THE DEVELOPMENT OF FARMING TECHNOLOGY SOLUTIONS

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SUMMARY

Producers must improve their management efficiency if they are to remain profitable and sustainable. Technology is available to assist producers do many routine tasks more easily and cost-effectively. Our thrust will be the consolidation of technological innovations from various sources into holistic Farming Technology Solutions (FTS) management systems that are fully-automated, remote-controlled, durable, ringer-proof and cost effective. Industry technology requirements were determined through broad-scale consultation. The Remote Information Management System (RIMS) is the communication platform for the transfer of information needed to operate the other component technologies. RIMS will undertake the development of cost effective video surveillance and telemetric control infrastructure for remote/rural area application. The development of Virtual Fencing (VF) and the Electronic Livestock Passport (ELP) are key modules of the animal control theme while NIRS, DNA Mapping and Nippidrink address the nutritional issues. This paper introduces these current product concepts, their inter-linkages, proposed research objectives and strategies towards commercialisation.

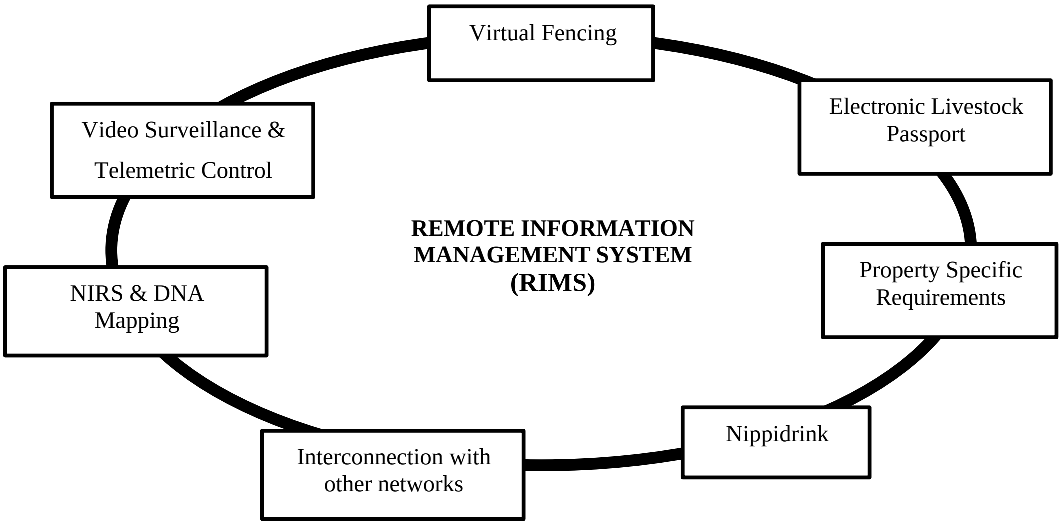
1. INTRODUCTION

The evolution of traditional product markets is challenging producers to improve their management efficiency if they are to remain profitable and sustainable. In many cases, innovative technology is available to assist producers do many routine tasks more easily and cost-effectively. The adoption of new technology by livestock producers has been slow and sporadic. A main cause of this is that most technologies are perceived by livestock managers as being disjointed and not cost-effective alternatives to current practices. Technology suppliers rarely market more than a few product lines and these lines are often not compatible for cross-integration into holistic management systems. The consolidation of technological innovations from various sources into holistic Farming Technology Solutions (FTS) products is the underpinning thrust of this project. In doing this, the value of FTS products will greatly exceed the sum value of their individual technology components, making investment in FTS products highly attractive to livestock managers and more so the reassignment of precious managerial time. The goal is to develop management technology that is robust and durable, ringer-proof, and cost-effective.

Industry technology requirements were determined through broad-scale consultation (GMS *1997*, Rouda *1999*). These can be grouped under the broad management headings of control and nutrition. The FTS technologies being developed are functional modular components of a complete FTS system. Each of these are discussed separately below. Their relationship is presented in Figure 1.

