Australian Pork Limited Final Project Report

Review of Precision Livestock Farming (PLF) technologies for the Australian pig industry

DAS Number: 1909

A report jointly prepared by

The National Centre for Engineering in Agriculture,

The Queensland Department of Primary Industries

AND

The South Australian Research and Development Institute Livestock System Alliance

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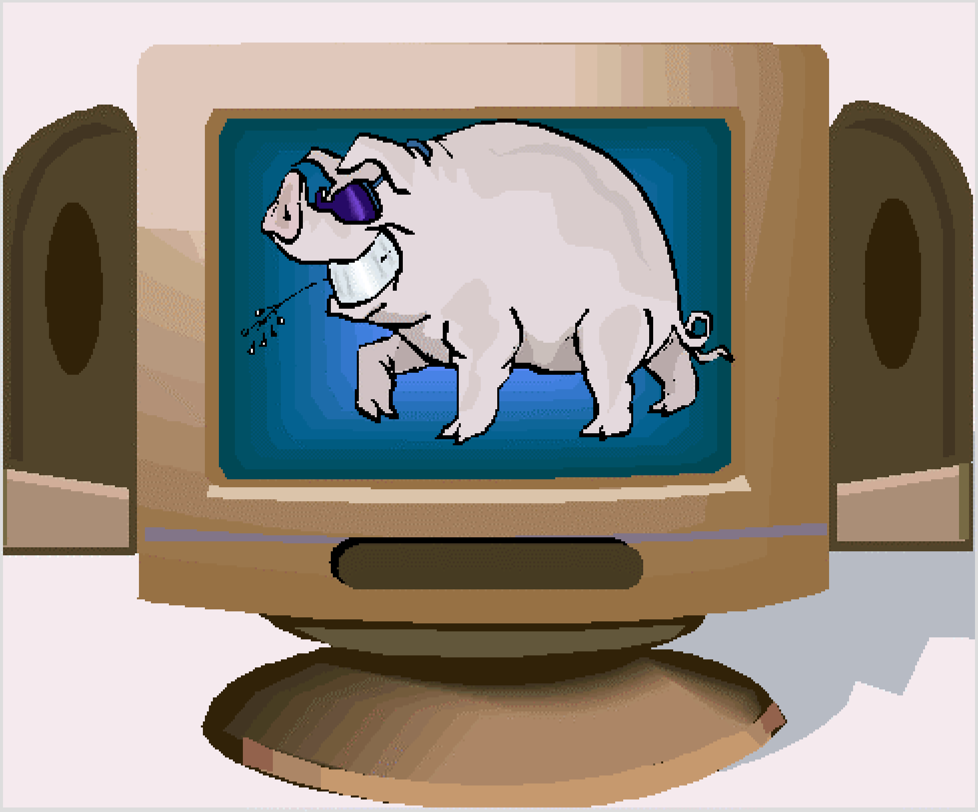

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Australian Pork

LIMITED

1 NON TECHNICAL SUMMARY

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1.1 PROJECT OVERVIEW

This project has been developed in response to a call made by the Australian Pork Limited (APL). Researchers who have undertaken this project have been intimately involved with the three Precision Livestock Farming (PLF) workshops which preceded this call (Banhazi *et al.*, 2002) and used the documentation developed in association with these workshops as a guide of identifying appropriate areas of investigation. It is understood that this project represents the first stage of a series of possible steps toward facilitating the implementation of Precision Livestock Technologies (PLT) into the Australian pig industry. The terms of reference provided required a review of currently available PLT in two main areas:

Hardware:

- Sensor and measurement systems; (Persaud, 2001)
- Automated Control Systems; and (Pietersma *et al.*, 1998)
- Data communication and storage protocols. (Schofield *et al.*, 1994)

Commercially available products were assessed by the main body of the review. A literature review of current research work was also undertaken to capture emerging technologies.

Software:

- Data analysis and interpretation software. (Black, 2001)

The emphasis was on products which can be integrated into "PLF Systems" rather than a comprehensive review of all available products.

1.2 MAIN OBJECTIVES

1. Establish the credentials of currently available technologies in this area via a comprehensive review
2. Identification of commercial products and suppliers with particular reference to the Australian Industry
3. Development of industry recommendations

2 SUMMARY OF PROJECT RESULTS

In meeting the specific objectives of the project proposal the team have achieved at least the followings:

1. Establish the credentials of currently available technologies in this area via a comprehensive review
    - The research team has been able to determine the state of development and suitability of a wide range of technology types within the context of precision farming technology suitable for the pig industry.

2. Identification of commercial products and suppliers with particular reference to the Australian Industry
    - The research team have developed a list of products and suppliers providing products and services relevant to the adoption of precision livestock technology in pig production.
3. Development of industry recommendations
    - The research team have developed a series of recommendations regarding the adoption and continued development of Precision Livestock Technologies within the Pig Industry.

2.1 A VISION FOR THE ADOPTION OF PLF TECHNOLOGIES WITHIN THE AUSTRALIAN PIG INDUSTRY

The adoption of Precision Livestock Farming Technologies within the Australian Pig Industry could occur along the following paths:

1. A grower developed system – involving adhoc adaptation of off the shelf hardware and software specifically designed to meet individual grower requirements:

- The risk associated with this approach is that there is no standardisation and hence little opportunity for coordination of research input. In addition it relies on grower initiated development which will be slow given their current capacity in this area.

2. Establishment of a full function Integrated Management System – designed from the ground up to meet the industries needs:

- A fine goal but likely to be unsuccessful as it will require an enormous investment of industry funds with very little up front performance.

3. Commercial Sector Driven System Development – leave the development of the entire system up to the existing commercial sector:

- The risk under this scenario is the development of competing systems and again a lack of industry coordination.

4. Integrated Development System – the coordination of current hardware and software components and systems to run on a standardised data communication protocol:

- This approach optimises the value of existing developments but supports the utilisation of whole of industry coordination.

Figure 1 represents a schematic presentation of the Integrated System proposed above (in 4). At the heart of this system is the Australian production model "AUSPIG".

The suggestion of the team is for the industry to support Precision Livestock Technology Developments which integrate with Auspig and facilitate the data transfer in and out of the Auspig Model.

Subsequently support should be given to PLT activities which interface with the mainstream Herd Management software programs used in Australia.

Ultimately then the loop becomes closed by a direct interface with yet to be constructed Decision Support Systems creating a uniquely Australian Integrated Management System.

The research team believes that if the industry supports developments along these lines then it is most likely to create a sustainable competitive advantage for the Australian industry. This opportunity is potentially easier for Australia to capture given the strong cross industry research infrastructure already in place, the strong market share for the Auspig Model across the industry and the relatively small number of herd management software programs utilised across the industry.

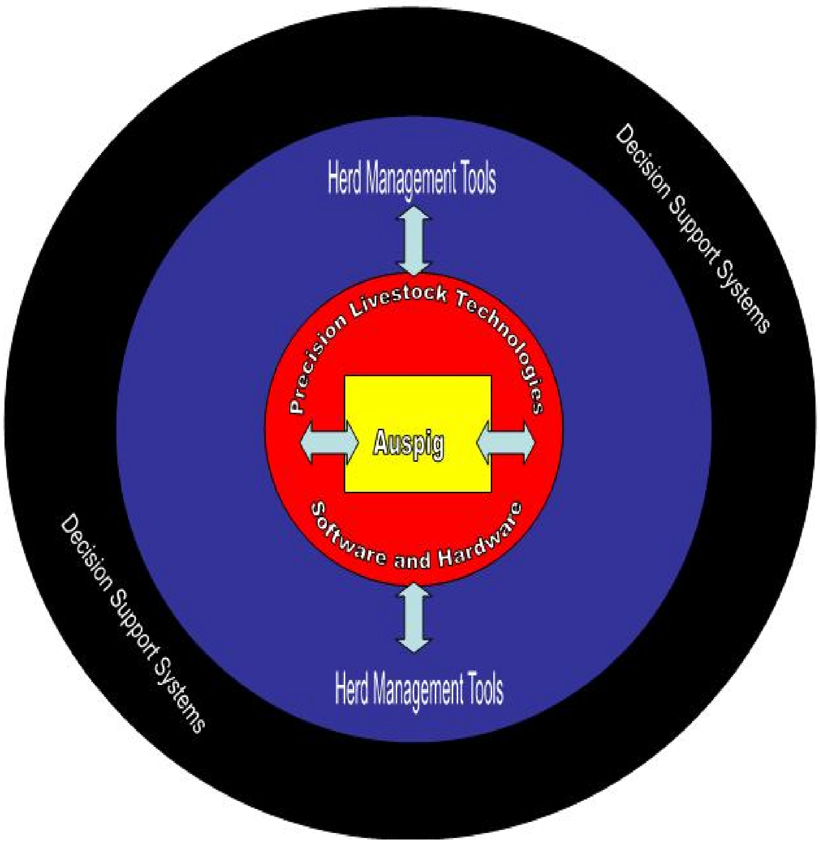

Figure 1. Australian PLF Vision

Note that the main barrier to this complete solution is currently data compatibility and transfer. All the required hardware and software components exist in the marketplace, but there is no agreed standard for stitching these solutions into a complete product.

In delivering on the vision expressed in Figure 1 the industry must recognise the need for at least the following investment:

- Some form of industry coordination through the establishment of a Task Force or Committee to oversee PLT implementation industry wide;

- The engagement of a PLT Coordinator to support the aims of the former entity;

- Investment in a coordinated awareness raising and industry training program to support appropriate PLT adoption; and

- Investment in an effectively targeted Research and Development program to plug the gaps and optimise the value of existing technology.

2.2 KEY RECOMMENDATIONS

In response to the discussion regarding future development of PLT in the pig industry a full discussion of our recommendations can be found in Section 8.0. In summary these recommendations are as follows:

1. The establishment of a Precision Livestock Technology Task Force headed by a Precision Livestock Technology Coordinator. Major functions of this group would be to:
    - Coordinate research and development activities within the industry and between industries in this area;
    - Coordinate a national awareness and promotion program for the area through national industry press and associated booklet development;
    - Deliver targeted training and support services for interested farmer groups and individuals; and
    - Organise an annual PLT Workshop to promote the overall vision and determine progress towards this goals.

2. The development of an integrated PLT Extension Program:
    - At the very least APL should support an Annual PLT Workshop (hopefully facilitated by the PLT Coordinator) at which the industry reviews its progress in relation to an overall industry vision such as Figure 1;
    - A broader awareness raising program involving articles in trade magazines, farm note style extension documents and presentations at industry functions regarding the general area and the potential benefits of adoption;
    - Targeted workshop presentations to interested grower groups on how to implement PLT on farm. The current document would form a sound basis for the development of these workshop sessions.

3. Core Research and Development Activities:
    - With respect to software R&D clearly the most critical issue to be resolved are those associated with data compatibility and transfer. There are some unique research activities to be addressed here but in the first instance the key function required is one of coordination;

- With reference to hardware R&D requirements the key issue again is compatibility and transfer and R&D projects which supported developments in this area and allowed the industry to maximise the value of currently available sensor technology are critical;
- The lack of an off the shelf real time live weight sensing system suitable for widespread implementation in the pig industry is a major impediment to the more widespread adoption of PLT in the pig industry. The research team believes that load cell based technology represents the best option for the short term resolution of this problem.
- Image Analysis Systems are still some way off commercial release in relation to live weight measurement. This technology may provide significant benefits in relation to the capture of conformational and condition scoring information as well as weight which could be of great benefit to the industry and as such industry funds should be invested in developing internal capacity in relation to this technology.

3 BACKGROUND TO RESEARCH

"Precision Farming" (PF) principles and techniques are already widely utilised within the broad-acre and row-crop industries of Australia and overseas. The principal component of precision farming in these industries is the development of accurate real time yield or performance mapping systems utilising GPS technology. The development of new sensing and data management systems will allow the development of analogous systems within the Intensive Animal Industries. In other industries the key benefit of these technologies has been in allowing producers to target specific areas in their production more efficiently for improvement (Lemin *et al.*, 1991). A key element of the system's success will be the potential to allow effective on farm research trials at a minimal cost to the producer.

The main principle of precision farming is quite simple: by using advanced IT technologies the efficiency of production can be improved as the application of resources can be more targeted and the control of production process more precise. The potential of the system is considerable, given the fact that all information measured on-line can then be processed by management models such as AUSPIG (Black *et al.*, 1999).

Most of the technological components of PF systems such as climate control equipment, automated feeding systems, computer models and decision support softwares are well developed and available commercially. However, the integration and data management aspects of PLF systems need further research & development work (Frost *et al.*, 1997).

3.1 POTENTIAL BENEFITS OF THE SYSTEM

Large scale adoption of appropriate PLT products throughout the industry will deliver: ·

- Improved on farm efficiency through direct performance monitoring
- The ability to achieve continuous improvement loops via on farm research
- Improved research efficiency generally
- Increased product consistency and the potential for real time supply chain management throughout the industry
- Improved scientific understanding of nutritional, health and environmental effects on the animals as almost all important parameters will be monitored by the system and later on new measurement parameters can be added as necessary

4 METHODOLOGY

The methodology was similar for both aspects of the study and involved the following steps:

A literature review

- Generation of a comprehensive list of current research providers and product development personnel and organisations;
- Review current status of research programs;
- Interviews with selected (key) researchers working in the area via e-mail or phone

Identification of commercial products and suppliers

- Standard commercial search engines were employed to identify potential suppliers;
- Lists of potential suppliers and technologies were obtained through industry contacts;
- A request for information was distributed internationally through relevant industry contacts;
- Direct contacts were made with potential information sources internationally to identify and assess supplier and product options.

5 HARDWARE REVIEW

5.1 INTRODUCTION

This section provides an overview of hardware components and systems, and a review of the core technologies for data acquisition and management.

Precision Livestock Farming (PLF) hardware in general can initially be broken down into three categories:

- Sensors (electronic data capture)
- Controllers (output)
- Communications Protocols (data transfer between components)

5.2 SENSORS

Sensors are devices designed to obtain data about the physical (temperature, weight) or non-physical (market prices) environment. The output given by the sensors may be either digital or analogue.

- *Analogue* output is usually a DC voltage range from minimum to maximum reflecting the quantity being measured. A typical temperature sensor, for example, may return 0-10 V dc calibrated from –30 to 70°C.
- *Digital* output is a coded representation of the measured quantity in some particular format, transmitted by a particular method. For example, a weighing machine may transmit the weight of an animal in ASCII (the **format**), via an RS232 serial interface (the **method**). This will be discussed further in C*ommunication Protocols* (Section 5.4)

Controllers, data loggers and control systems may accept either analogue or digital signals, depending on the specifications.

This review is specifically interested in sensors to measure data that has been identified as important for improving efficiency and competitiveness for Australian pig enterprises. These items are:

- **Environmental Data**. These data variables are crucial to the efficient management of piggery buildings. It has been shown (Banhazi *et al.*, 2001; Banhazi *et al.*, 2000a; Kadzere *et al.*, 2002) that within the thermo-neutral zone the feed conversion of animals is the most efficient. This means that significant economical benefits can be obtained simply by controlling the temperature in piggery buildings with relatively cheap temperature sensors and controllers. Other environmental variables to be measured are:
    - Shed Temperature, humidity, wind speed and direction
    - Outside temperature, humidity, wind speed and direction
    - Shed Dust concentration
    - Shed CO2 concentration
    - Shed Ammonia concentration

  - Shed and outdoor Odour level

The current BASE-Q project (funded by APL) is aimed at developing a sensor system and related software package to obtain most of the above mentioned variables cost effectively (Banhazi, 2003).

- **Input Data**. One aspect of calculating the efficiency of an enterprise is measuring the income versus the expenses, and maximising the returns. This is done by measuring the main input variables (such as the amount of feed, labour, medication, water etc. used) and relating to the income (price of pork meat). Producers rarely measure the amount of feed used per day and in addition there is increasing demand to measure the feed intake per pig to get a more precise cost benefit analysis for breeding programs and different feed mixtures. Water use is also becoming an issue, as more focus is placed on water use efficiency in the current environment where water costs are rising rapidly and environmental issues becoming important aspects of livestock production.
  - Feed intake
  - Water intake

- **Output Data**. The measurement of outputs is also an important part of any enterprise management system. Whether for feedback into the control systems or to alert the user for manual intervention, these variables are important for production control purposes.
  - Pig weight and variation
  - Proportion and duration of wet skin
  - Audio capture
  - Video capture
  - Back fat thickness
  - Oestrus detection
  - Market feedback

The following issues should be addressed when deciding on sensors:

- Accuracy. Devices should typically operate at better than 5% accuracy to make capturing of data worthwhile. However, the cost benefit of accuracies of better than 1% may well not be positive.
- Reliability and Environmental robustness. In a live working environment, sensors should be designed for industrial purposes and be at least water- and dust-proof and resistant to knocks and falls.
- Availability of data for logging. Read out devices can be useful for on the spot assessment but the real value of data is in its post processing against other performance parameters.

Data loggers are a critical component of any data capture system. Manual collation of data is not only time consuming but prone to serious errors of omission and accuracy. These devices record samples of the value being measured by a sensor at standard time intervals and store them for later processing. This data can then be downloaded and analysed using a variety of software. For example, data logging the temperature in a pig shed every 10 minutes may reveal a period in each day of higher than normal temperatures that would not be noticed otherwise.

In Appendix A information on sensor suppliers is presented together with information regarding their performance and applicability.

