus applied. Some animals progress across the line. If an animal bolts, the system shuts down. No animal training – animals are straight from the saleyards.
	UAVs Salah - issue is making UAVs farmer friendly. Can build a UAV platform. • Infrared – cheapest option. Determines if there is heat produced by a living "thing" or animal. Questioned operation of infrared in higher ambient temperature. Timing impacts on use of Infrared. • Radar tags – use harmonic radar technology – using this in locust work. Next cheapest option. • Imaging sensors. • Animal Classification comes down to the algorithms. Need to be close to determine if animals. • UAVs used in Plant biosecurity work – could adapt to this industry. • What is the benefit over any technology that exists now? • Payload capacity impacts on-board fuel. Bigger ones fly 2-3 hours with 5kg payload – up to 50kms/hr. Hourly cost compared to R22 – UAV $50-70/hr. $380-400/hr wet helicopter. • How would UAV direct animals eg mustering? Use animal behaviour knowledge (as used with helicopter mustering) and techniques. • Safety is a big hurdle. • Use planes for image work eg crops, predicting yield and protein. Surveillance "eye in the sky" applications. • Training required – this is an issue. • Mustering – could reduce number of musters. • Advances in satellite type imagery eg Google – where is this info going – potential for real-time information. Data frequency, resolution (to define animals). Turnaround time – taking image vs time using information. Satellite imagery is generally quite poor. 1cm resolution needed for individual animal identification. Higher resolution = higher cost.

Applications – livestock classes and scales of management	**Virtual Fencing** • Dave: envisages a series of applications. Environmental protection CSIRO's key area – production benefit. • Need flexible system which integrates with the landscape. As technology evolves breadth of applications will change – could address for example mustering, cell grazing. Flood fence applications are possible – soft-type boundaries which manage landscape in a softer way. Assist with managing overgrazing – enable rejuvenation while pasture regenerates. • Social behaviour – maternal variance, bull libido. CSIRO looking at close social interactions. Philosophy has been development of cheap, low cost wireless sensor network. Antenna size dictates coverage – consider this in extensive operations. • Radio devices under a wireless network are the most cost effective. • Neal cited examples of lightweight devices already available. **Applications**: • Managing animals. • Manipulations within paddock more than replacing boundary fencing. • Animal location – reduces mustering costs. • Resource management
Enterprise benefits – productivity, cost or price	**Virtual Fencing** • Salah: raised dynamics of mustering and impact on battery life. Muster actively or passively. Nutritional manipulation. • TS: Use virtual fencing can control grazing length – allow increased carrying capacity by better management. Use fence to confine cattle prior to mustering. Profitability and land management are high priorities. • Need to understand what management costs vs technology costs. • Cost benefit - what is already available at scale – eg mobile phone • Quantify public benefits.
Adoption and adaptation Considerations	**Virtual Fencing** • Cost and size of device. Ear tags currently available $14/tag includes. Drawbacks – from a disease perspective – individually IDing animals – technology can ID whole mob but IDing one animal in one place is difficult. • Timeframe for adoption: if sufficient funding 3-5 years for a specific, focussed application – 10 years with current resources. Cell grazing and mustering applications could be addressed. Battery life – balancing capacity with need. *John: Look at animal-generated options – methane or movement.* Interfacing with animal and getting algorithm to optimize power available/needed. • Compatibility with NLIS. Biosecurity related information is beneficial. • Consider animal welfare issues with virtual fencing and shocking animals. Research required into welfare considerations. • What technologies are other industries using – adopt for our industry eg laser fencing, sensors in shops.
	UAVs • UAVs already exist to get through the CASA restrictions. QUT doing work on finding emergency.

	• Surveillance opportunities could be delivered short-term. • Intensive areas could share expense eg checking flood gates. • Big question is why producers don't take up new technology cited phosphorus, walk over weighing technology – been around for a long time but slow uptake. • Bigger Defence industry related applications due to availability of funding. • What is an acceptable rate of reduction to state a technology is "successful".
Development and commercialisation	**UAVs**: • CASA regulations – where UAVs can fly eg controlled zones. CASA flexible in remote areas. Operation certificate required. • Classifying animals – need to use colour plus Infrared – 1-2 years away. • Actively muster cattle – from R&D perspective 3-5 years. Commercial perspective - takes longer to get on-farm application as need to address training and safety issues. • Cost – potential efficiencies. Range of other applications a UAV platform could be used for and multiple benefits would accrue.