Remote Information Management Systems (RIMS) is the communication platform for the transfer of information needed to operate the other component technologies. RIMS will undertake the development of cost effective video surveillance and telemetric control infrastructure for remote area application. The development of Virtual Fencing (VF) and the Electronic Livestock Passport (ELP) are key modules of the animal control theme while NIRS, DNA mapping and Nippidrink address several complex nutritional issues. This paper introduces the current product concepts, their inter-linkages, proposed research objectives and strategies towards commercialisation.

Figure 1. Technology components and their relationship within the conceptual FTS management framework



2. MODULAR COMPONENTS OF FTS

Remote Information Management Systems (RIMS).

The large size of rangelands properties means significant human resources are consumed in routine checking of property infrastructure. These resources could be reclaimed through remote monitoring of watering points, dams, cattle, feeders, equipment and other key locations around properties. The status of a site could be quickly determined and appropriate action taken if required. This paper describes a remote video monitoring system under development by the Communications Technology Research Group (CTRG), Curtin University of Technology and the Department of Agriculture Western Australia. Seed funding for early development has been provided by the Gascoyne Murchison Strategy and the Dairy Research & Development Corporation (DRDC). RIMS uses remote camera units connected to a radio network as discussed by Chung and Rouda (*2002*). The camera units transmit images via radio using RIMS to a standard personal computer, which acts as a central controller and database. Using this computer an operator can monitor live images or review recorded footage. One of the major advantages remote monitoring can bring to rangelands property management is in the maintenance of watering points. They normally require frequent checking and repair, as an inoperable watering point can have severe consequences on livestock productivity and welfare. Remote monitoring could be used to determine watering points requiring servicing, facilitating improved time management and a reduction in stock deaths from dehydration. Remote monitoring can also serve other applications including security surveillance, capturing and storing images for later review or distribution to clients via the Internet or email, environmental data and monitoring livestock behaviour. When applied in conjunction with remote automation and electronic livestock passports as described by Fung et al. (*2002*), the possible applications and synergies are numerous.

Radio telemetry systems are commercially available and already in use on some properties. These typically provide information from remote sites in the form of status lights, text messages or simple graphics. These systems can be very useful, however images can provide a clearer understanding of what is actually occurring at a remote location, regardless of the problem scenario. With telemetry systems the cause of a problem can be unclear, with only a finite condition provided on the status of remote equipment. For example, a watering point with a leaking trough or contaminated water would more than likely be reported as fully functional because the water level remains above a certain preset value. Also, anecdotal evidence suggests that property managers would prefer visual confirmation of telemetry data before expending time checking on a warning indicator. Often, prior knowledge from images is valuable for making appropriate preparations before traveling to a remote site to effect repairs. An example is the correct equipment to bring along and the personnel required. The potential of video in remote monitoring is evident and yet existing commercial video systems are not in use on rangelands properties. Several wireless video systems are commercially available but almost without exception these systems are considered too expensive or fragile for use on farm properties. Many of these systems are analogue and not compatible with low bandwidth transmission. Furthermore, the analog video signals do not render for flexible storage and retrieval. A few of the more advanced digital video systems, which employed image compression, tend to target applications in which performance is a higher priority than cost, such as video surveillance in casinos.

This project will design a versatile digital video system, which can be integrated into RIMS for remote monitoring and surveillance of rural properties. For these applications, time lapsed images, rather than continuous real-time video is normally deemed desirable in view of the small storage and transmission overheads required. As equipment cost is a prime consideration, the specified picture quality obtainable from the proposed system must be kept to a level commensurate with the cost sensitivity of such applications. Also, to keep the system development costs down, efforts will be made to adopt the use of as many off-the-shelf components as possible. The pre-commercial development costs for RIMS have been estimated at $815,000.