In summary the key issues to be aware of when examining potential sensors are:

- **Reliability and robustness;**
- **Accuracy; and**
- **Data Accessibility.**

5.3 CONTROLLERS

Controllers are devices capable of manipulating the physical environment based on some input(s). Controllers may be connected to one or many sensors. There are several categories:

- **Single Loop**. These are generally stand-alone controllers with preset limits on a single input to perform some output function. An example of this is a temperature control set to run a motor to open shutters when the temperature reaches a certain point, and close them when the temperature drops. There may or may not be measured output available for data logging and serial communications.
- **Multiple Loop**. These controllers can perform more complex operations on multiple inputs. Many different variables can be controlled in a coordinated fashion. Data such as age of pigs may be entered to affect the process. Feedback from other sources can be used as a reference for the system. An example of this is using the daily weight gain of the pigs to affect the feeding control system.
- **New generation (intelligent) controllers** (see literature review 7.7.1)

Most producers would have some exposure to at least the Single Loop Controllers and are familiar with their operation including setting critical control points, alarm settings and manual override functions.

The issues to be considered when selecting controllers for a task are:

- Type – as above, single or multiple loops may be required, depending on the situation.
- Inputs – ensure that the sensor input is compatible in terms of signal type (analogue/digital) and in terms of system relevance – there is no point in measuring the temperature in one part of a shed and having it control ventilation in another.
- Output - ensure that the controller can manipulate the output (i.e., run the motor etc)
- Extendibility – the system should allow for incorporation of additional sensor elements and controlled outputs over time as conditions within the piggery change.
- Power requirements. Most controllers run from standard mains power although some may use battery power as a standalone or backup system.
- Reliability and robustness.

Although control systems of various types are common within the pig industry very few of these systems are subject to any form of rigorous performance assessment. Shed ventilation control units can be easily assessed in terms of the variation between ambient and shed temperature levels in a controlled versus a non-controlled environment. Most controllers on the market incorporate some form of data logging capacity which would easily facilitate this level of performance assessment but our understanding is that these features are rarely accessed by producers.

5.4 COMMUNICATION PROTOCOLS

Analogue signals are generally easy to read but difficult to store and transfer between components of a control system. It is for this reason that the bulk of data transfer within modern electronics equipment is in the digital form. Digital data is primarily based around the binary form common within all computer systems. In order to store or transfer digital or binary data sets it is critical that the Communication protocol is defined. This effectively means the language in which the data is stored.

Protocols are a set of standards to be adhered to by a component within a system to ensure that all other components using that protocol can access the data. Any system that passes data between components or stores data needs to have some form of communication protocol. This may be proprietary or standard.

Proprietary protocols are those developed and owned by specific organisations to service their own particular brand of sensor, controller or logging system. The use of proprietary protocols becomes more common as the complexity of the data sets being analysed increases. Most simple temperature sensors conform to one of the industry standards. More complex multi sensor environmental monitoring packages may choose in the interests of internal security and efficiency to develop their own system.

Industry Standard Protocols are created by consensus within an industry to allow more open access and transfer of data between systems. Examples of these standard systems are the ASCII or Comma Delimited File Types commonly used for the transfer of financial data or the NMEA Protocol used for the transfer of Global Positioning Systems data sets.

Obviously, standard protocols allow for extending the system with components from other vendors. This issue will play a major part in the success of any PLF system as it is the keystone for components of the system to 'talk' to each other.

***O**pen **S**ystem **I**nterconnection (OSI)* defines a standard for worldwide communications. This standard defines a networking (i.e., a system with multiple components) framework for implementing protocols in seven layers. In terms of control systems, only layers 1, 2 and 7 are used or of interest.

OSI layer 1 (physical layer) specifies the format (in low level, voltage and timing terms) of the data being passed.

OSI layer 2 (data link or data bus layer) is basically the method and format of messages passed between system components and exported from components to a Personal Computer (PC). This becomes important for extending a system and interchanging components. If a standard protocol is used, any component using that protocol can be added to the system. Growers may be familiar with the CanBus system used on modern tractors as the basis of the communication system between the multiple sensor and control elements. This CanBus system allows new sensors and control relays to be incorporated into the existing wiring harness of a tractor without running separate wiring through the entire system.

The application layer (OSI layer 7) is the software level. This layer contains information on the character sets and data storage format.

Character Sets are the encoding of characters into byte level format for transmission. Obviously, the data sent and received must be processed in the same character set. The way the data is stored is called the database format. Examples of this are dBase and DB2. If non-vendor tools for modelling and manipulating data are to be used, the data should be stored in a standard format that can be converted as required.

In summary the various OSI Protocol Levels define the following components of the system:

- Layer 1 (physical): What sort of cable do I need? How many pins on the plug at each end of the cable? What voltage is present in the cable? (eg RS232 Cable.)
- Layer 2 (data bus): How many components can I connect? How fast can data be transmitted? (eg USB has a maximum of 127 nodes)
- Layer 7 (application): how is the data stored? Can I access it with some form of industry standard software? (eg. Excel can utilise any form of comma delimited file type.)

5.5 PRECISION LIVESTOCK FARMING SYSTEMS

The ultimate aim of a PLF system will be the complete implementation of data capture and automated control functions defined within Figures 2-4. These systems will have a suite of sensor and controller components integrated to make a customised whole system. The system will record and analyse the variable data gained from the sensors and also the output data from the controllers. The system will provide a user interface to update settings and report on alarms and current values. The data gained can be used for predictive and interpretive modelling. The systems will be computer controlled, either on-site or remotely. Distributed networks can be created for multiple rooms or multiple production sites. The data will be passed between components and the controlling computer on a data bus network (Layer 2 protocol as above) with built in redundancy to deal with broken cables or other hardware failures. The data will be stored in a database or set of database files and kept for as long as it may be required.

Note that no system as described above exists in complete state, however many companies are moving in this direction of total data integration. See Appendix A for some suppliers with extendible networked systems.

Figure 1 defines the sensor inputs into an overall PLF system with Figure 3 providing details of the proposed output or automated control component of the system.

Figure 2 explains the role of performance analysis in defining the potential opportunities for system improvements.

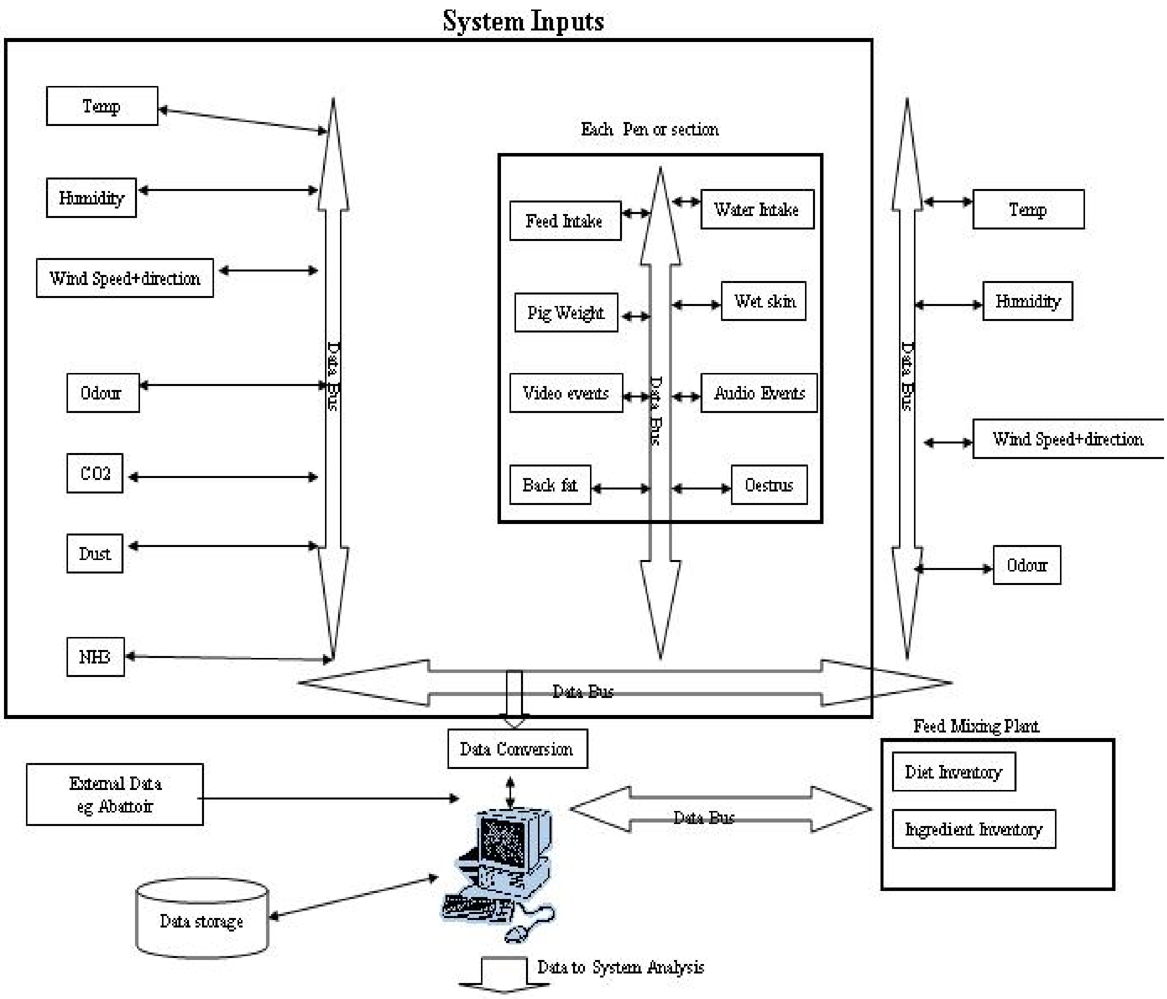

Figure 2. System Inputs

All of the input signal generators which feed in via standard Data Bus systems and are compiled within an online PC after appropriate data conversion processes have been undertaken to allow any file type discrepancies to be resolved prior to entry within a standardised data base.

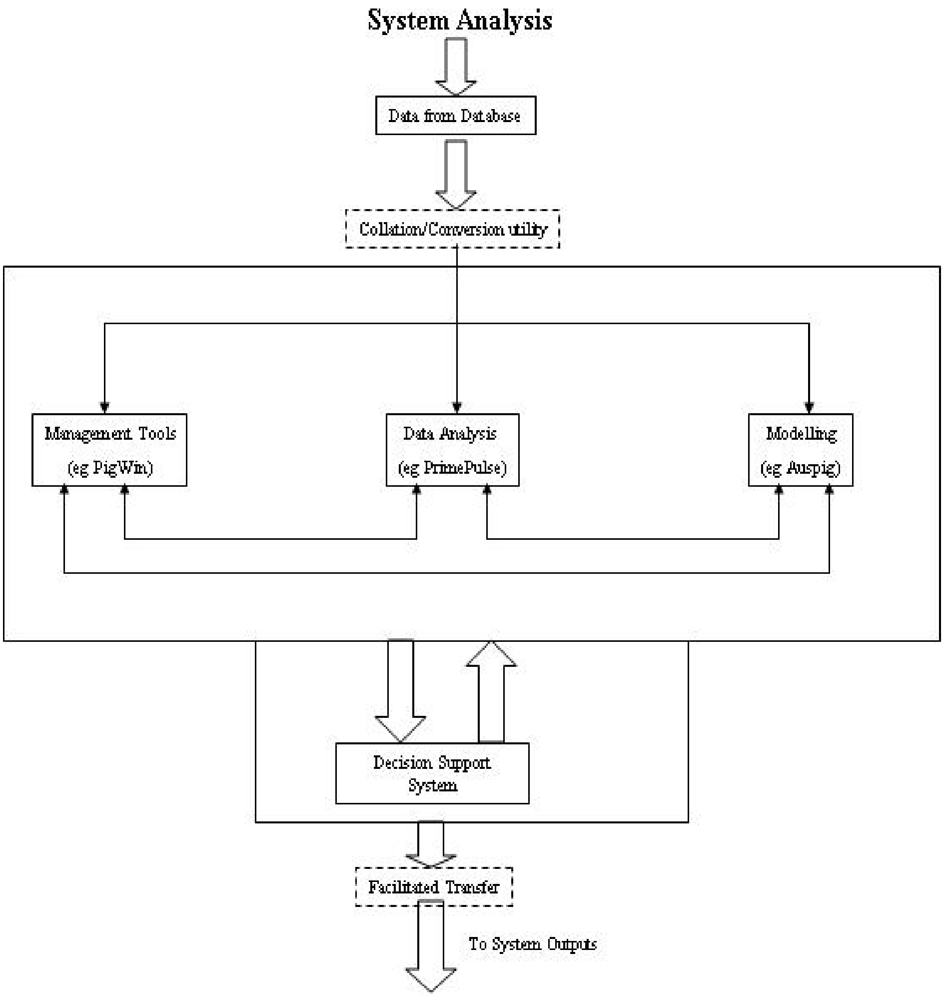

Figure 3. System Analysis

Currently the bulk of the outputs of these systems come in the form of specialist consultant advice (facilitated transfer) and are not automatically inter linked in production control systems. The system analysis phase will be dealt with in more detail in Section 6 of this document – Software review.

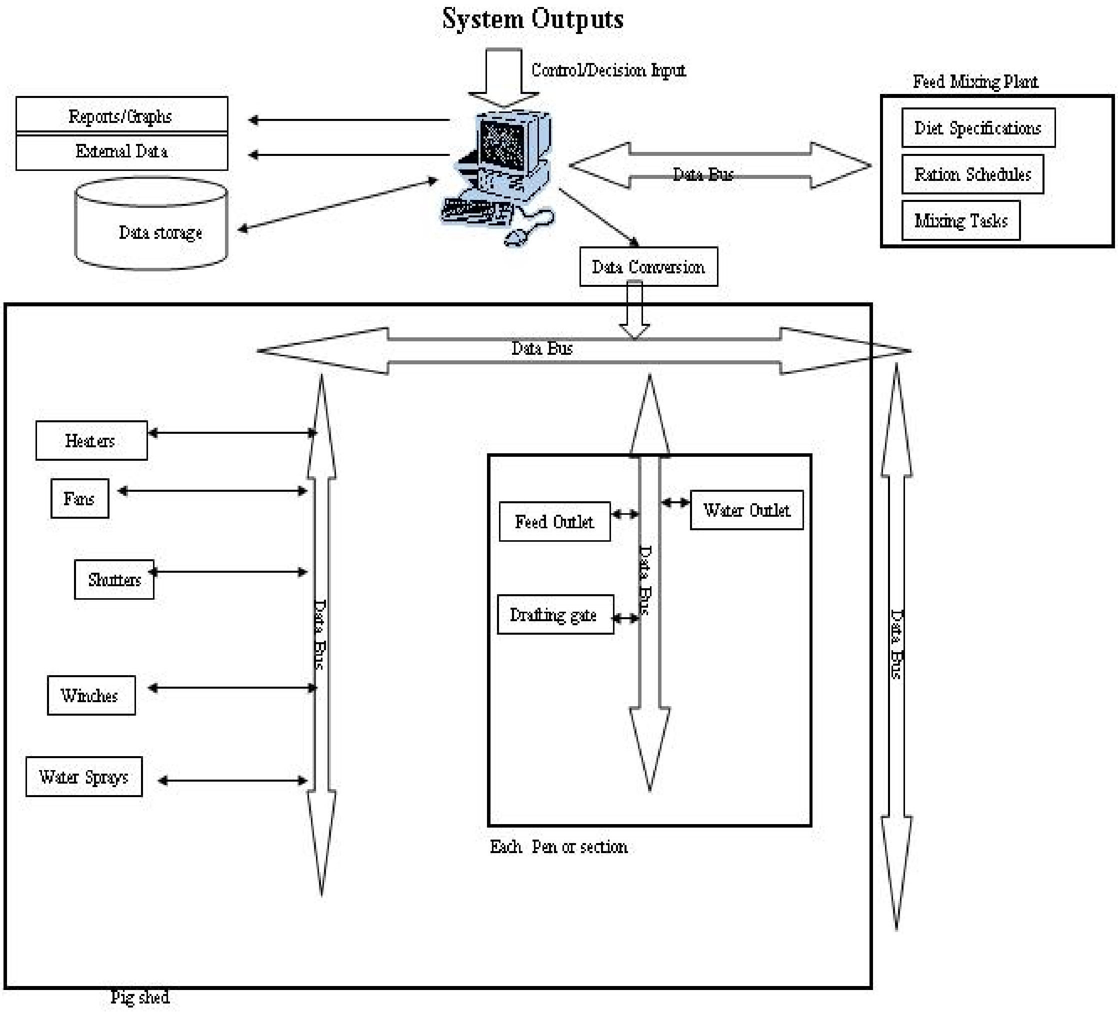

Figure 4. System Outputs

In many cases these may be manually implemented such as feed ration changes or pen selection. Some system parameters are automatically controlled such as shed temperature. **There is significant opportunity to increase this level of automation.**

5.6 IMPLEMENTATION OPTIONS

Depending on the situation, the needs and requirements of a particular site vary widely. There are currently three approaches a producer can take in implementing a data management system on farm. (The fourth option – new system development – is not discussed here, as it is deemed to be impractical.)

5.6.1 Do-It-Yourself Data Capture and Analysis.

Environmental monitoring sensors can be easily purchased off the shelf as one-off items and the associated cabling and data logging devices integrated into the system. Similarly, load cells and flow rate sensors for live weight, feed consumption and water consumption can be independently wired up and information logged on an adhoc basis.

Advantages:
- The system will be cheaper than a turn-key solution.
- The system will usually be simple and fast to set up and get working.