Raised but excluded as outside the scope of today's workshop:

- Automated changing of water to induce stock movement (excluding automatic drafting – linked to data management).

Machine Vision

- Low cost camera and computer can give a lot of data.
- Use MV to develop body condition score (done via the rump).
- Animal recognition type technology – can we work out what species it is and can we estimate weight and condition score – 2-3 years away. Lasers could also give condition score.
- If scales included have weight.
- Have not considered ViaScan technology currently used in abattoir for carcase imaging. Two processors currently using ViaScan. Business model hampering implementation, specifically being charged for each photograph.
- Bathroom scales and gyms can determine body fat – can we adapt this technology to the industry?
- Industry uptake of walk over weighing technology is an issue. Walk over weighing has never been a product producers can buy off the shelf and use.
- Machine vision makes weight more reliable as four legs can be identified.
- Applying this to a relatively niche market. Limited number of applications will be adopted - 25% of this number is market saturation. Unlike feedlot where there's different motivators for adoption. Whilst technically possible to do something need to be realistic about likely adoption.
- Accuracy of current systems was questioned. (Revisit this.)

EID Tags / RFID

- Already have tags, readers.
- Smart Cards already exist that can contain large amounts of data that don't need to be powered vs EID tags that solely store a unique serial number only. Developers are continually researching internationally available technology.
- Issues: privacy laws, meet international standards. Australian EID is at the top of the technology tree – little advances expected in the near future. NLIS standards has provision to adopt new technology enhancements eg Smart Cards.
- Discussed proportion of producers that use NLIS data to assist management decision-making. Pat G estimated 50% of cattle producers are doing something like linking a weight to RFID.

Walk over weighing

- True-test algorithms. Discussed error rates.
- Issue is animal behaviour – how do you get an animal on a platform standing steadily for 1 second you will get good data. Need to control the system to be assured weight etc registered is accurate, especially if used to draft. Tim: you never draft on one weight recording – usually 7 days data – moving average. Need a system which includes it as a management tool. Napperby research indicates tolerance +- 20kg weight range of static weight. When static weigh animals they have an element of curfew so static weight is lower as less gut fill. When drafted still need to check animals then weigh again if sold on weight. DK in Generation 1 are using True-test off the shelf product. Issues raised here are being addressed in Generation 2. Confidence comes from number of measurements. DKCRC working on other weighing systems and algorithms.
- Sheep CRC research indicates 2kg difference after a drink.
- Level of confidence in True-test algorithms.
- For 100% weight accuracy - static weighing.
- Need transformation in way people are managing their animals at the individual level.

Auto Drafting – In Yard or Remotely in paddock

- Current auto drafting on feral animals, production animals and dairy cows.
- Need to understand animal behaviour to maximize technology.
- Drafting accuracy on single pass 94% on a tag reader. Same tolerance as weight tolerance if 100% needed must be static.
- Significant limitations with patents, especially overseas. Technically it is possible to do but patent restrictions limit applications. This applies to camera based system – USA systems (Micro booth) have substantial patent issues. John: patents are not a reason "not to do something" but a reason to do it better. Should check legalities of components used to create a new system.

Data Management and processing / decision-making

- When does data need to be analysed – real time?
- Who manages the data – producer or outsource? Cost/benefit?
- Lowering long term cost of longitudinal management style.
- Dumb vs smart devices. With weighing we've made "smart-dumb" devices. Generational change with scale indicators is they're smarter but build on a dumb platform.
- Is there a need to develop something for a specific niche? Compatibility issues.
- External consultants in cotton industry make many of the decisions for farmers – they manage the data.
- Off-site data management has been done for many years – issue is how much will people pay to interpret data? Evolutionary process – technology is improving and costs are reducing.
- Data collection systems built off findings of mining and defence systems.
- Powerful algorithms exist today to enable deeper analysis of data analysis.

Equipment Communication

- Ability for systems co-located to communicate with each other at the same physical location.
- Establish standards to facilitate connectivity – mining industry has managed these problems.

Telemetry

- Common language between telemetry.
- Long term cost of operating network drives return. Power drives cost of everything. Packaging is important – cited dry land cropping analogy and over-investment in cab technology.
- Need for a diagnostic capability – need technician that can log onto WoW system and fault find, diagnose, up-date settings.