Virtual Fencing

Virtual Fencing is an innovative alternative method for controlling grazing animal movement that does not involve conventional wire fencing. Once fully developed, VF technology will be readily applicable to grazing enterprises across the meat, dairy and wool industries. The concept of "wireless fencing" was pioneered in the US by researchers driven by the need for a cheaper means of keeping cattle away from sensitive river frontage (Quigley *et al. 1990*; Tiedemann and Quigley, *1994*). Tibbs *et al*. (*1994*) investigated the effect of audio-electrical diversion on cattle grazing behaviour, nutritional physiology, stress physiology and performance. They found animals controlled by conventional fences selected diets higher (P<0.05) in crude protein than those subjected to audio-electrical diversion but no differences (P<0.10) in body condition or serum hormones levels (used as physiological stress indicators) between the two groups were observed. Fay *et al.* (1989) reported pulsed-radio-wave-activated shock collars were an effective means of containing goats within a weed infested area as biological control agents. Encouraged by these findings, the Department of Agriculture Western Australia (DAWA) collaborated with Land and Water Australia (LWA) and Environment Australia (EA) to develop VF in Australia (Rouda, *1999*).

The current basic conceptual VF system is based on a radio-wire type fence that radiates an electromagnetic (EM) field to create an exclusion zone and an on-animal receiver that will pick up this EM field within a defined range. Animals are trained to alter their direction of movement in response to audio-electrical stimuli delivered by the on-animal receiver. In addition, a programmable remote herding vehicle (RHV) equipped with a transmitter may be used to create a mobile inclusion zone for moving animals around. The virtual exclusion zone is created using a single radio wire hung on two to three metre high posts, well out of the way of farm machinery and/or river flooding. As animals come within a certain distance of the radio wire they are signaled to turn around and move in an opposite direction. Conversely, the virtual inclusion zone is created using animals equipped with the same receiver device configured to provide an audio-electrical stimulus once an animal begins to move outside of the range of the EM field transmitted from a mobile RHV. In this mode, the animals are encouraged to stay within a set distance of the RHV. Furthermore, a RHV can be remotely programmed to move its assigned animals to any location at a given speed. It can also receive seasonal condition intelligence via satellite and adjust its travel route accordingly. The various operational modes of the current conceptual models have been graphically presented in Rouda (1999). In view of the rapid development in the GPS technology and its imminent incorporation in mobile telephony, it promises to become an attractive alternative approach for the establishment of VF. It is envisaged that such an approach will be more cost effective and flexible in terms of boundary reconfiguration in the long run as well as being able to achieve a consistent boundary resolution. As such, incorporating a programmable GPS-compatible chip into the on-animal receiver device will eliminate the need for both the radio fence and the remote herding vehicle as on-ground directors. In principle, animal movement could be keyboard orchestrated via satellite or terrestrial communication, such as the RIMS radio network, by altering the GPS coordinates. Further, the possibility of incorporating the information from satellite pasture monitoring technology to the VF environment is conceivable. Also, the on-animal "tag" would ideally contain the necessary electronics to support the National Livestock/Flock Identification Schemes (or the advanced Electronic Livestock Passport) and milking parlor management.

The need to establish the long-term cost effectiveness of VF technology over the single wire electric fencing systems now commonly used on grazing enterprises across Australia is well recognised. However, it is envisaged VF will provide livestock producers with many benefits that include allowing them to locate and/or move their animals with a few strokes of the key board, utilise satellite intelligence to fully exploit seasonal conditions, achieve uniform and proper use of natural resources and take full advantage of existing property infrastructure. The goal will be a benefit to cost ratio in excess of 5. In terms of mustering alone, the potential savings to production costs could be as high as $110,000 per annum. (Rouda, *1999*).

A plan outlining the various stages of the VF developmental process is presented in Table 1. With stage 1 now completed, the current project will focus on resolving the fundamental issues related to animal response to various remotely-controlled electronic aversion cues (testing animal welfare and conditioning to invisible barriers). Subsequent reports suggest the methodology used by Tibbs et al. (*1994*) may have confounded the results reported (Stricklin and Mench, *1990).* We will also investigate the fundmental aspects of technological efficacy of establishing well defined EM boundaries using ground based and satellite (GPS) technologies. The cost of completion to Stage 3 is estimated at $1,870,000 with a further $3,000,000 needed for commercialisation.