Disadvantages:
- There are no (or limited) data analysis tools available off the shelf. The producer may end up with large volumes of data, but will be unable to convert this into useful information to improve productivity. For example, a producer may develop a large file with a year's worth of temperature readings, however it means nothing without something to relate it to, for example daily weight gain and a data analysis package to demonstrate these relationships (such as PrimePulse).
- Expansion of the system may not be possible. If the producer wants to expand the system later to measure other variables, it may not be possible to integrate new hardware into the existing data communication and storage system. This will mean either replacing the existing hardware, or trying to integrate the data later, which can be problematical for non-technical computer users.
- There will usually be no support if things go wrong. Single components are usually sold off the shelf, with a warranty, but no technical support.

Despite the limitations of this approach it can provide a valuable entry level into the world of PLF systems. See section 9.5 for an example implementation using this method

5.6.2 Turn-key

In purchasing turn-key solution, you know that the system has been developed and researched and is using known configurations. These solutions are normally installed and supported by the supplier.

Advantages:
- Support. The suppliers of these systems will normally provide a telephone and/or personal visit support for the producer.
- Customised set up. Usually, each installation will be investigated and the best design chosen for the producer's layout.
- Software supplied. Most hardware solutions now have software analysis programs provided as part of the installation. These programs will have at least some analysis functions.

Disadvantages:
- Inflexibility. Some hardware or software may not provide the exact requirements of a producer as his needs change and grow. As most large suppliers provide the same software for all their users, it is not feasible to make changes to cater for individual users.
- Extendibility. There may be compatibility issues to be aware of if the system is to be extended with sensors or components from other suppliers. This is especially important when it comes to networked components as there are currently no standard communications protocols being used in the agricultural sector.

- Cost. These solutions will normally have a large capital expense involved, and some suppliers may also charge on-going support fees.

These systems vary in terms of complexity there are three basic levels of complexity demonstrated in the market today:

- Simple single loop controller systems with or without data logging and analysis systems – such as the ventilation control products available. The key questions to ask in relation to these products relate to data access and communication protocols, and extendibility.

- Data Warehousing Programs such as Farmex. These products are specifically designed to facilitate data capture and analysis and are not primarily designed to incorporate an integrated control function although this can be arranged. Sensor extension is not normally a problem with the communications protocols designed to simplify adding in new sensors. Data analysis and presentation options are often well done. There may be some concern in relation to ultimate data access and the subsequent use of this data within alternative analysis packages as the data may be stored in a proprietary format on a proprietary computer server.

- The most advanced Turn Key Solutions are best defined by the Big Dutchman or Skov style products which incorporate data capture, storage, analysis and control outputs. Again the most important question to ask in relation to these systems is the nature of the data storage protocols and their availability for analysis via external programs.

5.6.3 Integrated Management System

This report has started the Australian pig industry down the path towards a complete Integrated Management System. As described in the preceding section, it is envisaged that the end result will be a flexible system capable of delivering results to the needs of any producer.
Advantages:

- Complete system for farm management and automated control
- Flexible network system for ‘plug and play’ of new or different sensors to change or add to the information being collected.
- Support for Australian producers
- Complete software integration with herd management, data capture, data analysis, automatic control, modelling and financial components.
- Producers can have input to the design by industry consultation processes.

Disadvantages

- This system is not yet complete. This report is an early phase in this process.
- Cost. These solutions will probably have a moderate initial capital expense, but this can be mitigated somewhat by the fact that it can be installed with only a few sensors, and easily extended later.
- Complexity. A technician will be required install the system and provide scheduled maintenance visits.

5.7 IMPLEMENTATION OF PLF WITH EXISTING HARDWARE TECHNOLOGY

All major Production System suppliers have hardware to measure most of the parameters reviewed. When building a new shed, the constraints and requirements of PLF technologies are an important consideration. The most cost effective option for the installation of any technology is at construction. The major issue when considering systems for installation is data access and compatibility. Installing a particular system may be a dead end (in PLF terms) if there is no possibility for integration later into the farm-wide data analysis system. See table 9.4 in the main report for an overview of system suppliers.

5.7.1 Retro fitting to existing sheds

In this circumstance, the fitting of PLF technology will be on a case by case basis. There is no single set of hardware that can be installed to measure all the required parameters; instead several discrete items can be installed to perform the task. **Again, data compatibility problems are the main issue. There are many hardware options that can be purchased and installed with no problems, but there is currently no method for integrating the data into a meaningful whole system.** The following core technologies are appropriate.

5.7.1.1 Live Weight

All commercially marketed sensors are currently based on load cell technology. The current options in this area are only where the scales are placed in the shed.

Traditional load cell scales, such as the Ruddweigh, Sierens and AlleyWeigh™ scales (and many other readily available brands) can be used for periodical weighing with automatic data capture. These scales are installed in a laneway so that as each animal enters, the doors are shut manually, the measurement is taken, and the exit doors are opened. The measurements can usually be acquired as csv files on the PC. Manual/automatic identification options are available for adding to weight data.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Install into barn	1
Connect to laptop/portable PC	1

Advantages

Cheaper option

Some existing installations already have PC capabilities, only need training to enable

Disadvantages

More manual work required

Data collected is unconnected to other data held on PC.

The latest designs for measuring live weight on a daily basis are based on a set of scales in an alley between the feeding and living sections for the pigs. This means that several measurements are taken for each pig each day. Examples of this are the Skiold Sorti-Pen™, the Farmweld FAST™ system and the Osborne Weight-Watcher™ system. The problem with implementing this option is that the barn layout may have to be changed, a costly and time-consuming task. There are many options for barn layout, depending on the producer's needs. Auto drafting obviously needs several staging areas for the drafted groups, each with water/feed facilities as required. This type of barn design allows a better flow of animals through the sheds. These installations come complete with PC upload or connection capabilities.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Change barn layout to allow for scale installation between areas. (includes possible changes to feed/water facilities)	4
Install Scales	1
Connect to laptop/PC	1

Advantages

Auto-drafting is an easy and accurate way of sorting animals into like groups.
Some products link with feed mixture/ inventory control software
Data collection is automatic and some analysis software is usually provided
Better flow of animals through the shed after layout changes

Disadvantages

Expensive systems
May not integrate data into other areas of PLF implementation
Barn layout changes can be difficult and expensive

Another option is to purchase feeding stations which have an individual feeding station on the scales. (see below)

5.7.1.2 Feed Usage Measurement

For a fast measurement technique, simply placing a load cell under the feed silo(/s) is an easy way of attaining feed use data for the entire shed. While obviously not as accurate as individual pen or pig feed intake measurements, this can still provide valuable information. A standard data logger can be purchased and installed to collect the data, and uploaded as required.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Install Load cell	1
Install data logger	2
Connect to PC/laptop	1

Advantages

Cheap, fast option. This work could be carried out in a day, and start providing information immediately.

Disadvantages

Whole of shed data only available.

For automatic dry feed measurement, Osborne Industries markets the FIRE™ Feeders, which have a load cell under the trough. Before, after and during a feeding event, the trough is weighed for the amount of feed left in it. The feed intake by the individual pig is recorded and the trough topped up as required.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Install Feeders	2
Install supporting network to Collect data	3

Connect to PC/laptop	1

Advantages

This method gives accurate, per-animal measurements for all feeding events.
Can be linked to inventory and feed mixing software

Disadvantages

Expensive to set up
May be too much information making it harder to analyse.
May cause a small bottleneck for multiple animals trying to use the feeder.

Another option for dry or liquid feed is the Callmatic™ from Big Dutchman. This feeder identifies the individual animal by ear tag and deposits an exact feed ration in the trough. Only one animal at a time is allowed into the feeding station. As each animal enters and consumes the rations, a weight reading may also be taken.
Barn layout changes may be required to put feeders in a laneway between areas. Feeders similar in operation are available from IVOG and Mannebeck.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Barn layout changes required	4
Install Feeders	2
Connect to PC/laptop	1

Advantages

The rations and even feed mixture can be accurately controlled for individual animals
Can be linked to inventory control software.

Disadvantages

Expensive to set up.
May cause a small bottleneck for multiple animals trying to use the feeder/s.

5.7.1.3 Water Measurement

This area has limited products of commercial availability at this stage, but more are coming onto the market.

One product by BSMAgri distributes the water at required intervals. Up to 20 troughs can be supplied up to 8 times per day, ensuring that animals at each trough get the exact amount required. The water pipe for each trough must be re-routed through the controller. There is no PC upload standard, but the water meters can be connected to a data logger and uploaded from there.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Re-route water pipes	3
Connect to PC/laptop	4

Advantages

Exact distributions
Temperature compensating (provides more water on hot days)

Disadvantages

Hard to capture data to PC

The other method is to measure the water intake directly. This is currently only done on a per-shed basis by environmental measurement packages such as the OMNI-4000™ by Phason or the DOL36™ by SKOV.

5.7.1.4 Environmental

Although no suppliers currently have an off-the-shelf system which measures all the reviewed parameters, there are several which have networking and extension capabilities that could be extended as required to measure other variables. The most notable of these systems are the Farmex Dicam™ system, Big Dutchman, Skov, Veng Systems, Hotraco, Phason and ChoreTime. Each of these systems has been developed specifically for barn conditions.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Install measurement and control system	3
Install supporting data network	3
Connect to PC/laptop	1

Advantages

Environmental control possible
Data analysis software usually supplied
Usually extendible to other sensors

Disadvantages

Limited current data links to other software such as herd recording programs or modelling packages.
Expensive to install

Another option is to install commercial weather stations. These packages do not usually have the full range of variables required, but have the fundamentals like temperature, humidity and wind speed and direction. Examples of this are packages from Environdata, Skye Instruments, Weather Experts and Specmeters. The big bonus to these systems is that they can be purchased, placed in the barn, and switched on.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Install measurement system	1
Connect to PC/laptop	1

Advantages

Cheaper and faster to install
Data analysis software usually supplied

Disadvantages

Data recording only, no control functionality
Limited current data links to other software such as herd recording programs or modelling packages.
Not easily extendible to other sensors

The last option is for the producer to buy individual sensors and install them individually. This option is not recommended as it will not have value in the medium to long term. However, individual sensors are available and can be installed very cheaply.

Requirements	**Level of Difficulty (1=minor, 5=major)**
Install individual sensors	1
Connect to PC/laptop	4

Advantages

Cheaper and faster to install

Disadvantages

Data recording only, no control functionality
No data analysis software supplied
No links between sensor data
Limited current data links to other software such as herd recording programs or modelling packages.

5.7.1.5 Backfat measurements

Handheld measurement devices are standard in this area. Some have the option for PC upload, usually via rs232 port on the device. May be linked to portable pc for recording additional animal information

Requirements	**Level of Difficulty (1=minor, 5=major)**
Connect to PC/laptop	1

Advantages
Used as purchased.
Disadvantages
Usually no data analysis software supplied
No data links to other measurements.

5.7.1.6 Other technologies

In the areas of Vision, Audio, Odour level and wet skin, there are currently no viable products for **meaningful** data capture available.

6 SOFTWARE REVIEW

6.1 INTRODUCTION AND OBJECTIVE

An integrated management system for pork production may be achieved by attempting to integrate pre-existing components and develop the balance of functionality, as priorities require. It is understood that such a fully integrated PLF system does not exist, however several independent software packages do exist that service discrete functions.

The alternative option of developing an entire hardware/software system from the ground-up to meet a wide-ranging specification of functionalities would be extremely costly and would also duplicate functions currently serviced within the market place. Therefore, this option is not considered in this report.

The objective of this part of the review is to briefly identify and evaluate currently used software that potentially offer themselves as components within a futuristic PLF system. **Given that this review has established that all the components of an elementary PLF system do exist and are presently used within the Australian Industry, there are strong grounds to at least initially pursue the objective of incrementally integrating these functions for industry trial and evaluation.**

6.2 SOFTWARE EVALUATION

Table 1 lists the software products assessed within this report. Although this list is not exhaustive it does provide a range of common products associated with each type of software functionality identified.

Table1. Potential software components of a PLF system

Component Function	Commercial Examples
Production Recording, Analysis & Reporting.	PigCHAMP, PigWIN, MIPS, PIGMANIA, PIGTALES, P&P, HERMAN,
Environmental Climate Control	Skov , Farmex, Hotraco, Phason
Air quality/environmental database	BASE-Q (APL Pno 1758)
Shed environment model	PHICS (PRDC Pno UM54P)
Health database	PigMon
Automatic Feeding Systems	BigDutchman, Skov, Hampshire
Automated drafting	Osborne, Ruddweigh, Skiold
Exception analysis & Intervention alarm System	PrimePulse, (data-mining, statistical packages etc) Browser
Production / Predictive Models	AUSPIG, PIGBLUP, E-PIGGERY
Expert System (intervention formulation)	Within AUSPIG, Rep CD
Multi-source integrated Data base storage & analysis	Metafarms
Communications connectivity (eg Web browser)	Metafarms, Farmex, Pig E Mail, Proposed APL web site

The core technology of Precision Livestock Farming is the ability to accurately model and predict the system (i.e. the production facility). **Capture and analysis of data has limited value without the modelling phase. Auspig has been developed specifically for Australian producers and is a very sophisticated tool. As such, it provides the base building block for extending the capabilities of PLF systems.**

Currently, there is no off-the-shelf package that contains all components required for a complete implementation; however there are discrete software packages that can be run separately to provide the functionality. This section of the report discusses the integration of some of these components into a complete system.

Several PLF system components service multiple component functions (eg Skov can integrate environmental, feed and pig weight measurement), indicating the natural progression towards an integrated end point. **But integration is only serviced within a single company's optional product line and no company offers the entire spectrum of products required.**

Climate control products have advanced to the automated intervention stage. This is primarily because they have all the information that is required to "close the loop" within their own system. For example, a required temperature range can be entered and sensors connect to a processing system that automates shutters and other temperature control systems.

Comparatively, the loop is still wide open within automated feeding systems as all the information required to intervene is not available within the system and the system is relatively more complex. For example, one commercial restricted "feed delivery system" senses residual feed and then decides to feed or not to feed. So although ten given feeds may have been automatically scheduled for the day, perhaps only seven are actually delivered. The issue is that future feed deliveries are not automatically affected by past feed deliveries, so the feedback loop is incomplete.

Completing the feedback loop can be approached in two ways:

1) By making better use of resident data, for example is the feed refusal rate in this pen an isolated event (Local Cause – health?, mortality? Water intake? Etc) or is the exception replicated (Common Cause – temperature? or feed contaminant? etc). Also is the pattern of feed refusal prevalent at certain times and could missed feeds be automatically compensated for at a more successful feeding time?
2) By accessing information external to the system (for example if feed intake is depressed and temperature is within the thermo comfort range, is diet density or fibre content an economic intervention option?). A host of additional functions are required to answer these questions (eg price schedules, ingredient costs and profit modelling etc).

Initial evaluations indicate that there is significant room to improve the use of resident data, and the extent of this potential warrants detailed review. It may eventuate that a simple expert system could save users substantial manual intervention time and or invoke more successful interventions. For example, one commercial feeding system requires users to visually scroll through all feed deliveries to all feed locations (usually pens) to identify "missed feeds". Most feed systems evaluated support data export facilities that would enable independent or collaborative trial expert system development. Although this opportunity exists the research team found no evidence that users of these systems had successfully utilised resident data generated within these systems in this way.

Drafting and Pig weighing systems (eg Osborne, Farmex, Skov, see appendix A) are available but do not yet fully integrate within feeding, watering and climate control systems. It is envisaged that further integration is possible within the bounds of "making better use of resident data" (eg crudely modifying feeding regimes upon the evaluation of pig weight). However, once this potential is realised, a modelling component is required to secure further advantage (eg. model the best way to feed a slow growing female pen of pigs for the next four weeks and then automatically draft it to be sent to the slaughterhouse, knowing that the temperature is going up for this period and price is coming down).

The commercial sector alone is unlikely to purse the integration required to create the ultimate integrated management system as a result of the financial model in which it is currently operating. At present the bulk of the PLT industry income is generated through the sale of PLT Hardware - not through the supply of expert system services.

The development of products such as Farmex which encourage data analysis and the fact that many hardware system manufacturers do support a relatively open data transfer architecture is an encouraging sign that greater collaboration between these manufacturers and the research community can result in better products and services in future.