Laser measurement

No specific discussion recorded.

Preg Testing

No specific discussion recorded.

X Ray

- John suggested it is worth looking into the law surrounding use of x-ray.

Applications for above technology
Napperby system uses water as attractant. System going into Douglas Daley for buffel grass pastures.

How does this technology make producers more money?

- Weighing, drafting, strategic supplementation, managing individual animals.
- Labour – cow/calf operation – draft weaners. Animal husbandry issues. Less stress on the cow. Don't draft all cows – calves can be pulled off – draft on "no tag" recognition.
- Threshold management – induction process for animals. Track animals against weights. If fall below threshold decide how to manage individual animal. Key is having something to compare daily weights to. Need financial modelling to underpin the decision-making.
- Manage individual animals to optimal end point. Costs associated with keeping animals beyond optimal point.
- Feedlot situation – cost of weighing is cost of liveweight gain. Compare this to cost gained by not mustering.
- Pedigree is a critical issue – ability to track an animal's pedigree. Follow progeny through to meatworks. Look at financial profitability of that dam. Pedigree matchmaker software - lamb and ewe linked by ear tags. Not as accurate as DNA testing but this is sometimes questioned too.
- Immediate benefits eg labour saving. Longer term benefits eg genetic improvement. Use data to help identify impediments to on-farm systems. MLA funding work on understanding causes of variation in liveweight gain in growing animals.
- Application in terms of breeders handing lactating versus non-lactating animals. Software enables drafting on a range of reasons – practical application is the issue. Huge human impacts on what we do that impact on efficiency and fertility.
- How will this technology apply in big surface areas with lots of cattle that are hard to control? Limited day-to-day opportunities. What is the potential market application? Good in highly intensive areas where cattle are handled regularly – limited in areas such as VRD. If attractants are other than water the market is wider.
- Trying to run an "objective" type business in a "subjective" environment.
- Hugh efficiency gains from getting right data collected at crush-side. Scale has limited application.
- Discussed cow/calf separator technology – why wasn't uptake greater? Issue isn't whether things work, it's how they're packaged and presented to the market. Technology is now more acceptable.
- Using data to make decisions is a significant challenge. Managing volume of data. Integration between various points of data to analyse it without inputting to another system.
- Excel spreadsheets is a huge limitation – makes it very easy for people to stuff up data. Garry cited examples of problems. Causes problems with NLIS.
- Data management processing is a major constraint.
- Defence industry is addressing data fusion.

Feedlot Measurement and Management

Potential components:

- Substantial discussion about how technology could be used to identify sick animals in a feedlot – currently reliant on a pen rider.
- Currently lack antenna mechanism to determine when an animal feeds or drinks that they are sick.
- Involves technologies to detect data then transfer data to a receive point – then analyse data to determine which animals.
- Bovine Respiratory Disease (BRD) is ~60% of disease in feedlot. Seasonal issue. Symptoms: runny and crusty nose (similar to human cold and flu combined), increase in body temperature (not all vets agree with body temp criteria); sunken eyes. Initiated by virus then bacterial infection. Animals do not eat and drink when sick – approx 4 days advantage of early detection, treatment and recovery – equates to less production loss and death.
- Canadian system has lots of problems.
- BRD costs $40m / year mortality, lost production and treatment.
- Behavioural and sick shy feeders. Identify these animals early and treat or move to pens with less competition.
- Barriers to current technology – cost (approx $20k for readers around a trough); is this expensive in the big picture?
- Options in terms of machine vision. Cited example in theme park where tags are scanned and any pictures taken during the day pop up on the screen - Israeli technology. Use proximity detectors (radio which transmits and receives) – logger on each animal, one near the water and one on the trough. Data can be accessed real time.
- John queried how long does it spend in the feedlot and how many in an enclosure – 100-200 days / 100-300 head per pen.
- Increased efficiency with labour resources in cattle handling area. Reweigh of cattle from dispatch – explained “Grow Safe” in-pen weighing station – weighs front legs and correlation done for full body weight. Can we take dataset from weighing and feed into automatic drafting system to save having to weigh cattle. Use this system to identify cattle not feeding. System only allows one animal at a time on the scale. Approx cost $7.5k per system. Use in sorting pen to reduce number of scales required. Geoff Cornford: custom build a pen specifically for the weighing. More problems but more benefits managing feed use efficiency in the pen. Prefers to manage whole mobs, rather than individual animals. Taking animals out of feedlot and weighing reduces weight gain hence profitability. Prior to sale weighing/drafting decision vs day/day weighing and information. Rotate a WoW system through pens. Problems generally occur at the beginning – this is when closer management is required. Little disease issue at Geoff’s feedlot as animals are primarily company owned due to vertical integration.
- If feedlot industry isn’t maximizing WoW systems – what is likely uptake for grazing industry?
- Roy: issues raised for feedlots similar to grazing production discussed earlier e.g infrastructure
- No figures on the % of feedlot cattle come in pre-treated as feedlot-ready cattle.