Electronic Livestock Passport

The Australian livestock industries are important national economic pillars. However, the strong dependence on the global market also means that the producers are facing intense competition and the need to satisfy customers' demands for quality-assured products. In order to maintain high standards and efficiency, the industry must meet international and national standards and improve quality and yield through better production and management processes. International standards have been set by bodies such as the International Committee for Animal Recording (ICAR) and the International Standards Organization (ISO). ICAR is in the process of establishing international agreement governing the recording practices of animal identification. With respect to the use of radio frequency identification (RFID) for animals, ISO has issued two standards, ISO-11784 and ISO-11785, concerning the code structure on the RFID and the technical concept on how information is being transferred. These have formed the basis of the commendable National Livestock Identification Scheme (NLIS) developed by MLA. While NLIS is a voluntary national system, it is extremely important for the producers to meet compliance in the overseas markets. Although NLIS tags meet the standards and legislation requirements, the bottom line for their adoption rest with the business interest of the producers. It would be an additional economic burden if new technology does not improve the quality of the product and

Table 1 Virtual Fencing Development Plan.

PHASE	ACTIVITIES	OUTPUTS	TOTAL PHASE COST	FUNDING SOURCES INVOLVED	COMPLETION DATE
1. Conceptualisation	• US Study Tour • Pre-feasibility study • IP Protection	• US prototype purchased • Conceptual design, projected benefits, promotion • Patent protection in Australia, US and NZ	300,000	DAWA, LWA, EA	1996 1999 In progress
2. Feasibility Screening	• Research fundamental issues	• Animal response to various remotely-controlled electronic aversion cues • Efficacy of establishing well-defined EM boundaries using ground and satellite based technologies	690,000	RDCs ARC Link DCT COMET DAWA CUT & UWA	June 2004
3. Pre-Commercial Product Development	• Initial product development • Laboratory & field testing • Product development • Commercial partnering • Field trials	• Product specifications • Functional prototype • Pre-production model • Licensing arrangements • Functionality confirmation	880,000	RDCs ARC Link DCT COMET DAWA CUT & UWA Commercial Partner	June 2006
4. Commercialisation	• Market testing • Product manufacturing • Strategic Marketing	• Market segmentation • Tooling for production or contract manufacturing • Pricing, promotion, distribution & sales	3,000,000	Licensee	2008

the profit margins. Hence, it is more important that NLIS or any new scheme must be able to improve the management process in order to lift the quality and profit. The proposed Electronic Livestock Passport (ELP) utilises the Read-Write RFID technology and as such presents a significant upgrade of the current NLIS tag that only provides a read-only code. ELP will allow a certain amount of information to be stored, read, updated and modified according to different requirements. The information will be stored in "safe-boxes" which are protected and encrypted in order to maintain the data's security and integrity. During different stages of the livestock's life cycle, different individual parties may access to different part of the tag's memory that is of relevance to their operations. This allows access to the information that is pertinent to the relevant party. Incorporating with the RIMS proposed by Chung and Rouda (*2002*) and video monitoring system presented in Jerrat et al. (*2002*), the ELP provides an integrated approach to the entire production, sales and marketing process. The current project aims to develop a smart identification tag for trader livestock that can passively transmit, receive and store information to streamline the recording of a multitude of production parameters/traits of interest to each segment of the supply chain. The pre-commercial development costs for the ELP have been estimated at $600,000.