6.2.1 Integration of software components

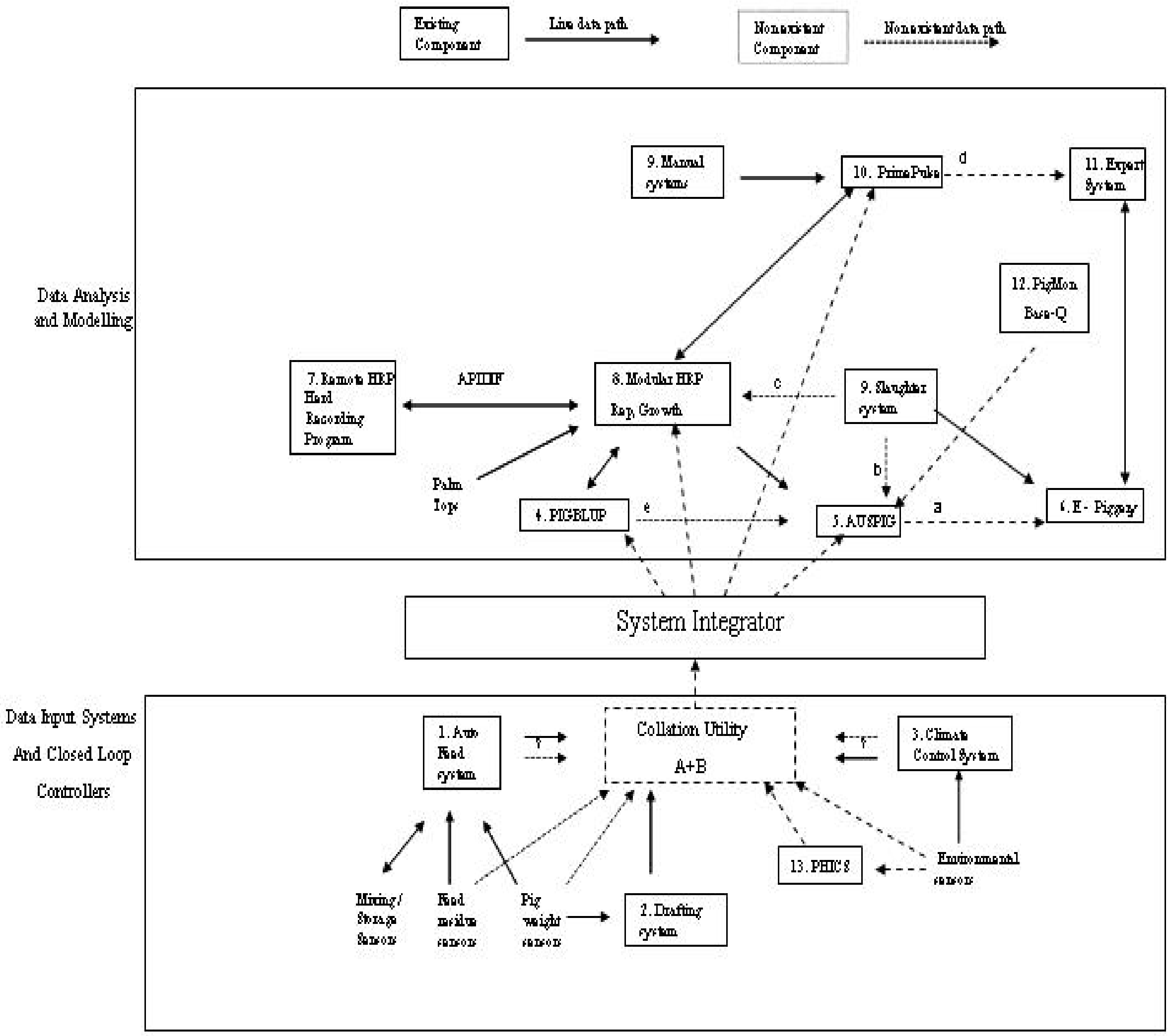

Figure 5. PLF data pathways – system integration

Figure 5 demonstrates the major data transfer routes within a fully integrated PLT System. Three main elements highlighted are:

- The Data Input Systems and Closed Loop Controllers;
- The Data Analysis and Modelling Component; and
- The Systems Integrator – essentially a data transfer facilitation component to consolidate data transfer and software interface protocols.

The core function of this Systems Integration Function is to:

1) Optimise the beneficial application of existing data sources to unlinked external applications (eg AUSPIG calibration from an automatic feeding system).
2) Enable multiple data sources to be automatically collated to enable advanced analysis processes to be efficiently conducted (eg PigPulse, data cubes, data-mining or any off the shelf statistical application).
3) Utilise Step 2 above to provide a practical working environment to:
    a. Enable ease of manual modelling and intervention processes.

   b. Evaluate the potential cost benefit of advancing to a fully integrated system.
   c. Preview and trial solutions to integration barriers experienced.

4) Provide the primary linked components required to assemble an overlying data repository for research and development purposes (eg Metafarms equivalent, see appendix B).

Broken arrows indicate data pathways that are dysfunctional because 1) the source program does not support a data export facility, or 2) the destination program does not support an import facility specified to accept the source export format or 3) both 1 and 2. Potential interface pathways are labelled alphabetically in order of development priority. Thus the System Integrator connects components 1 (Auto Feed System), 2 and 3 to components 4, 5, 7 & 10. Component 12 (PigMon Health and BASE-Q air quality databases) is a potential data source for AUSPIG in the future, when the functions associated with these databases (health & air quality tuning factors) are fully developed within AUSPIG. Component 13 (PHICS) can be used to interpret environmental data supplied by different sensors and predict environmental conditions within animal buildings.

As components 1 and 2 support export interfaces (unbroken arrows), the development of a collation utility (new component) could potentially service four linked components (PIGBLUP, Herd Recording programs, PrimePulse and AUSPIG). As there are several different types of Automatic feeding and drafting systems, a standardized export facility would significantly reduce the development overhead of such a utility. Similarly, a separate collation Utility B could service climate data and could potentially be combined with Utility A. Ideally these utilities could be developed for embedded inclusion within source and or destination programs to accelerate adoption.

Utility A would convey feed weight, pig weight, water volume, pig movement transactions mapped to physical locations eg (pen addresses) and time. Similarly, Utility B would convey temperature, humidity, air quality etc mapped to the same or different locations and times.

6.2.1.1 Benefits to PIGBLUP

Direct PIGBLUP (see appendix B) users could potentially improve the accuracy of genetic modelling by incorporating "sensor" production data (eg feed intake). Additional information available from improved electronic recording devices could be used to improve models for existing traits and/or develop new traits that better describe performance in commercial environments. Automated access to climatic data may also assist in the assignment of contemporary groups.

6.2.1.2 Benefits to Herd Recording Programs

Climatic data is not serviced by HRP’s and offers no known benefit for inclusion within HRP’s. However, Feed usage and pig weight and pig movements are supported by different HRP’s to varying extents. At the low end of the spectrum the benefits are largely the avoidance of dual data entry and exposure to previously “unused” production traits and associated reporting formats (eg Herd Feed Conversion Rates – very poorly recorded by industry at present yet is a critically important determinant of profit). PigGAIN (see appendix B) is representative of the high end of the spectrum and could also potentially utilize sentinel group weights and pig movement transactions to incorporate advanced analysis processes (eg monitored flow systems).

A critical component of future developments will be the capacity of standard HRP's to accept, analyse and report on new data sets generated by a range of PLT hardware sensors as well as supporting the output from other production system models.

6.2.1.3 Benefits to PrimePulse

The System Integrator would enable automated acquisition of real time growth and climate traits that are presently unsupported (eg Temperature) or poorly supported (eg FCR – error prone inventory based extrapolations removed from real time due to batch closing time lags). Feed and water offered, liveweight, liveweight gain (LG), and FCR could be accurately collated into discrete production phases (eg Porkers 14 to 18 week phase) that relate to shed locations or management groups. The benefits of interim phase growth monitoring in designing and timing intervention strategies have been comprehensively reported before (Cook, 1999).

6.2.1.4 Benefits to AUSPIG

The primary benefit to AUSPIG is to automate the acquisition of sensor data required to calibrate the model (both present and future requirements). Current sensory systems do not support all AUSPIG input variables required (eg wet skin percentage), but the majority of key variables are captured.

Captured source data required by the current version of AUSPIG are as follows:

- Multiple replicates of weaner groups sampled over the growth period for live weight and feed offered (cohort groups).
- A start and finish live weight with two additional interim weights are a minimum requirement.
- Two or more sexes are monitored independently.
- Hourly min and max ambient temperature, relative humidity & air speed.
- Air quality and disease levels – future developments

There are several dimensions to the value of accessing sensory data to calibrate AUSPIG (see appendix B):

- It removes the practical barriers preventing the adoption of AUSPIG.
- It reduces the exposure to manual feeding and recording errors.
- It provides an evolving platform to rapidly acquire new data as sensor technologies continue to develop.
- It enables greater accuracy precision and frequency of iterative samples across time.
- It provides scope to significantly increase sample size and replicate and or stratify samples without the incumbent labour overheads inherently associated.

The last two dimensions listed above require further investigation to establish recommendations specifying the optimal requirement of these attributes to achieve modelling calibration requirements.

6.2.1.5 Independent benefits

As the System Integrator is embodied within a potentially independently distributable utility it may be directly connected to commercial data logging equipment to establish a very low cost data capture system suitable for consultant use (eg AUSPIG calibration service) or trial use (measure two treatments) or holistic farm use (put a silo on weigh cells to measure daily shed feed use).

Interface “a” enables the outputs of AUSPIG (recommendation schedules expressed as response curves for feed intake, Live Weight , Live Weight Gain, P2 Fat deposition, Dressing Percentage, FCR etc) to be incorporated into E-Piggery. E-Piggery interfaces to PrimePulse (see appendix B) to effectively enable real time physical production changes to be prioritised according to the financial impact of deviating from AUSPIG recommendations. This provides the basis to automatically sort through potentially numerous “production issues” to prioritise the design of the most important interventions required.

Interface “b” enables AUSPIG to acquire abattoir price schemes. The only benefit of this interface is that it removes the manual entry of price schemes (estimated at < 2 hours per week). Although E-Piggery has achieved this interface with one abattoir (one other in development), nation wide standardization is required across abattoirs which will be difficult to achieve.

Interface “c” is low priority and subject to the same standardization issues impacting on interface “b”. The primary benefit of interface “c” is that it enables live pig records to be related to dead pig records for treatment trial analysis within Herd Recording Programs (thus the System Integrator is a pre-requisite). Access to slaughter data will also enhance HRP compliance to PIGBLUP carcase record requirements.

Interface “d” is specified but not yet supported and is intended to communicate Production Issues requiring intervention to expert systems used to devise intervention actions. Similarly, interface “d” could be used to return issues to AUSPIG’s expert system, or any other expert system intended for the purpose.

Interface “e” is intended to convey Estimated Breeding Value (EBV) information to assist in genotype selection (see appendix B) within AUSPIG This interface has been placed in low priority as it is of unknown value to AUSPIG and may require collaborative developments within PIGBLUP and Herd Recording Programs.

The decision to develop these interfaces also needs to be considered with regard to the potential development of an integrated database connecting all sources to a central repository. A single interface benefits linked components only. Each interface is a step towards enabling a central repository. A fully automated PLF system will require an expert system component that will conceivably require access to all components. The establishment of a central “data-warehouse” for the Australian pig industry, would also enable selected researchers and industry personnel to access wast amount of information conveniently and use it for the benefit for the whole industry. Marketing & product promotion, on-farm research, quality assurance are few examples of industry development areas, which can benefit from such an approach.

6.3 RECOMMENDATIONS

1. Detailed investigation of data interface capacity of automatic feeding and climate control systems to evaluate the potential scope of the System Integrator.
2. Communicate findings to potential destination software systems (PIGBLUP, Herd Recording Programs, PrimePulse and AUSPIG) to specify interface requirements.
3. If the System Integrator warrants development, interface "a" should also be addressed to value add upon the data conveyed in the System Integrator (Interface "b" is a very minor task with respect to the System Integrator).
4. Develop Collation Utilities and the System Integrator and interface "a" with input from stakeholder representatives.
5. Once the System Integrator is achieved and evaluated, the relative merits of proceeding with other interfaces may be compared to the alternatives of developing an overall parent data base (Metafarms equivalent) or trailing the implementation of the Metafarms product.
6. Any decision to move towards the development of Collation Utilities or the overall parent data base should consider the requirements of PIGSTATS being addressed in APL project 1929 (Development of a Trial National Pork Industry Benchmarking Study).

6.4 IMPLEMENTATION OF PLF WITH EXISTING SOFTWARE TECHNOLOGY

The work required to implement PLF systems using existing software components on commercial farms is difficult to gauge and describe in advance, as system implementation will evolve during the process. However, the best way to describe the likely work involved in integration is to describe the processes involved in achieving data access which will enable the integration of multiple data sources within a PLT system.

Several issues need consideration to evaluate the most efficient means of achieving the objective of data integration and data flow between system components:

- Are source systems "Open" or "Closed" data bases? (i.e. presently do/don't support an export interface)
- The number of proprietary data sources to accommodate?
- The scope of source data to be acquired?
- Standardisation of data exchange formats?
- Ongoing Interface maintenance required?

The five issues presented above act as multipliers that additively increase the degree of difficulty in achieving the objective. Thus the idea is to minimize the exposure to these attributes in designing the process to achieve data integration. If a practical outcome is required it will be achieved by downsizing the system largely by way of source attrition.

Notes re "barrier" attributes:

"Open" data base sources allow data flows beyond the source system, while "Closed" data sources are either intentionally prevent data flows or have not perceived any demand for data access. Only cooperative "Open" data base sources can be feasibly considered for integration due to the degree of difficulty, risk of failure and potential legal implications of integrating "Closed" data sources.

The more sources that are to be integrated the more difficult the task is likely to be. The only alleviating factor is the extent of natural standardization within independent sources.

The wider the scope of variables to service from any given source the more challenging the task becomes for those sources to comply with the common denominator of selected variables.

Standardisation and the exposure to interface maintenance are directly correlated. If standardization is achieved, costly interface maintenance can be largely avoided. If all sources comply to a standard, any future developments within the source do not effect the standard interface. Conversely, if the source program does not support a standard format, and that format is continuously under development, then the interface must also continuously be updated to maintain data communication.

Recommendations:

1. Interfacing should not be pursued without achieving standardization.
2. A standard interface is an acceptable and desired outcome that will enable immediate industry advantage to motivate future standard compliance at least cost.

7 LITERATURE REVIEW

7.1 FOREWORD

The widespread use of computer technology in all aspects of our life has caused a significant change in the way which information technology (IT) is viewed and used in livestock production (Lewis, 1998; Thysen, 2000). In the past, IT use in the livestock industries was relatively modest. However this situation is changing dramatically as certain production practices such as the use of chemicals, antibiotics and sow crates are being restricted or banned in livestock production. More efficient information management will therefore become important as greater precision will be required in management. Therefore, easy to use, cost effective and practical PLF applications are being demanded by the farming community to support the increasingly complex operational aspects of livestock farming.

This review, part of the APL funded "Desktop evaluation of Precision Livestock Farming (PLF) technologies" project, is aimed at assessing available technologies to be used in comprehensive PLF systems and the R&D required before these systems can be implemented. In addition to the general literature, papers presented at the 1st European Precision Livestock Farming (EPLFC) and the 4th European Federation of Information Technology in Agriculture Conferences (EFITA) were extensively used.

7.2 ABSTRACT

The wide spread application of computers is changing the way in which information technology (IT) is used in livestock production. "Precision livestock farming" (PLF) is a relatively new concept and has developed rapidly in the last few years. It is aimed at improving the utilisation of available IT technologies on farms. This approach can be likened to events which occurred in other manufacturing industries 15-20 years ago.

This review aims to assess the available precision livestock farming technologies to be used as components of comprehensive PLF systems. PLF research is currently focusing on different components of the envisaged system. However, to our knowledge to date, very few groups have attempted to combine these components into one working system. Current research efforts can be grouped into three major areas; development and/or improvements of **data acquisition, data analysis and control systems**.

7.3 INTRODUCTION

7.3.1 General issues

Precision livestock farming is a relatively new concept in livestock management and has developed rapidly in the last few years. It is aimed at improving the utilisation of available IT technologies on farms and this approach is likened to events which occurred in other manufacturing industries perhaps 15-20 years ago. The main benefit of PLF implementation on farms is to maximise the utilization of information to help producers make the best management decision under specific circumstances and therefore have better control over the production process. As a result of better information recording on farms, management will become more specialized. Producers will be able to continuously improve their management and meet the product specifications demanded by consumers (Wathes *et al.*, 2001). Up to now, detailed and reliable data related to livestock production has been difficult or expensive to acquire (Schmoldt, 2001). Recent advances in electronics, communications, and computing power have removed most of the technical barriers, and in principle enabled livestock managers to easily acquire and better use the available information (Auernhammer, 2001; Black, 2001). There are good examples in the literature that **automated and innovative processing of the available data could provide livestock producers with information that is practical and useful in solving management problems** (Freson *et al.*, 1998; Maltz *et al.*, 2003). Most of the quality assurance procedures, educational and extension activities are also related to better information management.

7.3.2 Economic Aspects and Benefits of PLF

The need for an holistic systems approach in livestock management has been increased with recent political pressures on primary producers to reduce pollution, improve product safety and efficiency, and enhance the environment and animal welfare (Gibon *et al.*, 1999). Precision livestock farming is aimed at enhancing the utilisation of available information to deal with these issues. However, there are both costs and potential benefits associated with information collection, management and use. Therefore, the benefits have to be maximised and the costs minimised in order to justify the investment in enhanced IT technologies (Schmoldt, 2001). It is therefore important to take into consideration additional benefits not directly linked to production efficiency, such as improved product safety, environmental and welfare outcomes (Banhazi *et al.*, 2003). Producers will be able to document conditions associated with the production of certain food items and therefore promote their environmentally sound and welfare friendly production methods. It is most likely that PLF will dramatically gain in importance when additional benefits, such as above mentioned ones and QA are recognised and rewarded (Auernhammer, 2001).

7.3.3 Attempts to Integrate Systems

Some components which can be used in a fully integrated system are already available commercially for most livestock industries (Frost *et al.*, 1997). Companies and research groups involved in the development of PLF technologies are developing commercially sound components of the future integrated system. However, to our knowledge very few groups have attempted to combine these components into one system (Schofield *et al.*, 1994), because of the technical/operational difficulties involved and the economically unrewarding nature of such development work for the integrator. For this reason, companies supplying the components of the system are relatively unmotivated to undertake the work required for system integration. The industry utilising the system and component suppliers will be gaining significant benefits. However, harmonization and coordination are required to initiate the integration of the comprehensive system. Research institutions and/or government agencies might have to take the lead and galvanise enough support to initiate the first steps towards full integration.