- Geoff uses technology to draft animals at dispatch. Implementing a system to scan cattle when transferred between pens.
- Discussed tag losses (minimal at Geoff Cornford's operation).
- All big feedlots use same industry standard and technology – little information from producers.
- Info transfer along the supply chain. Little connectivity between various components of supply chain – data transfer protocol.
- Industry wise data transfer standard from saleyards to processors.
- Individual feedlots benchmark supply performance. More a company differentiation than industry. Difficult when competing for cattle at the saleyards.
- Heat stress – most large feedlots have weather stations. Forecast service provides 6 day forecast from 80 sites around Australia in major lot feeding areas. Use forecasts to monitor their own environment and make decisions accordingly. Have risk assessment package for different classes of cattle within feedlot – different treatment protocols accordingly. Sean: Infrared technology/ eye scanning technology patented?
- Variability in performance of cattle growing on stations – Sheep CRC has the same issue. Large degree of variance between pens of cattle – is there opportunity to ID and draft better performers early in the process. Geoff: done figures on that – more cost effective to leave bad performers in a pen than take them out.

Comments / Impressions on the day
Tony S: One shoe doesn't fit all industry sectors – who will get the best advantage from the technology? Project will do economic modelling at enterprise and industry level.

9.2 Milestone 2: Report on Objective 2

Objective 2: *Document in detail the range of potential on-farm applications of PLMs and describe how various technology and innovation components underpin each application. This may require identifying and evaluating different technology components and innovation approaches being developed for the same application eg walk-over weighing and auto-drafting.*

Range of potential on-farm applications of PLM and the technology that underpins them
Potential on-farm applications for PLM technologies and systems that the workshop identified are summarised below. The responsible research organisation, the applications and the components of each technology are listed for each PLM.

1) Cattle Mustering and Movement

1.1) Unmanned Aerial Vehicles (UAV's)

Issue	**Detail**
Research organisations & contact	• Field Robotics - Salah Sukkarieh (Australian Centre for Field Robotics)
Applications	• Surveillance • Weed monitoring • Mustering animals • Monitoring animals • Biosecurity
Technology/Components	• Mobile device (helicopter, aircraft, vehicle) • Radio • Sensors (infrared, radar, images) • Computer • Battery

The key issue with this technology is delivering practical tools for producers to use on property. Much of this technology is still in the research phase.

1.2) Virtual Fencing

Issue	**Detail**
Research organisations & contact	• CSIRO - Greg Bishop-Hurley & Dave Swain
Applications	• Controlling grazing distribution (environmental and production application) • Moving animals • Locating animals • Research to understand animal behaviour • Linking cow to calf
Technology/Components	• GPS chips – Power usage a major issue • Radio unit for communication • Sensor platforms, including animal status and temperature • Battery – Endurance and weight are significant issues • Animal interaction – Audio or electric shock • Base station and interface • Base station aerials

2) Advanced cattle measurement and management

2.1) Machine Vision

Issue	Detail
Research organisations & contact	• The University of Queensland - Neal Finch • National Centre for Engineering and Agriculture (USQ) – John Billingsley • QDPI - John Lapworth • QDPI - Les Zeller
Applications	• Recognition of animal species for drafting, walk over weighing and research purposes • Scan carcass characteristics (eg ViaScan)
Technology/Components	• Camera + capture and transmission of data – the latest cameras can transmit the data to a mobile phone (thus a role for Telstra) • Computer • Output device (eg gate activator)

This technology has application is a relatively small niche integrated with other PLM technology. The key technical issue currently appears to be the accuracy of the systems.