Near Infrared Reflectance Spectroscopy and DNA Mapping

The quality of diets consumed by grazing animals has a profound effect on their productivity and profitability. Extended periods of nutrient deficiency (nitrogen, phosphorus and other essential nutrients) are often the cause of losses in animal body weight and condition, reduced feed intake and diet digestibility and poor reproductive performance. Managers are often faced with difficult and costly decisions as to when to start and when to stop supplementing these nutrients to their animals. Conventional methods for estimating nutritional attributes and the intake of grazed pastures are time consuming, costly and somewhat unreliable. Dr David Coates (CSIRO Townsville) has pioneered new technology that analyzes animal feces using Near Infrared Reflectance Spectroscopy (NIRS). Dr Coates has recently been granted additional MLA funding to progress NIRS and he is keen to see NIRS analyses extended to other regions across Australia. Under the current MLA-funded project, there are several sites in Queensland, a few in the NT, one in SA *but none in WA.* Chemistry Centre WA (CCWA) owns compatible NIRS equipment and CSIRO has offered to provide its calibration equations as a preliminary step towards a future on-going program of validation and expansion to increase the robustness of these equations. CSIRO has yet to obtain calibration data from saltbush and seeded pastures data on which is readily obtainable in WA.

A major shortcoming of the NIRS method is that while it provides an estimate of feed intake (and subsequent production) in grazing animals, it does not provide any accurate and precise information as to what the animals are actually consuming within a desirable degree of resolution (i.e. specific composition of the diet). This issue is of particular importance to grazing in the fragile environment of the rangelands. Being able to identify what the grazing animal actually consumes will enable managers to pinpoint the ‘at risk’ species and formulate appropriate grazing management strategies to conserve/protect these species.
There are a number of techniques available for assessing the diet composition of grazing animals. These include direct observation, microhistological identification of plant material in esophageal or fecal samples and the use of alkane markers (unique to each species and identified in the feces). Direct observation has very limited practical application, especially in the rangelands. The greatest limitations of microhistological identification are that overall accuracy is a problem; the time required to train technicians and variation in accuracy between technicians. Differences in the alkane patterns or concentrations between plant species (Dove 1992) and the assumption that these alkanes are not (totally) absorbed is used to determine dietary composition. However, alkane profile differs between plant parts and at different stages of maturity (Dove 1992) and this limits the ability of the profile to be used as a unique identifier of that species (Lee & Nolan 2003). The DNA profile or map of a plant does not alter, regardless of the plant part or stage of plant maturity. This project will develop NIRS fecal analyses capability in Western Australia for the determination of diet quality attributes for animals grazing natural and improved pastures. It will also evaluate the effectiveness of DNA mapping to determine the species components of rangeland diets and compare the use of alkane profiles and DNA mapping for the determination of dietary composition. Finally it will

provide livestock managers with cost effective and reliable tools for tactical animal nutritional management and establish best-practice/strategic nutritional management guidelines for various grazing livestock systems in WA. The development costs for this component have been estimated at $800,000. Sampling collaboration with CSIRO's remote sensing of food-on-offer is currently being negotiated

Nippidrink

Research into novel watering devices for free-ranging stock has not progressed significantly since the introduction of the watering trough (Rouda, unpublished data). This system, though functional, is not very efficient as water is lost through evaporation and routine cleaning (estimated at approximately 6,200 litres per year for each standard 3-metre trough), and troughs require constant monitoring and maintenance to ensure they operate effectively. Even if information technology soon becomes available to remotely monitor water troughs, producers will still need to visit their troughs to clean them. Trough maintenance costs producers an estimated $15,600 –20,800 every year, and if this could be reduced, profitability would increase by an estimated $10,000 annually. In April 2000, members of the Nullarbor Eyre Highway Land Conservation District Committee (LCDC) received PIRD funding from Australian Wool Innovations to develop a watering device that ensured grazing livestock had reliable access to quality water, free of algae and other contaminants. Low capital investment, reduced maintenance costs and ease of animal training were key considerations. LCDC members worked closely with CMAE scientists to design and test an innovative stock water delivery device, now known as Nippidrink (Nd). Nippidrink may greatly enhance the control and dispensing of nutritional/medicational products and soluble lures (aniseed/salt) to keep stock on waters equipped with trap yards all year round even when there is large amounts of paddock surface water (Total Grazing Management Systems after Pearce et al. *1998.*). Nippidrink design features will also help control feral predators.