The closest scientists have come to producing fully integrated systems are research groups working with the poultry and the dairy industries. Some examples are listed below and should serve as encouragement for the pig industry, which has yet to implement a fully integrated PLF system.

Canadian researchers developed a fully integrated and computerised information system to help dairy producers deal with the increased complexity of decision making (Pietersma *et al.*, 1998). The main principle behind the IT program was the full integration of data acquisition, data analysis and data management to enhance the coordinated management of dairy farming. The creation of this system was approached in the following way:

- The main management and control activities were defined.
- The information necessary to execute the activities was itemised.
- Decision making/control functions were facilitated by computerised information transfer.

The authors of the article stated that the interdependence among decisions in the various areas of farm management (nutrition, breeding, health, environment etc.) makes it necessary to adopt a computerised management and control system that is fully integrated and purposely designed to support the information transfer.

The other current research on a better integrated system is being attempted by researchers at the Silsoe Research Institute (Robertson *et al.*, 2002). This research is aimed at developing an integrated system for broilers, which will manage growth in relation to pollution emission targets. A relationship was found between ammonia emission levels and the amount of protein consumed by the birds (Frost *et al.*, 2003) and hence on-line diet manipulation is used to control pollutant emission.

Aquaculture systems are also being developed to control inputs (Venugopal, 2002) (e.g. water, oxygen, temperature, feed rate and stocking density) and therefore the final outputs (e.g. ammonia, pH and growth rate) of intensive fish rearing facilities (Lee, 2000).

7.4 CURRENT RESEARCH AREAS

Progress in PLF could not be achieved without the enormous advances in computer processing power, sensor technology, networking (Jongebreur, 2000), microelectronics, systems and control engineering (Stafford, 2000). Utilizing these recent advancements, researchers working in the PLF area are focusing their R&D efforts on the following main areas of PLF systems:

1. Information acquisition

- IMAGE ANALYSIS
- WEIGHING SYSTEMS
- SENSORS AND BIO-SENSORS
- SOUND ANALYSIS
- ANIMAL ID
- RADIOTELEMETRY
- MOVEMENT DETECTION

2. Data management and analysis

- MANAGEMENT SOFTWARE
- DECISION SUPPORT SYSTEMS
- MODELS
- OTHER DATA ANALYSIS METHODS
- DATA TRANSFER

3. Control function and data manipulation

- ENVIRONMENTAL CONTROL
- NUTRITIONAL CONTROL
- ECONOMICALLY FOCUSED PRODUCTION CONTROL
- ROBOTIC SYSTEMS
- DATA PRESENTATION

In the following pages these research areas will be reviewed briefly.

7.5 INFORMATION ACQUISITION

Innovative data acquisition systems are essential components of any comprehensive PLF system. Many of the data acquisition systems used in PLF were originally developed for industrial applications and not specifically designed for shed environments. Therefore the challenge is to first identify and then adopt these technologies so they can collect relevant information in livestock buildings. Generally, hardware components associated with these data capture systems are relatively low cost items, therefore they only represent fraction of the total costs of PLF systems.

7.5.1 Image analysis

7.5.1.1 Weight measurements

Currently a number of projects are in progress in Denmark (Brandl and Jorgensen, 1996) and in the UK (Schofield, 1990; Schofield, 1992) to improve the accuracy of live weight measurements of pigs using image analysis systems. The main aim of these projects is to improve the precision of live weight prediction using image analysis and reduce the technical competency required to use the system. The Danish system is designed to eliminate the need for the pigs to stand in certain positions in order to take reliable pictures, which can be used for weight prediction. A model is also being developed by Danish researchers to work in concert with the image analysis system and accurately predict the weight of pigs in order to optimise the selection of a batch of pigs for market (Kristensen, 2003).

7.5.1.2 Tracking and inspection

Image analysis can also be used to track animal movements in buildings (Tillett *et al.*, 1997) and therefore gain a better understanding of the physical needs of the animals (Marchant and Schofield, 1993; Tillett, 1991) or characterise animal behaviour (Onyango *et al.*, 1995). Livestock managers wanting to incorporate practical production ethology into the production system can benefit from this technology (Sergeant *et al.*, 1998). However, there are technical difficulties associated with this new technology (Onyango *et al.*, 1997; Schmoldt *et al.*, 1997).

In addition, image analysis has been used to evaluate cleanliness of body surfaces, for example the teats of cows before robotic milking (Bull *et al.*, 1995). The potential of detecting dirt on animal skin (teats) using information from images was assessed (Bull *et al.*, 1996). It was found, that classification of the teats into clean and dirty categories was in reasonable agreement with human assessment. This type of image analysis could have application for assessment of building hygiene, which has been shown to be a critical factor for maintaining optimal shed environments (Banhazi *et al.*, 2000b).

On-line inspection of poultry (and potentially other animals) carcasses are also possible using image analysis (Chao *et al.*, 2002; Park and Chen, 2000; Park and Chen, 2001; Park *et al.*, 1998; Park *et al.*, 2002).

7.5.2 Weighing systems

Methods to estimate the individual body weight of group-housed pigs using a forelegs weighing system have been developed overseas (Ramaekers *et al.*, 1995) and in Australia as well (Williams *et al.*, 1995; Williams *et al.*, 1996). Both research groups demonstrated that a foreleg weighing system is a practical and viable method to estimate the body weight of group housed pigs.

7.5.3 Sensors/bio-sensors

This review will not focus on routinely used sensors (such as temperature, humidity, carbon dioxide etc sensors), as such sensors are reviewed in the commercial section of this report.

A comprehensive air quality monitoring instrumentation kit is under development currently (funded by APL) and should be considered as a potential component of the fully integrated system. Further information is presented in Appendix C (Banhazi, 2003). A commercially available shed monitoring system has been released recently on the European market (Pessl and Denzer, 2003). The hardware is quite simple compared to the Australian development; however there are synergies between the two systems. Currently, the Australian R&D team and the Austrian company marketing this product are discussing the possibility of combining future development efforts.

Development of biosensor technologies has increased dramatically in recent years due to the requirements of the medical and food processing industries for sensitive, fast and accurate analysis (Tothill, 2001). Typically, biosensor technology is harnessing the specificity and sensitivity of biological systems in small, low cost devices (Velasco-Garcia and Mottram, 2003). Biosensors can also potentially be incorporated into PLF systems as on-line monitoring devices (Zwiggelaar and Bull, 1996) and in principle, these sensors can be used to assess important parameters such as product, feed, environmental quality etc. There are a growing number of research groups working on biosensor development. **The challenge is to identify and adopt these sensors to fit the requirements of the livestock industries and make them practically relevant and functional in livestock environments.**

Studies were also conducted to assess viability of using biosensors for pathogen monitoring within the pig supply chain (Meeusen *et al.*, 2001). It was concluded that biosensors could be useful in proving a complementary detection system to the standard lab-based systems for pathogen detection. In general, the use of biosensors for food safety purposes has to be fully exploited as biosensors offer rapid, on-line detection of microorganisms. On the other hand, consumers are increasingly concerned with food safety issues which could galvanise support for this R&D area in Australia (Firstenberg-Eden *et al.*, 2002; Hall, 2002; Patel, 2002; Radke and Alocilja, 2002)

7.5.4 Sound analysis

Sound recordings are being used to either utilize the data as an **(1)** early warning system for impending respiratory problems in pigs and indirectly as an indicator of the level of airborne pollution (Van Hirtum and Berckmans, 2002) or as a **(2)** warning system to reduce crushing of piglets by the sow (Friend *et al.*, 1989). Belgian researchers studying the coughing sound of pigs suggested that incorporating the sound-analysis into building ventilation systems could improve the functionality of the ventilation systems by reducing the effects of airborne pollution (Chedad *et al.*, 2001; Moshou *et al.*, 2001).

Sound patterns have also been studied in order to be potentially used as an animal identification method (Ikeda *et al.*, 2003) or as a tool to evaluate stress/restlessness levels experienced by the animals (Schon *et al.*, 2003).

7.5.5 Animal ID

Individual identification and monitoring of animals is an important step towards enhancing the traceability of livestock products (Naas, 2002). The latest generation of animal ID devices could also incorporate sensors, store additional data and provide authentication protocols. ID devices with built-in sensors could be used for tasks such as health and reproduction status monitoring (Eradus and Rossing, 1994; Geers, 1994; Lammers *et al.*, 1995). Individual animal ID technology will enable livestock managers to once again treat animals as individuals rather then herd or flock. This could facilitate the provision of individually tailored diet (Perez-Munoz *et al.*, 1998) and environment control, which has enormous potential to improve productivity and welfare. The use of miniature injectable transponders could improve the security and practicality of electronic identification (Klindtworth *et al.*, 1999; Rossing, 1999) as this application reduces the risk of transponder loss and fraud (Figure 6). However, injected transponders have to be biologically compatible, technically feasible and easily recoverable in slaughterhouses (Eradus and Jansen, 1999).

Figure 6. Different animal ID devices (Rossing 1999)

It is expected that electronic identification systems will be further enhanced by technologies used for smart-cards and can potentially be used to control production processes (Artmann, 1999) However, potential problems with compatibility between different systems have to be resolved (Kampers *et al.*, 1999).

A cutting edge technology, the use of retinal vascular pattern recognition combined with Global Positioning Satellite (GPS) system, was described recently as a secure source verification of livestock. The authors suggested that this technology offers a "fraud-free" verification of livestock in food safety or food retail systems (Whittier *et al.*, 2003).

7.5.6 Radiotelemetry

Radiotelemetry systems are available to remotely monitor and record physiological parameters, such as heart rate and deep body temperature of animals (Kettlewell *et al.*, 1997). The transmitters are either ingested, fixed in the ear canal by expandable foam or surgically implanted (Chesmore *et al.*, 2003). It is reported that these devices do not interfere with normal physiological function and behaviour of the animals. These systems can be particularly useful in monitoring physiological responses of animals to environmental stressors in outdoor settings (Harris *et al.*, 2001) or during transport (Geers *et al.*, 1997).

7.5.7 Oestrus detection

Different electronic technologies have been developed to improve oestrus detection (Rorie *et al.*, 2002) in number of species. Intravaginal probes and mount sensors are mainly used to monitor beef and dairy cattle (Gupta and Purohit, 2001; Norup *et al.*, 2001; Rezac *et al.*, 2001; van Asseldonk *et al.*, 1998; Velasco-Garcia and Mottram, 2001). However, simple infra-red movement detectors, first used by Danish research workers, were evaluated as potential sensors for automated oestrus detection in sows (Freson *et al.*, 1998; Pedersen and Pedersen, 1995). The infrared sensors were mounted above the sows and the difference in body movements was evaluated. Up to 80% of the sows were classified correctly as being in oestrus based on the level of daily activity. However, in dairy cows the best oestrus detection rate was achieved when different traits were analysed in combination using multivariate fuzzy logic models (Krieter *et al.*, 2003).

This research is a good example of how advanced and innovative data analysis, combined with the use of simple and cost effective sensors can solve real production management problems. **The potential benefits are not gained as a result of operating expensive hardware, but more from improved computer analysis of the data. This principle is probably true for the vast majority of PLF applications.**

7.6 DATA MANAGEMENT AND ANALYSIS

In recent years an increasing number of software packages are being used to aid livestock managers in decision making (Kuhlmann and Brodersen, 2001) and planning/executing management tasks (Thomson and Schmoldt, 2001). This section of the review discusses some of the interesting examples of management programs currently used and/or under development.

7.6.1 Current management software

Widely used management software (such as PigMon, PigChamp, PigWin etc.) will not be discussed here, as the commercial review component of this report will deal with routinely used management software.

However, a few innovative management programs have been produced in the last few years. A system called PKS SCHWEIN has been reported by (Krause, 1990), which was designed to assist producers managing pig breeding herds. The system comprised a series of modules to be used for sow organisation, breeding and reproduction management (Schofield *et al.*, 1994). LOGIPORK (Cordier and Gaudin, 1990) and CHESS (Dijkhuizen and Huirne, 1990) are similar and commercially available systems designed to analyse productivity levels of livestock. These systems use comparative trend analysis as a tool to evaluate and contrast historical performance data of similar farms.

7.6.2 Decision Support Systems (DSS)

7.6.2.1 Value of computer programs

The value of utilising management programs was evaluated on pig farms (Verstegen and Huirne, 2001). It was found that the management competency of pig producers was positively correlated with the value obtained from information systems. In other words, pig producers with better management skills obtained more benefits from information systems than farmers with low management skills. The relationship between attitude towards IT technology and the level of benefits obtained was also evaluated by researchers (Guilhermino and Esslemont, 1997). It appears that a positive attitude towards IT technology can further improve the level of benefits obtained. There are some very important messages in these papers for the Australian livestock industries. Obviously these principles have to be taken into consideration when selecting target groups to promote the use of IT technologies on farm.

7.6.2.2 Health issues

Dutch researchers reported the development of a Decision Support System (DSS) to improve herd-health management on pig farms (Enting *et al.*, 2000). The system provided farm advisors with a tool to understand and evaluate the interaction between disease incidence in the herd and environmental/managerial factors influencing the development of these diseases. It is essentially a tool to improve the evaluation of different risk factors for certain diseases. The main outputs of the system are:

- A list of risk factors identified on the farm.

- Recommendations for management intervention.

This DSS system can also be used as part of a preventative program, evaluating housing, climate and hygienic conditions in order to remove risk factors before they can predispose pigs to different diseases.

7.6.2.3 Design support

A behaviour-based simulation model has been developed to enable agricultural engineers to optimise dairy farm design specifically for robotic milking (Halachmi, 2000). As robotic milking is a new technology, experience with such installations is limited. This model was created to overcome the lack of available experience and to facilitate the design of "optimal milking sheds" while taking into consideration the circumstances of individual farmers. While this system was designed for dairy farmers, it is a good example how DSS can be used to collect, preserve and disperse management experience/knowledge which might be in sort supply.

7.6.2.4 Waste management and economic decisions

There are DSS available both in Australia and overseas to manage animal waste on farms (Guerrin, 2001). These systems can help producers to maximise efficiency and farming sustainability by minimising environmental risk. By applying these programs producers can evaluate and choose alternative waste management strategies, ensuring optimal environmental outcomes.

Computer models can also be used to aid pig producers with investment decisions by simulating the outcomes of certain investment scenarios (Backus *et al.*, 1995)

7.6.2.5 Expert systems

An expert system for managing important aspects of production, such as feeding, shed environment and disease was developed for layer birds (Lokhorst and Lamaker, 1996). Knowledge of a number of experts was stored in the database. Based on the advice of these experts, different quantitative and qualitative data helped managers to detect irregularities in the production process and respond to it. However, it was highlighted that one of the critical aspects of developing an expert (knowledge based) system is the acquisition of appropriate and relevant knowledge (Enting *et al.*, 1999).

7.6.3 Models

7.6.3.1 Growth models

There are a number of growth models available within the pig industry globally (Fialho *et al.*, 1997a; Fialho *et al.*, 1997b; Knap, 1999; Whittemore *et al.*, 2001). AUSPIG is one of the most widely used program in the Australian pig industry and world wide (Banhazi *et al.*, 2002; Black, 2001; Black, 2002). This review will not detail the benefits of using AUSPIG, as it is generally well known and the "Software review" section of this report will deal with AUSPIG related issues.

However, an interesting alternative modelling approach (called dynamic data-based modelling) was reported by Belgian researchers, which could be used to control the metabolic response of broiler chickens (Aerts *et al.,* 2003). It was demonstrated that dynamic data-based models are appropriate tools for growth control in broilers. It was argued that these relatively simple models are extremely suitable tools for production (process) control. A similar, compact model is under development in the UK for pigs (Whittemore *et al.*, 2001).

7.6.3.2 Emission models

Different models can be used to predict the behaviour and the spread of different pollutants emitted from livestock buildings (Koppolu *et al.*, 2002; Quinn *et al.*, 2001; Schauberger *et al.*, 2000; Zhu *et al.*, 2000). Although the use of these programs requires considerable technical expertise, there is an opportunity to semi-automate these modelling functions. Indeed it has been reported that an industrial company in the US established a website as a public relation exercise (Pisaniello, pers. comm.). People living near a chemical plant were able to check the predicted emission level and spread of the odour plume on the website, which was frequently and automatically updated. Apart from the public relation benefits, this site enabled the residents to prepare themselves and therefore minimise the impact of impending emissions on their properties.

7.6.4 Other data analysis methods

Sophisticated data analysis methods such as data-mining or machine learning are highly applicable to very large data sets, such as the ones generated by PLF systems (McQueen *et al.*, 1995). Commercially available “software workbenches” can be used to interrogate data and discover relationships or “patterns” within the data obtained.

Signal processing is another highly technical but useful method of data interrogation (Marchant, 2003). It is the science of understanding and interpreting different “signals” such as for example measurements of heart rate of an animal in order to assess the wellbeing of that animal or perhaps control aspects of the production process. Signal processing issues are especially relevant for so called complex, sensor-rich environments, such as animal buildings and greenhouses (Beaulah *et al.*, 1998). Indeed researchers at the Silsoe Research Institute are convinced that the successful development of PLF systems will require the utilisation of advance signal processing and machine learning techniques (Schofield *et al.*, 1994).

The authors of this report believe that advanced data analysis methods need to be investigated and used in conjunction with PLF systems. The main benefits obtained when using PLF systems have occurred as a result of innovative and computerised analysis of the available data and not so much the result of using expensive hardware.