2.2) EID Tags/RFID

Issue	Detail
Research organisations & contact	• Allflex - Pat Gunston • Aleis - John Finlayson
Applications	• Individual animal identification • Storage of information (eg smart card)
Technology/Components	• Electronic tag • Electronic reader devices • Scales to store data • Computer to analyses and store data

This technology has been well developed and is in the commercial domain. The key issue is the capacity to use these devices to improve the productivity and traceability of animals through the production system.

2.3) Walk-over weighing

Issue	Detail
Research organisations & contact	• Desert Knowledge CRC – Craig James and Andrew Bubb
Applications	• Weighing animals while in the paddock
Technology/Components	• Scales • Race/gates to channel animals over scales • Paddock to channel animals to the water point • Weight recording device • Computer and algorithms to store and analyse data • Telemetry?

The key issue is still animal behaviour ie getting animals to stay on the platform long enough to get an accurate weight. The second generation True test equipment may assist to overcome this problem.

2.4) Auto drafting

Issue	Detail
Research organisations & contact	• CAWD - Tim Driver • Desert Knowledge CRC – Craig James and Andrew Bubb
Applications	• Draft animals with specific management requirements from the mob (eg sale, supplement, etc) • Draft feral animal from domestic animals
Technology/Components	• Race/gates to channel animals over scales • Paddock to channel animals to the water point • RFID tags • Tag readers • Machine vision? • Computer to make decisions on the draft • Telemetry?

This technology has potential for the integration with automatic weighing and machine vision. The key issue is still animal behaviour.

2.5) Telemetry

Issue	Detail
Research organisations & contact	• Observant – Matthew Prior • Desert Knowledge CRC – Craig James and Andrew Bubb
Applications	• Monitor water levels in reservoirs and troughs • Start and stop remote bore motors • Collect and send images from remote locations (eg troughs, gates, etc) • Collect, store and transmit rainfall information • Monitor water medication devices • Send animal weight information from yards to a homestead
Technology/Components	• Sensor device (level sensor, camera, etc) • Computer to process information • Battery • Solar panel • Radio to transmit signal • Aerial • Base station and interface

This technology is well advanced and commercially available. Application of this technology within the pastoral industry will determine its economic impact.

2.6) Data management and processing/decision making

Issue	Detail
Research organisations & contact	• Sheep CRC – Mark Copeland • Desert Knowledge CRC – Craig James and Andrew Bubb • Outcross - Tom Newson • Livestock Exchange – Gary Edwards
Applications	• Make good management decisions using the data collected (eg selection based on individual animal performance eg link progeny to mother, select on growth potential, etc)
Technology/Components	• Computer-based models to analyse data • Competent person/agency to analyse data leaving producer with more time for essential on-property activities.

The key issue with this technology is the efficient and practical analysis of the data collected. In many cases this will need to be completed off farm.

3) Feedlot performance measurement and Management

3.1) Individual animal management using feed intake and production data

Issue	Detail
Research organisations & contact	• MLA - Des Rinehart • ALFA members and others
Applications	• Identify good and poor performance animals early in the feeding operation for segregation and targeted management • Early identification of disease or stress • Identify superior sources of feedlot animals
Technology/Components	• RFID tags • RFID tag readers • Scales • Individual feed intake measuring device – some uncertainty regarding availability and cost effectiveness • Computer for analysis

The missing technology is apparently a cost effective capacity to measure individual animal feed intake and associated performance. The focus is currently on pen-scale management which is at odds with making gains through exerting selection pressure on the variation that exists in any population – in this case a pen of animals.

Overall progress of the project

On this occasion Milestone report (2.1) is being supplemented by Milestone report 2.2. The latter provides a description of each PLM in terms of likely applications and is 60% completed at this stage. The reporting of Milestone 2 will be completed by November 2009 with full details going into the project's final report. The next task confronting the project is an enterprise level analysis for the purpose of determining the marginal effect on costs and returns of particular technologies.

Recommendations

The timing of this project has been affected by a delay in developing the contract but from this point (mid-June 2009) it should be possible for the project to proceed as originally intended. For this particular project, it is expected there will be a close working relationship between all members of the project team, including its manager Rodd Dyer.