Basically the Nd system consists of a set of commercial pig nipples connected in series to a water pipe set at a given height above the ground. Development was initiated in May 2000 at the Muresk Institute of Agriculture at Northam in Western Australia. Four trials were conducted to establish preliminary design features and animal training requirements of the Nd system (Krebs et al. 2000). The Muresk prototype built by W.D. Moore and Co., consisted of 18 mm polypipe fed from the mains connected to 40 mm PVC piping, 1.8 m long and slanted (600mm at one end and 400 mm at the other, off the ground). The nipple delivery system was developed along the line of PVC piping. The line consisted of 500 mm lengths of PVC connected with threaded T-sections for attaching nipples, with a 40 mm cap at the end. Nipples where attached to both the front and back faces of the PVC piping at an offset spacing of 50 mm, and directed downwards at a 25 degree angle. Initially the nipples were made to drip by jarring their toggle open using a rubber band and sheep fed a mixture of chaff and lupins containing 10 grams of salt learnt to use the nipples in less than one hour, suggesting induced thirst provided an ideal incentive for accelerated learning. Sheep preferred the higher positioned nipples.

The first of two station trials was conducted in July 2000 on a 2 sq km holding paddock at Noondoonia Station, situated 200 km east of Norsemen WA. One hundred sheep of mixed age and sex were used. The nipple line was fixed in place at a slightly modified height with the lower end at 350 mm and upper end at 750 mm above the ground. Each T-section had a spacing of 250 mm and the nipples were placed alternatively, i.e. 500 mm between each nipple on the same side of the pipe and 250 mm between nipples on the opposite to offset eye contact between sheep drinking on opposite sides of the pipe. The delivery pipe was 50 mm industrial polypipe (threaded at either end) with 50 mm industrial poly T-sections threaded in all three directions. A total of 21 nipples were placed along the line giving a total operational length of 11 m. It took approximately 3 days for the entire flock to learn to use the nipples. Again, preference for the higher positioned nipples was observed and significant water wastage was noted at the lower end of the delivery system, suggesting increasing the height of the nipple pipe would be advantageous. The second station trial was conducted at Fraser Range Station, 100 km east of Norsemen in mid-July 2000, to test and refine the design for commercial applications. A Nd device, modified in accordance with the Noondoonia findings, was installed in a 4,900 ha paddock containing three conventional water troughs spaced 3 km apart and 600 merino ewes with lambs. The Nd replaced one of the established troughs, which was completely disabled. The Nd tested on Fraser Range was 700 mm at its lower end and 110 mm at its higher end. Plastic netting was placed under the pipe line to prevent animals from moving under it and angle iron was attached to the upper side of the pipeline to reinforce its strength and provide shading. There were fewer support pipes used and a pressure regulator set at 7 psi was installed in line. Despite the other two troughs remaining functional, mobs containing as many as 300 sheep of various ages were observed using the Nd system within a week of it being installed. Observations indicate animals again showed a preference for nipples located at the higher end of the pipe. The small amounts of water regularly found under the nipple pipe suggested further modification of the nipple design was required to reduce wastage.

The station trials indicated that more work was needed to improve Nd's efficiency and reduce water wastage. Therefore another set of experiments were conducted at the Bentley Campus of Curtin University of Technology in early 2002 to determine water flow rates and optimal pressure ranges for rangeland applications (Chung et al. 2002, unpublished data). A 2 m long nipple pipe with 4 nipples attached 500 mm apart was used. A 45 l drum fed water to the pipe via an 18 mm hose. Results indicated a 2.9 m gravitational gradient was needed for enough water to flow through the nipples to achieve a one litre per minute delivery rate. Further, the results suggested flow rates were not affected by the number of nipples activated at any one time. What was critical was the amount of water entering the nipple pipe that had to always be more than the quantum of water being discharged through the nipples. This finding has important implications for the length specification of the nipple pipe. As long as the cross sectional area of the input pipe remains greater than that of the output areas, the device should function effectively. This suggests drilling nipples directly into existing station reticulation piping, providing these are at an adequate height for animal access, may be practicable.