7.6.5 Data transfer

Precision agriculture has special requirements in networking as large amount of information is exchanged between different components of the system via networks such as the Internet (Cox, 2002; Munack and Speckman, 2001). Emerging networking technologies and their integration into PLF systems can facilitate improved communication procedures and the development of integrated digital environment (Schiefer, 2003; van Asseldonk *et al.*, 1999). A recent paper argued for the creation of a standard network solution for agricultural IT systems, which tend to be non-uniform in terms of manufacturing standards (Artmann, 2003). **Easy data transfer between currently used management software has to be facilitated as the coordinated utilisation of these programs can offer a major improvement in data utilisation on commercial farms.**

7.7 CONTROL FUNCTIONS

Environmental and feed delivery controls have been used extensively in the pig industry for a number of years. However, many control functions undertaken in livestock farming are difficult to automate. Control of these operations involves proper communication with and information transfer to either internal control agents (workers) or outside agents (consultants or sub-contractors), so they can execute their control function. The task which needs to be executed has to be clearly communicated to the relevant staff, so they are aware of the nature and timing of the control function which needs to be performed. Task specific information might also have to be provided, so the task can be performed with ease and confidence. Therefore issues such as communication and data presentation will be discussed here in addition to traditional (environmental and feed) control problems.

7.7.1 Environmental control

Conventional (staged) ventilation systems are commonly used in animal buildings to control internal temperatures. Strategies for improved heating and ventilation control have been reviewed previously (Zhang and Barber, 1995). However, American researchers claimed that existing ventilation systems could be significantly enhanced by incorporating fuzzy control methods (Gates and Banhazi, 2002; Gates *et al.*, 2001). These “intelligent” controllers enabling users to select the level of trade-off between energy use and control precision (Chao *et al.*, 2000) and some of these new controllers have the ability to take the thermal history of both the air space and the animal into consideration, when adjusting environmental temperature in animal buildings (Timmons *et al.*, 1995). Potential areas of improvements have also been studied in naturally ventilated buildings (Andonov *et al.*, 2003; van't Klooster *et al.*, 1995).

Researchers in Germany are evaluating the possibility of using low-cost ammonia sensors to control ventilation systems, thus reducing ammonia build-up inside livestock buildings (Grotz *et al.*, 2003).

Behaviour-based environmental control for animal buildings has inherent advantages over the conventional, temperature-based control methods (Shao *et al.*, 1998). It has been reported that postural images of pigs might be used to control environmental temperature in sheds. Cameras were used to capture behavioural pictures of animals, which were analysed to gain an understanding of their thermal comfort level (Wouters *et al.*, 1990).

7.7.2 Nutritional control

A real-time control systems for individual food intake of group-housed animals have been available for some time (Halachmi *et al.*, 1998; Scott, 1984). These systems enable measurement and utilization of data related to individual food intake and feeding behaviour information such as food access frequency, meal duration, intake rate and food quantity of individual animals kept in groups. Apart from the control aspect, the additional information gained can be used to identify impending management problems, such as ill health of individual animals.

7.7.3 Economically focused production control

A very interesting paper was published at the recent 1st EU PLF Conference about the potential to control the production of dairy farming operations in order to maximise profit (Maltz *et al.*, 2003). The research was carried out on dairy farms and a similar concept might be applicable for other farming operations, including piggeries. In Israel, where the trial was conducted, producers receive various amounts of bonuses on the amount of milk and milk fat/protein produced and this extra payment varies with seasons. Different management options have been evaluated to assist producers to better respond to the given market requirement. It was found that by simply changing milking frequency, dairy producers could manipulate milk production in order to maximise economic benefits. The concept of "economically-corrected milk production" was used to optimise production levels under varying market conditions. One of the main implications of the paper was to highlight the importance of maximising economical benefits (and not necessarily biological production levels) in order to maximise farm profitability and viability.

7.7.4 Robotic systems

A robotic system capable of holding a sensor in contact with pre-determined positions on the body of loosely constrained live animals was designed at the Silsoe Research Institute (Frost *et al.*, 2000). Image analysis was used to guide a robotic arm over predetermined points on the body of live pigs. This technology might be applied to automatically inject or automatically ultra-sound pigs, while minimising the involvement of human operators. Such additional treatments of animals might be done in conjunction with weighing events.

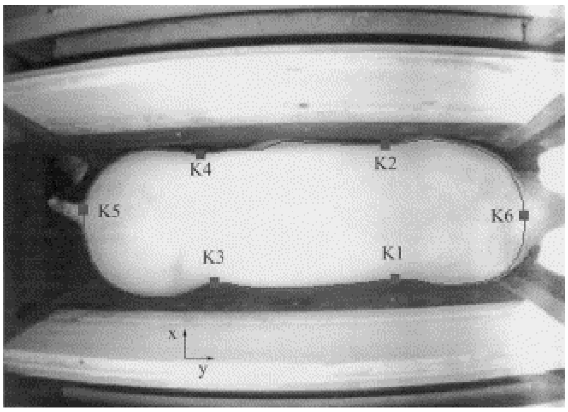

Figure 7. Video image of a pig taken from the overhead camera used to guide the robotic arm. (Frost et al., 2000).

Robotic systems have a lot of relevance in slaughter houses, where routine tasks, including grading operations can be automated in order to enhance the objectivity of the grading process (Goldenberg and Lu, 1997).

7.7.5 Data presentation and communication

The use of hypermedia techniques in agriculture have to be explored in order to facilitate more efficient knowledge and information transfer (Carrascal *et al.*, 1995).

The Internet is used in Denmark to allow producers to access a growth model and run their own diet simulations (Thysen *et al.*, 2003). While a simplified free-of-charge public version of this program is maintained on the Internet, the Danish Institute of Agricultural Science is also offering the customisation and enhancement of the program as a commercial service.

7.7.5.1 Hand-held computers

The utilisation of “hand-held computers” or personal digital assistants (PDA) is a fast developing area of information management. The computing power of PDAs is approaching the computing power of laptops and the latest generation of PDAs can be used for very complex computing applications (Zazueta and Vergot, 2003). The storage capacity of current PDAs has also been improved considerably, so these devices are suitable for data collection tasks in animal buildings. As an additional benefit, information collected on PDAs is usually automatically synchronised with databases on desktop computers. PDAs are also suitable tools for downloading and storing task specific information designed to assist the execution of control tasks in animal buildings. DSS softwares installed on PDAs could also assist producers in decision making in field situation.

7.8 SUMMARY OF LITERATURE REVIEW

Precision livestock farming is a relatively new concept and has developed rapidly in the last few years. This review was undertaken to assess technologies to be potentially used in comprehensive PLF systems and the R&D required before these systems can be implemented.

Some components of PLF systems are already available commercially for different livestock industries. However, very few groups have attempted to actually combine these components into one fully integrated system. Some examples of integration were presented to demonstrate that it is possible to establish integrated PLF systems.

Advanced data acquisition systems are important components of PLF systems. However, as many of the data acquisition systems were originally developed for industrial applications, they have to be modified to suit the purpose of livestock industries. Despite the importance of enhanced data gathering, the main benefits gained are usually the result of improved data analysis and not the result of using expensive hardware.

An increasing number of software packages are being used to aid livestock managers. For example, Decision Support Systems (DSS) have been developed for improved herd-health management on pig farms and behaviour-based simulation models are available to optimise farm design. DSS are available to manage animal waste or optimise investment decisions. Expert systems can be used to detect irregularities in production processes and dynamic data-based modelling has been developed to model the metabolic response of broiler chickens.

However, it was found that competent managers get more value out of information systems than less skilled managers and positive attitude towards IT technology further improves the level of benefits obtained. Obviously these factors have to be taken into consideration when selecting target groups for PLF implementation.

Sophisticated data analysis methods such as data-mining or machine learning can be used via commercially available “software workbenches” to interrogate large datasets generated by PLF systems. Signal processing techniques can be applied to analyse signals in complex, sensor-rich environments, such as animal buildings.

Although some automated control has been used in pig industry for number of years, the majority of the control functions performed around livestock are difficult to automate. Therefore, issues such as proper communication and data presentation need to be considered carefully to best facilitate manual process control functions.

However, there are exciting developments even in the traditional process control areas. New generation of environmental controllers are more “intelligent” and behaviour-based environmental control of animal buildings might also be possible.

8

CONCLUSIONS & RECOMMENDATIONS

The following sections list the issues and recommendations of the research team. These have been prioritised in Section 2.0. The following discussion of key issues and further R&D and extension issues details the approach we believe is required at this time to delivery PLF Systems to the Australian Industry. In summary the core actions required by industry at this time are:

1. Appoint and resource a PLF coordinator, and continued operation of the PLF Reference Group to ensure growth of PLF Technology within the industry is managed in the long term interests of the industry;

2. Initiate work with targeted demonstration farms that have already installed PLF Hardware to achieve the following priorities:

· Value adding to existing data sets through improved integration and analysis using existing software data management systems.

· Identification of "Data Capture Gaps" – in most instances there will relate to feed usage and live weight.

· Resolution of the data gaps through working proactively with the producer and commercial suppliers to create farm specific solutions to these problems.

· Promotion of the results of these demonstration sites to encourage other producers to take up the challenge.

· Where the PLF coordinator is working with a potential demonstration site then the results of the PLF review along with ongoing commercial discussions should focus on implementation plan that ensures optimised data integration and analysis opportunities.

3. Promote the value of an integrated data transfer system through out the PLF Hardware and Software industry and in relation to existing Herd Recording Program products and production model programs.

8.1 KEY ISSUES

8.1.1 Why do we need a PLF system?

The importance of incorporating PLF technologies into pig production systems are as follows:

For producers, it would be important to <u>monitor, analyse and therefore have better control</u> of pig production systems.

For researchers, it would be important to acquire better quality on-farm data, use innovative techniques to improve the precision of measurements and get access to farm data with numerous variables from large number of farms.

For Industry, it would be important to coordinate these developments and acquire strategic advantage over competitors.

8.1.2 How do we create an integrated PLF system?

- **Develop a new system** – too expensive, not practical and replicates current products and services
- **Do-it-yourself systems** – too risky for individual producers and will not improve the whole industry in a coordinated fashion.
- **Turn-key solutions** – everything is provided; therefore old components become redundant and new analysis tools or hardware systems will be difficult to accommodate within the system. Integration is only serviced within a single product line and no company offers the entire spectrum of products required.
- **Integration** – offers the best long-term solution; existing components are integrated, used and enhanced. The system is expandable and flexible enough to accommodate future changes.

8.1.3 What do we do?

8.1.3.1 Enhance program management

Establishment of a National task-force, Coordinator position and funding allocation

- It is clear that the commercial sector has a limited capacity to pursue integration to the end point required by industry.
- A National PLF coordinator position has to be established to coordinate the R&D and extension efforts across the livestock industries. As the most important aspect of PLF is integration, therefore the R&D and extension efforts have to be also integrated and coordinated nationally.
- A national task force, assisting the coordinator will become a knowledge and expertise resource for the industry and coordinate public and commercial sector R&D.
- The group has to be well resourced otherwise the technology might fail and producers can become disillusioned with the technology. However, funding should also be coordinated across different industries to maximise cost-benefit ratio.

8.1.3.2 Enhance extension/education

- The Industry should develop a simple communications strategy to demonstrate the opportunities available with PLF technologies.
- Annual workshops need to be organised for researchers and producers.
- Extension articles, perhaps a newsletter needs to be produced to continuously educate producers about the use of available technologies.
- The production of a comprehensive manual should be considered, perhaps using CD technologies.
- General extension activities, consulting and facilitation services have to be provided in order to raise the general technology awareness of the industry. Some of these cervices can be provided by the private sector, however public and private extension efforts have to be coordinated.

8.1.3.3 Enhance R&D

The main aim of R&D efforts should be the integration of currently available hardware and software components. Very few new components need to be developed, although there is a clear need for continuous weight data acquisition. Some development work might also be required to fine-tune available technologies, modify hardware/software components and develop systems linking together these components (communication protocols, translator programs etc). An integrated PLF system needs to be developed, which can accommodate a range of hardware and software components. Therefore, it will be flexible and able to accommodate the specific requirements of individual producers. The two main areas of development will be:

Hardware components

- Identification and adoption of sensors
- Automation of control functions

Software and analysis issues

- Improving data transfer, communication protocol and compatibility between components
- Developing and enhancing data analysis by
    - Combining data from different sources
    - Storing and making data available in one “virtual” place
    - Automating processing of data
    - Using enhanced statistical analysis, data-mining and signal processing tools to get more information out of the available data
- Enhancing communication and data presentation to improve “usability” of system.

8.2 EXTENSION RECOMMENDATIONS

Appropriate adoption of PLF technologies within the Australian Pig Industry will only occur if all sectors of the industry take up the challenge to upgrade their knowledge and understanding of the area.

If the industry is serious about taking advantage of these technologies it will need to invest in a coordinated program of awareness raising, training and ultimately capacity building through educational programs.

It is proposed that this coordinated approach can only be achieved through the establishment of a Precision Livestock Farming Coordination Task Force made up of industry representatives and supported by a part time coordinator.

8.2.1 Precision Livestock Farming Coordinator

The major role of this position would be the development of shared vision between growers, researchers and equipment supply organisations. Figure 1 in Section 2.0 provides a proposed format for such a coordinated approach toward the implementation of PLF Systems to the Australian Pig Industry.

After this vision had been agreed upon the coordinators role would be to support its development through the extension related activities suggested below.

8.2.2 Precision Livestock Farming Awareness Raising

Many sectors of the industry are currently completely unaware of the opportunities which PLF technologies can provide and of the products and service which are currently available. For instance the number of producers who already have automated environmental monitoring equipment installed in their sheds in conjunction with automated ventilation systems but do not take advantage of the logging capabilities of this equipment to benchmark their sheds performance over the year.

The first step in raising awareness would be through appropriately pitched articles in industry trade journals, and presentations at industry functions. Much of this work can be done in conjunction with and financially supported by supply organisations although the coordination of this funding activity would need to be undertaken by the PLF Coordinator.

8.2.3 Training and Education

This needs to occur at all levels within the industry:

- Growers – the current document could form the basis of an effective ½ day training event on the types of systems and issues associated with their implementation. Follow up workshops may be required in relation specific implementation issues.

- Technical Personnel – the personnel currently servicing our industry technically need to upgrade their skills in terms of the installation and maintenance of these systems. APL needs to discuss this opportunity with industry representatives to see if there is a training gap which needs filling in this regard. There may need to be some additional training programs offered within apprenticeship schemes or formal linkages with equipment manufacturers developed to ensure accredited installers are available to the industry.

- The Consultant Industry – This is the most critical area to target in the first instance in order to maximise the effective implementation of the equipment on farm. APL may need to initiate some form of formal training and accreditation process in order to ensure appropriate levels of service area provided.

- Tertiary Education Programs – there is a need for specialist trained professionals to be developed not only in the area of hardware and software development but importantly animal health and production professionals must be made aware of the opportunities available as a result of these technologies. This will require incorporation of appropriate undergraduate training and funding for a reasonable number of post graduate positions in the area generally to build the capacity for tomorrow in terms of new system design and implementation.

8.2.4 Accreditation

This term has been mentioned a number of times in relation to the training programs. APL should investigate the need to establish some form of minimum standard in relation to the installation of these systems because they have the capacity to do so much harm so rapidly to the performance of a piggery unit.

8.3 R&D RECOMMENDATIONS

Main recommendation – establishment of demonstration farms

One of the main objectives of a methodological data collection and analysis is to improve the economic performance of the enterprise. The proposed on-farm implementation of the system will be aimed at:

- Collecting information (such as individual pig weight, pen feed intake, internal shed temperature, humidity, air speed, respirable dust and viable bacteria) on farms, which will enable improvements in management, productivity and profitability of individual production units or enterprises.
- Developing a data collection kit, together with related software for application across the Australian pig industry.

Knowledge and experience gained during the on farm trials at selected piggeries will be used to ascertain the practical application of precision livestock farming systems. An appropriate, low labour input measurement system (for individual pig weight and automatic drafting, pen feed intake, internal shed temperature, humidity, air speed, respirable dust and viable bacteria) would enable the pig industry to capture production related data easily and efficiently, facilitate decision making and greater adoption of electronic management tools, such as AUSPIG to improve productivity and enterprise profitability.

The main objective of the project would be to:

- Develop in collaboration with participating producers **an individually tailored, reliable, but low cost measurement system for individual pig weight and automatic drafting, pen feed intake, internal shed temperature, humidity, air speed, respirable dust and viable bacteria.**
- Determine the impact of improved data collection and analysis on the profitability of commercial pig production enterprises.

This R&D/demonstration project will be implemented on farm using up to five sites. In principle agreements are in place with the following farms/producers and the arrangements will be finalised after the project has been approved by APL:

- Stockyard Industries, QLD
- Hall-McLean Farms, QLD (Discussion been held with Dr R. v. Barneveld, Director R&D)
- Auspork, SA (Discussion been held with R. Hamman, Executive Officer)
- RiverHeaven Enterprises, SA (Discussion been held with Mark McLean, Farm Owner)
- SOCOM Enterprises, SA (Discussion been held with Greg Ludvigsen, Farm Owner)

The following additional farms will be also approached after the financing of the project has been approved by APL. (It was felt that premature discussions about possible project implementation could raise false expectations within the industry and can jeopardise producer cooperation in the future.)

- Bunge/QAF Meat Industries, Vic
- Chapmans, SA

The project would be completed following the methodology proposed below:

- Selection of components: In collaboration with the participating **producers and commercial companies** the selection of data collection tools to be used on the demonstration farms will be finalised. The outcomes of the PLF "desktop-review" commissioned by APL, will be used to identify commercially available and reliable data collection and data-analysis components of the proposed system. However, a flexible approach to hardware selection will enable the research team to select hardware components which will be suit the individual needs of participating producers.
- Field trials and development: In collaboration with AUSPIG experts, different measurement and assessment techniques will be trialed on the demonstration farms. Participants of the Second PLF Workshop agreed, that the two most important electronic measurement systems to be introduced into Australian pig enterprises are live weight with automatic drafting and accurate measurement of feed intake on a pen (or sow) basis and these measurements will be incorporated into all demonstration systems.

One of the main focuses of the project will be the data-analysis component, where all the potential use of the collected data will be fully explored. The project will principally focus on value adding the data collected through existing industry data analysis tools and decision support packages such as AUSPIG and through the evaluation and development of new analysis tools.

8.3.1 General comments on PLF components

There could a number of components – no specific components are favoured or endorsed. Indeed the benefit of an integrated PLF system is to be able to accommodate a range of hardware and software components. Therefore, it will be flexible and will accommodate the specific requirements of individual producers. **However after detailed discussions with participating producers relevant hardware will be identified and all demonstration farms will be fitted with monitoring hardware, including weight and feed intake sensors. At this stage an interim progress report will be produced for APL detailing the actual hardware to be installed at the demonstration sites. At that time a "decision point" will be inserted into the project and APL will have the opportunity to terminate the project if the hardware proposed to be installed is not meeting the requirements of the APL management.**

The following issues will be dealt with during the projects:

8.3.2 Hardware components

- Identification and adoption of sensors (including weight and intake measurements) to fit the requirements of the participating producers and APL.
- Identification of opportunities to improve automation of control functions.

8.3.3 Software and analysis issues

- **Data transfer between different components, compatibility issues, data communication protocols -** These issues will play a major part in the success of any PLF system as it is the keystone for components of the system to 'talk' to each other.

Standard data communications protocol for Australian Agricultural industries should be defined. Note: this goes further than just the pig industry as there may be hardware/software solutions implemented in other areas that can one day be slotted in to the pig industry with ease (and vice versa).

- **Enhanced data analysis**
  - *Data fusion* – combining data from different sources.
  - *Data warehousing* – storing and therefore making data available in one "virtual" place.
  - *Automated analysis* - Automatic processing of data is essential – otherwise the time investment in data processing would be greater than the benefits gained. Producers might also encounter major problems with manual data processing. As an intermediate step, if manual data processing is used - external consultants should undertake the analysis.
  - *Signal processing* – image and sound analysis needs to incorporate signal processing techniques
  - *Advanced statistical analysis, data mining* – apart from currently available analysis tools, innovative, advanced statistical data analysis tools have to be used.
  - *Improved use of residential data* - Initial evaluations indicate that there is significant room to improve the use of resident data and advanced data analysis tools will enable producers to do so.

- **Enhanced communication and data presentation –** The better utilisation of hand-helds, CD-roms and advanced expert systems should be investigated for improved data collection, analysis and "control" tasks.

8.3.4 Proposed additional projects

Hardware projects

- Evaluation and integration of image analysis system into PLF systems. (Developing and using locally available expertise would enable the Australian livestock industries to capture future benefits of these systems, such as using image analysis for temperature control and slaughterhouse data acquisition.)
- Identification and evaluation trials of available biosensors for disease monitoring and injectable ID devices containing sensors (perhaps together with the sheep, beef industry) to be used in PLF systems.

Software projects

- Import/export functionality and data compatibility verification. Investigation of data interface capacity of automatic feeding and climate control systems should be undertaken and harmonised with potential destination software systems (PIGBLUP, Herd Recording Programs, PrimePulse and AUSPIG) to specify interface requirements.
- Development of Collation Utilities with input from stakeholder representatives.
- Investigation of alternative data analysis venues (data-mining, advanced statistical analysis etc) should be undertaken.

System integration/development projects

- Monitoring stress, oestrus and the onset of birth in sows by using combined measurement data of sound, movement and skin temperature (using low-cost sensors) and data mining, signal processing and machine learning techniques. This project would enable researchers working for the industry to develop their expertise in these fields and use these techniques for solving other industry problems in the future.

Management and extension projects

- Part-time appointment of a National Coordinator – this officer would coordinate both extension and R&D efforts nationally and across different industries. The officer would also be responsible organising the annual workshops for researchers and producers.

- Part-time appointment of a Technology Officer – this officer would be responsible for the dissemination of technology within the farming community and would be involved in practical facilitation, consulting and hands-on assistance for producers whishing to utilise PLF technologies.

8.3.5 Estimated budget

The following estimated expenditure was proposed as part of the first PLF report to enable researchers to deliver in the PLF area. This Table requires further modification, but provides a broad picture of the expenditure required.

Table 2. Proposed expenditure required (Durack, 2002).

EXPENSE AREA	DETAIL	ANNUAL COST
MANAGEMENT (Core funding required annually)		
	Program coordinator (Part-time funding)	$35,000
	Administrative support	$10,000
	Annual program meeting cost	$10,000
ANNUAL MANAGEMENT		$55,000
PROJECTS (Funded on a project by project basis as required – figure below given as a guide to the minimum level of activity required to create critical mass of research work required to give the program life):		
	Production Management	$120,000
TOTAL ANNUAL PROGRAM EXPENDITURE		**$175,000**

It is envisaged, that the "National coordinator" position will be supported by PLF Support Group (PLFSG) and specifically within the group, key experts will be required to play leading roles in coordinating/supervising National Research Projects. People with the following expertise will be required to have major input into formulating strategic research directions for the PLF area:

- Experts with good understanding of modelling and data analysis issues
- Experts with broad engineering knowledge
- Industry knowledge (producers and funding body representatives)
- Knowledge on support industries (key equipment/feed manufacturers)

A National coordinator would greatly improve the coordination and therefore the efficiency of research efforts in Australia and would also facilitate collaboration with overseas groups.

Farmex has been a very active supporter/developer of the PLF concept within the pig industry in the last few years. Its commercial focus will be helping the development of the Australian PLF system.

APPENDIX A – HARDWARE ISSUES

9.1 CURRENT SENSOR TECHNOLOGY

Below is a summary of the current status of each of the measurement items.

- Environmental Data

    - Shed Temperature, humidity, wind speed and direction, outside temperature, humidity, wind speed and direction. These environmental measurements are now a very mature science. There are plenty of component and system suppliers that can produce high accuracy, robust sensors and controls.
    - Shed Dust concentration. There are no specific products for shed dust concentration, but there are components from other industries that may be adapted for implementation with other environmental systems.
    - Shed CO_2 concentration. Many environmental measurement systems incorporate CO_2 within their suite, but these sensors can also be bought separately as extensions. A current APL funded project is addressing these measurements (Banhazi, 2003).
    - Shed Ammonia concentration. Similar to CO_2.
    - Shed and outdoor Odour level. There are very few commercial products available. R&D is still required in this area to produce a fast, no contact sensor. Most commercial products use air samples taken manually. Limited sensitivity and repeatability.

- Input Data
    - Feed intake. Several widely used systems available. Most require ear tags for individual animal identification. Data can be used in feedback loop for future modelling. Some systems incorporate the feed intake or supply measurements with scales for weight recording.
    - Water intake. Limited commercial products for recording water usage, even though this has been proven to have a major impact on growth.

- Output Data
    - Pig weight and variation. Many commercial components and systems are available using load cell technology. Several tie-ins with feed intake recording systems. Emerging trend is total barn design around weigh stations with auto drafting.
    - Proportion and duration of wet skin. No commercial products available.
    - Audio captures. No commercial products available to analyse sound routinely, but several interesting research projects are in progress (See 7.5.4).
    - Video capture. This is an emerging technology (see 7.5.1). More R&D is required in this area. Several new products available with limited support.
    - Back fat thickness. Several stand-alone components are available with data upload capabilities. More R&D required to tie-in with total system design.
    - Oestrus detection. Several commercially available sensors. Some tie-in with feeding pens.

9.2 COMMON PROTOCOLS FOR CONTROL SYSTEMS

There are currently no standard protocols selected and in broad use in a majority of Australian agricultural industries. This is an issue that must be addressed to allow standardisation of components and networks, which is one of the first steps towards a Precision Livestock Farming System.

9.2.1 Layer 1 (Physical)

Protocol	Configuration	Speed	Max distance	Other
RS232	Point-point	19.2kbps	20m	0-5V
RS422	Point-point	100kbps	1200m	0-5V
RS485	Multi point	100kbps	1200m	0-5V
ISO 11898	Multi point	1Mbps	1000m	2 wire
I^{2}C	Multi point	400kbps or 3.4Mbps	10m	2 wire

9.2.2 Layer 2 (data bus)

Protocol	Uses Layer1	Configuration	Speed	Nodes	Other features
CAN Bus	ISO11898	Multi-point	<1Mbps	Any	<40m, high noise resistance
Access Bus	I^{2}C	Multi-point	400kbps	Any	<10m
Ethernet	Ethernet	Multi-point	10,100,1000 Mbps	Any	
USB	USB	Tiered (Multi-point)	1.5,12Mbps	<127	
MODBus	MODBus	Point-point	1.2-115kbps	<247	
FieldBus	IEC1158-2	Multi-point	1,2.5Mbps	<64	Noise immunity
InterBus	RS485	Multi-point	500kbps	<256	
Measurement Bus	RS485	Multi-slave polling	110bps-1Mbps	<31	Plug+play

Configuration: point-point means direct 1:1 connection of components, multi point and tiered are a network of components can be all connected using the same wiring. Only systems with very few components should be using point-point configuration.
Speed: bps = bits per second, kbps = 1000's of bits per second, Mbps = millions of bits per second. 8 bits = 1 character (usually). The mainly non-time critical systems involved in this review indicate speed is not really an issue.
Distance: In larger barns, the maximum distance allowed between components may become an issue.
Nodes: This is the number of components that can be connected together. Large multi-sensor systems need plenty of node capability.

9.2.3 Common Character Sets

ASCII – 7 bit US standard
EBCDIC – 8bit mainframe
ISO646 – 7bit international equivalent of ASCII
ISO10646 (Unicode) – 32bit multilingual

Most software can now convert from one character set to another. ASCII is the most common character set in use.

9.2.4 Common Database/Data Storage formats

Microsoft Excel / Microsoft Access
Lotus 1-2-3 / Lotus Approach
dBase
DB2
Oracle
Sybase
Comma separated values (CSV) file

The specific database products above (dBase, DB2, Oracle, Sybase) cannot be interchanged without specific conversion software. The other formats are readable and interchangeable by most generic software. CSV files are the most popular generic storage format as they can easily be converted and are easy to understand.

There are currently no standard protocols selected and in use in Australian agricultural industries. This is an issue that must be addressed to allow standardisation of components and networks, which is one of the first steps towards an Integrated Management System.

9.3 SENSOR SUMMARY

Weight Measurement

System name	Contact details	Method/ functions	Sts	Accuracy	Power req'd	Env robust	Inputs	Analogue/ physical output	Digital outputs	Data Format	Software	Avail/ price	Comments
Ruddweigh	www.gallagher.com.au	2xload bars	C	100g	Recharge batt 8hrs +12V or 240 adaptor	Waterproof		3way drafting	2xrs232 comms ports	Excel			Excel examples supplied. Aus company
AlleyWeigh	www.mti-weigh.com	2x load bars	C				n/a	0				US$650	US company. Flexible - easy to move and install. (mat 1.75")
VIA – fire feeder add-on	www.osborne-ind.com	Video image	C/R						PC upload			N/a	
Weight-watcher	www.osborne-ind.com	Scales	C				RFID e-DISC	4way drafting on weight	PC upload		DailyWeigh		Total Barn design - scale between recreation and feed pens
Trutest JR2000	www.mcallisterfarms.com	2xloadbars	C	500g	12V battery / 240 adaptor		Manual tag entry, condition code	2way drafting	rs232+rs485			US$1216 (ind)+ $1300 (scales)	US company
FAST	www.farmweld.com	Weigh bars at top of scale	C			waterproof, corrosion resistant	EID/ ESP (electronic sense of position)	drafting	PC upload				US company, also record herd management info for later upload to PC.
Sorti-pen	www.skiold.nl	barn design / Weigh corridor	C				TROVAN ear tag reader	2way drafting	PC upload		TP11 system		Netherlands co. Barn design with weigh corridor.
Sierens	www.sierensequip.com	4 load cell	C			nema-4 rating		paint marking	PC upload				US company

Feed measurement

System name	Contact details	Method/ functions	Sts	Accuracy	Power req'd	Env robust	Inputs	Analogue/ physical output	Digital outputs	Data Format	Software	Avail /price	Comments
FIRE feeder	www.osborne-ind.com	Time,duration+weight recorded (feeder on load cell)	C			fibreglass	Ear tags req'd (ISO FDX-B) VIA	0	PC upload		FIRE software		data files easily exported.
IVOG	www.idento.nl	Time,duration + forelegs weight	C	5% on weight				0	PC upload				Holland. Algorithm for forelegs weight.
ACEMO	www.acemo.fr	Feed/water/prosgestagen dist Heat detection	C				Ear tags req'd	Ink marking					
Callmatic	www.bigdutchman.de	Feed on demand	C				Ear tags req'd		RS232/485				Germany. Links with feed ration system
Intec6000, FITMIX	www.mannebeck.com	Config feed/water on	C				ear tag (ALFLEX)		PC connected	csv			Multiple recognition points (entry, feed letdown and exit) + Total Barn

		demand											design
Water measurement													
System name	**Contact details**	**Method/ functions**	**Sts**	**Accuracy**	**Power req'd**	**Env robust**	**Inputs**	**Analogue/ physical output**	**Digital outputs**	**Data Format**	**Software**	**Avail/ price**	**Comments**
BSM	www.bsmagri.com	8 water distributions at 20 troughs					Manual program	Alarm + 2 aux					alarms for flow/leak etc. compensates for temp
(see omni-4000)													
(see DOL36)													
Environmental control													
System name	**Contact details**	**Method/ functions**	**Sts**	**Accuracy**	**Power req'd**	**Env robust**	**Inputs**	**Analogue/ physical output**	**Digital outputs**	**Data Format**	**Software**	**Avail/ price**	**Comments**
AP Systems	www.piggerysystems.com	temp	C						pc upload				
Hotraco	www.bmslots.com	temp,hum ,wind dir, co2,nh3	C						pc upload		HotWin/ Rainbow		Aus co (hotraco dist)
OMNI-4000	www.phason.ca	temp, feed, water, bulk feed, lot tracking	C				multi	various	PC connection	3rd party capable	Proprietary		256 power blocks - 6 types. Fully networked.some herd management inbuilt. Canada company, no Aus dist
DOL36	www.skov.dk	in/out temp, hum, water	C		230V AC		8 analogue 0-10V,	4 analogue, 0-10V. 16 relays, 1 alarm, 2 winch power supply	PC connection		InfoMatic		large scale env control. Controls multi fan/heating sources. Denmark company, Aus dist
Watchport	www.ionetworks.com	temp,hum, proximity	C		USB powered		128 USB	0	USB		Watchport Manager	per sensor	Sensor avail: temp, hum, video,water, proximity. Offer made for individual solution if required. US company, no Aus dist
Farmex	www.farmex.com	temp etc, multiple sensors	C			designed	8 + (flexible)	1 analogue 0-10V, 1-2 multiplexors	LAN		Barn Report/Barn watch	various	Data kept on secure website for download. 30 nodes max. US/UK co. no Aus dist.
FSU	www.fancom.com	temp, ventilation, RH, CO2, NH3	C					alarm	pc upload		F-Central		up to 8 sections controlled. Vent/heat control. Netherlands co, 3 aus dist
AC1500	www.rotem.com	temp, hum, pressure, wind direction,	C				11+	12 relays, alarm	pc upload		Rotem		Israel company, Aus distrib
titan	www.microfan.com	temp, rh, water/feed dosing	C		115V or 230V		4	2 analogue 2-10V	pc upload				Extension board available. Nl company, no Aus dist
mf-net	www.multifan.com	temp etc, extendable	C		230V AC		4	1alarm, 4analogue 0-10V					Network extendable. Nl company, no Aus dist
Mc34h	www.bigdutchman.de	Inside+ outside Temp, humidity,	C		240 V AC w/-		2 analogue	1Analogue 0-10vdc	PC upload (cable or		InfoMatic		German company, Aust distributers

		ventilation, alarm			backup battery		0-10V dc 2.2Mohm inp impedance	1500ohm, 1alarm relay, 1 winch motor	modem)				
combicool	www.bigdutchman.de	Highpressure fogging system	C				N/a	cooling+ const humidity + reduced dust	0	n/a	n/a		German company, Aust distributers
Livestock controls 2000	www.vengsystem.com	Temp+CO2+ammonia +alarm+ others.	C	amm= 2ppm	230V AC		10 networked	multiple controls	rs232	MS Excel			Denmark company, no Aus dist
Bsm temp controls	www.bsmagri.com	Temp	C			Sealed vs moist+dust	3 averaged	Fans, heaters, inlets and alarms	0	n/a	n/a		Canada company
PEC plus	www.canarm.com	Temp, user config growth curve	C		115/230V AC		network <32 units w/- 6 heat/cool stages	2 inlet actuators per unit	PC data logger		PlusWare		<32 controls RS485. Canada company, no Aus dist
Chore-tronics	www.choretime.com	Temp,hum,	C					Fans, winch, evap cooling, inlets, heaters	PC upload		C-Central		US company
Durag dr290	www.dialinfolink.com.au	Dust (LED sensor) via air outlet	C	Auto check cycle w/- reference value			0						sales only, no backup
Shc500	www.amkosystems.com	Dust (gravimetric)	C	Self-test	power pack		0		rs232 + rs422				canada co, no aus dist
DataHog2	www.skyeinstruments.com	datalogging w/- embedded RH + air temp	C	15 bit resolution	6 C batteries or 240/110V mains or solar	weatherproof robust and durable	multichannel voltage, current or digital count	4 optional relays	RS232C	ASCII 9600baud	Optional SkyeLinx		remote access via GSM . Uk co, no aus dist
METOS compact	www.metos.at/	datalogging temp, RH, wind spd+ direction	C		6 AA batteries		Extendable	n/a	IRDA comms		microLink		aimed at crop production (tomato, potato etc).. **Metos is very keen to collaborate on developing a shed AQ monitoring gear. **
WeatherMaster1600	www.environdata.com.au	datalogging temp, wind spd+direction, RH + spare channel	C		6V 3AH recharge battery + solar panel		4built in +1 extra channel	n/a	GSM/CDMA/UHF/satellite+ RS232		EasiAccess		extra input interfaces available on request.local company
AMT102	www.vaisala.com	datalogging ammonia 0-1000ppm	C		24VAC	optional w/proof housing	n/a	0-20mA + alarm	RS485				
Watchdog 450	www.specmeters.com	datalogging temp+RH +	C	approx 3%	3V		n/a	n/a	SpecWare cable		SpecWare	US$299	