Another group of station tests are planned to start later this year to determine actual animal intake rates, optimal nipple configuration, height, inclination and design to eliminate water wastage. Further, the functionality of the nipples with varying water quality will be examined and the effect of ambient temperature on nipple temperature (and animal use) will also be assessed. The simplicity of Nd suggests once producers become familiarised with the concept, most would be capable of building their own units. This will undoubtedly result in a multitude of variations in designs and applications (various classes of sheep, cattle & goats; in-series connection to water medicators). Nd may also help eliminate/reduce feral predation of biodiversity. For example, nipple height may be manipulated to prevent feral cats from exerting adequate nipple pressure for water let down. The development costs for Nippidrink have been estimated at $52,000.

3. DEVELOPMENT AND COMMERCIALISATION STRATEGIES

Most of the funding received to date has been provided by the Western Australian State government in partnership with various commonwealth environmental organisations, naming Land and Water Australia, Environment Australia and the Natural Heritage Trust, via its support for the Gascoyne Murchison Strategy (GMS). These commonwealth funders have advised they are unwilling to further invest program funds unless the animal industry groups provide significant contributions as most of the proposed technologies will enhance livestock productivity and sustainable profitability.

Our attempts to establish a national consortium of technology developers between 1999 and 2001 revealed commercial players were reluctant to fully engage in the development of technologies still at the conceptual stage. I am confident that if functional prototypes had been available at the time, product developers would have been prepared to burden the risk. I am now adamant that unless the seed funding for FTS prototype development is provided from industry R&D levies, the benefits to Australian producers will never be cost-effectively realised. Just over four million dollars will be needed to develop and field test a pre-commercial product. The commercialisation cost of FTS (stage 4) has been conservatively estimated at three million dollars. Successful tender(s) for the commercialisation of the component technologies may need to invest significant additional resources. A break down of the development costs for each component technology is presented in Table 2.

At the recent Northern Australian Beef Cattle Research Council workshop held at Anna Plains Station in August 2003, Virtual Fencing development was used to illustrate a Project Development Process. At a later NABRC meeting in Brisbane on 12 September 2002, it was resolved to pursue the development of Virtual Fencing in Australia.

The DRDC has also expressed a keen interest in our FTS project and have to date invested significant funding towards the development of the RIMS component. Industry recently encouraged key representatives from Meat and Livestock Australia (MLA), Australian Wool Innovations (AWI) and DRDC to participate in discussions on a

Table 2. Development costs to pre-commercial FTS systems

Modular Component	Dollars
Remote Information Management System	815,000
Vrtual Fencing	1,870,000
Electronic Livestock Passport	600,000
NIRS & DNA Mapping	800,000
Nippidrink	52,000
TOTAL	**4,137,000**

united approach to FTS development. The meeting held in Melbourne in mid January 2003 resulted in a number of issues being raised and these have been addressed in a number of project proposals currently being considered by these three key industry research and development corporations (RDCs).

We are keen to progress the development of the various FTS technologies in partnership with third parties. Pending a favorable outcome from the RDCs and given the complexity of the technologies and the diverse range of applications that will require testing, it is anticipated that a number of state orgainsations will be invited to partner the development process. Our Department's joint venture with Curtin University of Technology (known as the Centre for the Management of Arid Environments or CMAE) has allowed us to combine DAWA specialist with talented engineers and graduate students. In addition, the FTS project exposes young engineering professionals to the livestock industries' needs and promotes their continued involvement well beyond the current life of the FTS project. The FTS project team also includes an animal behaviour specialist from UWA, animal nutritionists at the Mursek Agricultural Institute (a division of CUT), analytical chemists at the state's Chemistry Centre (CCWA) and remote sensing researchers at CSIRO in Floreat. To ensure the full integration and cross-compatibility of the various components of the FTS product line, it is imperative that a holistic development approach is taken.

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