		2channels											
WeatherMonitor II	www.weatherexperts.com	datalogging temp, wind spd+ direction, RH	C				n/a	n/a	PC upload		WeatherLink	US$430.00	US co, no Aus dist

Odour control

System name	Contact details	Method/ functions	Sts	Accuracy	Power req'd	Env robust	Inputs	Analogue/ physical output	Digital outputs	Data Format	Software	Avail /price	Comments
ozonaire	www.permroofing.com	Ozone neutralisation	C		110V/60 Hz		Ozone level sensor	0	0	n/a	n/a	running cost = 18kW.hrs per 1000 head	US co, no Aus dist
biocurtain	www.beiagsolutions.com	Physical barrier for shed air outlet	C	N/a	N/a	<130mph wind >10 yr life span	0	n/a	n/a	n/a	n/a		US co, no Aus dist
alpha-mos	www.alpha-mos.com	olfactory sampling	C				air samples 5min						vial samples required

Vision systems

System name	Contact details	Method/ functions	Sts	Accuracy	Power req'd	Env robust	Inputs	Analogue/ physical output	Digital outputs	Data Format	Software	Avail/ price	Comments
VIA	PC Shofield / Osborne ind	top view Area pixel count	R/C	<90%	N/a		0	0	PC upload				
ethovision	www.noldus.com	Color tag tracking software	C		N/a	N/a	N/a	N/a	N/a	N/a	N/a		

Backfat measurement

System name	Contact details	Method/ functions	Sts	Accuracy	Power req'd	Env robust	Inputs	Analogue/ physical output	Digital outputs	Data Format	Software	Avail/price	Comments
Sono-grader	www.rencocorp.com	A mode ultrasound	C		100h per 4AA batteries	Durable, portable	N/a	0	rs232		Sono-grader software	US$2248	
Lean meater	www.rencocorp.com	A mode ultrasound	C	+-1mm	Battery	Shielded	N/a	0	0	n/a	n/a	US$539	
Piglog 105	www.sis-pro.com	A mode ultrasound	C				N/a	0	PC upload				
Super tester	www.draminski,com	Ultrasound	C		9V battery		N/a	0	0	n/a	n/a	US$1775	

9.4 SENSOR INSTALLATION REQUIREMENTS

Weight measurement			
System name	**Contact details**	**PC link**	**Implementation requirements**
Ruddweigh	www.gallagher.com.au	a) direct cable to pc (Ruddweigh 300) OR upload software supplied (500 or 600). PC software supplied (MyScale Pro)	Install load bars + crate + reader.
AlleyWeigh	www.mti-weigh.com	Purchase Winwedge software to capture data from RS232 port on indicator.	portable scale - install in any alley. Laptop/portable pc connected for data capture
VIA – fire feeder add-on	www.osborne-ind.com	Not recommended - accuracy improvements required	not available in Australia
Weight-watcher	www.osborne-ind.com	DailyWeigh software supplied. E-LOG data capture devices available for portable data recording	Barn layout changes may be required to fit with auto drafting components.
FAST	www.farmweld.com	Software supplied. Upload to laptop/portable pc or direct cable connect.	Barn layout changes may be required to fit with auto drafting components.
Sorti-pen	www.skiold.nl	TP11 software supplied.	Barn layout changes may be required to fit with auto drafting components.
Sierens	www.sierensequip.com	Upload to laptop/portable pc.	Portable scale cage.
Feed measurement			
System name	**Contact details**	**PC link**	**Implementation requirements**
FIRE feeder	www.osborne-ind.com	real-time data collection. Pc upload	installed per-pen.
IVOG	www.idento.nl	PC upload required.	one feeder per 8-12 pigs
Callmatic	www.bigdutchman.de	Software supplied	
Intec6000, FITMIX	www.mannebeck.com	Network connection - pc	Installation + network wiring required

Water measurement			
System name	**Contact details**	**PC link**	**Implementation requirements**
BSM	www.bsmagri.com	Data logger required for PC upload	water pipe layout changes may be required to pass through controller
Environmental control			
System name	**Contact details**	**PC link**	**Implementation requirements**
Hotraco	www.bmslots.com	HOTWIN software supplied for online control and logging	no issues
OMNI-4000	www.phason.ca	Direct PC control. Control and recoding software supplied	Win95 required.
DOL36	www.skov.dk	Infomatic and FarmWatch software	Infomatic network installation required
Watchport	www.ionetworks.com	Direct pc/network connection	Network/hub system required for multiple sensors
Farmex	www.farmex.com	Upload to internet server - download to pc. Barnwatch/BarnReport software supplied	Network/ internet connection required
FSU	www.fancom.com	F-Central software supplied. Direct connection or modem	modem/phone line for remote connection
AC1500	www.rotem.com	Software supplied. Upload via direct connect or modem	Positive, Natural or Tunnel ventilation houses
titan	www.microfan.com	laptop/portable pc upload.	no issues
mf-net	www.multifan.com	mf-net software. Laptop/portable pc upload	no issues
Mc34h	www.bigdutchman.de	direct/remote PC upload. Software supplied	modem/phone line for remote connection
combicool	www.bigdutchman.de	direct/remote PC upload. Software supplied	modem/phone line for remote connection
Livestock controls 2000	www.vengsystem.com	Direct network connection to PC. Software supplied	no issues

Bsm temp controls	www.bsmagri.com	Data logger required for PC upload	no issues
PEC plus	www.canarm.com	PC network upload. Plusware software supplied	PC network required.
Chore-tronics	www.choretime.com	C-Central software supplied. Remote modem upload from multiple sites/	modem/phone line
DataHog2	www.skyeinstruments.com	Data offload & logger setup via RS232 port (cable and software supplied as standard for PC).	designed for external use
METOS compact	www.metos.at/	IRDA (infra-red) communications upload	IRDA capabilities. Designed for external use.
WeatherMaster1600	www.environdata.com.au	remote access software supplied	designed for external use
Watchdog 450	www.specmeters.com	direct connect. Software supplied	designed for external use
WeatherMonitor II	www.weatherexperts.com	WeatherLink. Upload to laptop/portable pc	designed for external use
Odour control			
System name	**Contact details**	**PC link**	**Implementation requirements**
ozonaire	www.permroofing.com	n/a	no data recording
biocurtain	www.beiagsolutions.com	n/a	no data recording
alpha-mos	www.alpha-mos.com	Direct connect (pc provided)	manual sampling required.
Vision systems			
System name	**Contact details**	**PC link**	**Implementation requirements**
VIA	PC Shofield / Osborne ind	Direct connect	not for application in Aus
ethovision	www.noldus.com	Direct connect	PC required.

Backfat measurement			
System name	**Contact details**	**PC link**	**Implementation requirements**
Sono-grader	www.rencocorp.com	RS232 upload to pc	no issues
Lean meater	www.rencocorp.com	no upload to pc	n/a
Piglog 105	www.sis-pro.com	data logging - upload to PC.	no issues
Super tester	www.draminski,com	no upload to pc	n/a

9.5 SYSTEM SUMMARY

Name	Shed temp	shed humidity	shed wind speed	shed wind dir	outside temp	outside humidity	outside wind spd	outside wind dir	shed dust	shed CO2	shed NH3	shed odour	outdoor odour	feed intake	water intake	pig weight	wet skin	audio events	video events	back fat	oestrus	**********************	market feedback	Aus support	automated control	logging	non-std sensor	network	handheld data entry	**********************	pc upload	analysis software	import	export	storage	Protocol
Farmex	√	√	√	√	√	√	√	√	●	●	●			√	√	●	●	●	●	●	●	*	●	√	√	√	√	√		*	√	√	√	√	web	
Environdata	√	√	√	√	√	√	√	√														*		√		√				*	√	√			pdb	rs232, modem dial , gsm/cdma , uhf
Ruddweigh																√						*		√		√				*	√				csv	rs232
Skov	√	√	●	●	√	√	●	●	●	●	●			√	√	√				●	●	*	●	√	√	√	√	√		*	√	√	√	√	pdb	
Piggery Systems & design	√				√																	*		√	√	√				*	√					
Hotraco (B&M Slots)	√	√		√	√	√		√		√	√			√	√							*		√	√	√	√	√		*	√	√	x	√	asc	rs232/ modem
Big Dutchman	√	√			√	√								√	√	√						*		√	√	√	√	√		*	√					
Veng System	√	√	√	√	√	√	√	√	√	√	√			√	√							*			√	√	√	√		*	√			√		rs232
Multifan	√	√			√	√																*			√		√	√		*	√					
Microfan	√	√			√																	*			√	√				*	√					
Rotem	√	√		√	√									√	√							*			√	√				*	√					cable, modem
Fancom	√	√			√	√				√	√											*			√	√				*	√	√				cable, modem
Watchport	√	√			√	√																*				√		√		*	√					usb/ethernet
Phason	√				√									√	√							*			√	√	√	√		*	√	√				
bsmagri	√																					*			√					*						
choretronics	√	√																				*			√	√				*	√	√				cable, modem
Ozonaire												√	√									*			√					*						
Biocurtain												√	√									*								*						
VIA - (osborne)																√			√			*				√				*	√	√				cable

Ethovision																		√			*				√				*	√	√				cable
Farmweld															√						*			√					*	√	√				wireles s
Osborne	√	√											√		√					√	*			√	√			√	*	√	√	√	√	csv	rs232
tru-test scales															√						*								*	√				csv	rs232+ rs485
skiold /sorti-pen															√						*			√					*	√					
IVOG													√		√					√	*								*						
Mannebeck													√						√	√	*		√		√			√	*	√					
Sono-grader																			√		*								*	√	√	√	√	csv	handhe ld upload
Lean meater																			√		*								*						
Piglog 105																			√		*								*	√					
Super tester																			√		*								*						
																					*								*						

√=standard
●=non-std sensors may be added to system

DISCLAIMER – The information in the above tables was taken from Internet sites and feedback information provided by equipment suppliers. All care has been taken to accurately describe these systems and components, but the reader should be aware that the information in these tables is indicative only, and further investigation should be undertaken before purchasing or installing items.

9.6 IMPLEMENTATION EXAMPLE

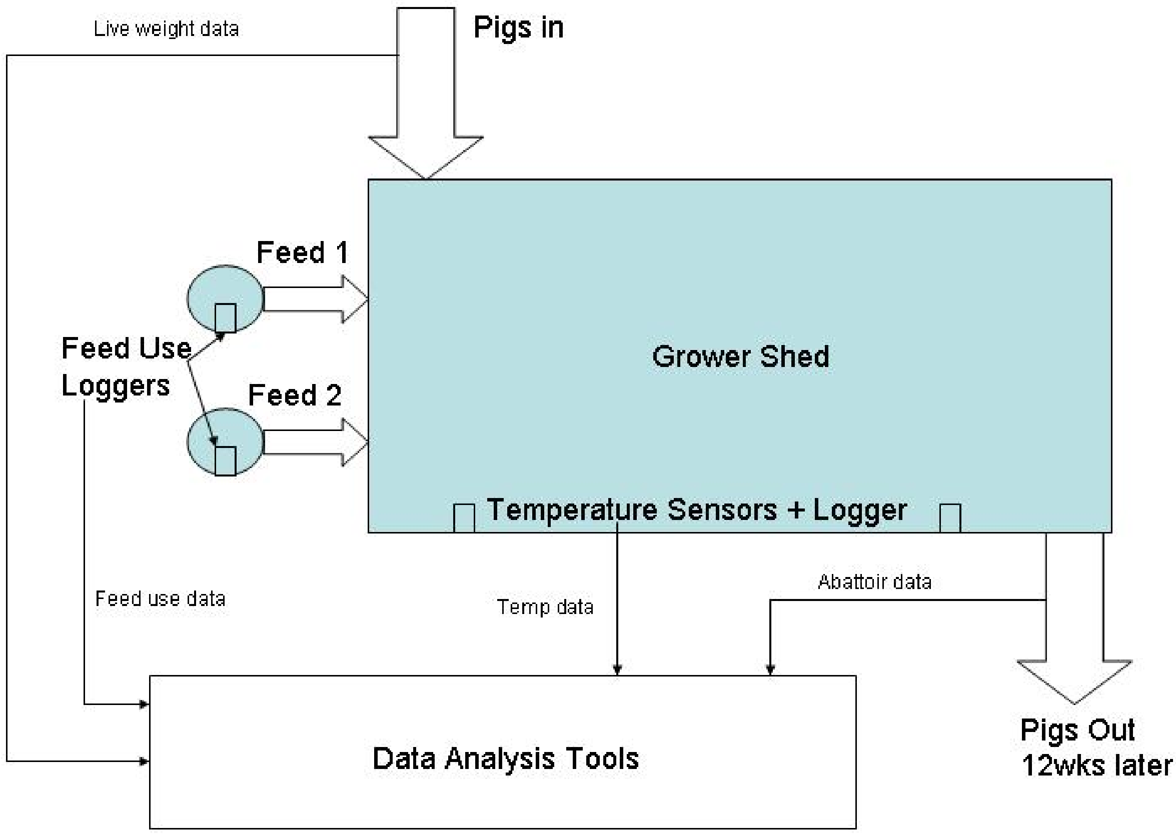

Figure 8. Example of implementation

Figure 8 above shows an example implementation of a data capture and analysis system that can be installed on most existing farms with very little work.

Logging temperature sensors are relatively cheap at under $250 per unit and can store up to 12 months data continuously. Even such a simple device can be used to evaluate shed performance and benchmark environmental conditions against optimal circumstances. These loggers come with simple graphical display functions and multiple loggers can be displayed together or comparative data sets cross referenced.

Load cells placed under the feed silos are another area where important information can be gained with little effort. Combined with the Live Weight data when the pigs arrive, and the data from the abattoir after they leave, there is a lot of information available for analysis. Simply loading the data into a generic tool such as Excel can show trends in weight gain, feed use efficiency and temperature effects.

There are also examples of producers who have successful integrated continuous weighing systems with automated drafting components to facilitate management of large groups of grower pigs. These systems can be manufactured with off the shelf components and the support of your local electrician.

The difficulty in both of these examples though is the integration of these data sets with existing management programs. The data sets generated become orphans, they cannot be incorporated into standard data management recording systems and so tend to be left for analysis in adhoc spreadsheets or proprietary logger programs.

10 APPENDIX B – SOFTWARE ISSUES

10.1 AUSPIG REVIEW

Currently AUSPIG faces adoption barriers due to the front end work load associated with data capture and user inputs required to calibrate an AUSPIG simulation.

Key barriers identified are:
- Additional staff work load to manually measure feed and pig weight.
- Exposure to multiple staff responsible for manual data recording injects error.
- Practical issues of "bypassing" automated feeding systems to isolate trial data capture groups.

Trial use of a mobile feed trailer mounted on load cells has not practically resolved these issues:
- It does solve the ease of feed measurement.
- Injects physical compatibilities associated with loading feed from different on farm mixing plants or storage bins.
- Does not avoid complications required to bypass existing feed delivery systems.
- Does not reduce scope for manual error attributed to staff changes.

As a consequence data is predominantly captured by weighing mobile feed barrows within laneway load cell weighing systems as this also enables pig weight capture as well (cohort required).

Adoption rates could conceivably double if these barriers could be avoided by way of 1) integrating sensor technologies to acquire data and 2) developing utility functionality to collate data into required formats, and 3) implement import functions within AUSPIG to import source data.

The source data required by the current version of AUSPIG are as follows:
- Multiple replicates of weaner groups sampled over the growth period for live weight and feed offered (cohort groups).
- A start and finish live weight with two additional interim weights is a minimum requirement.
- Finishing P2 slaughter fat depth
- A finishing dressed weight to establish dressing percentage
- Two or more sexes are monitored independently.
- Hourly min and max ambient temperature, relative humidity & air speed.

Individual pig weights may offer modelling improvements by way of more closely defining multiple “growth subgroups”. Similarly, more frequent growth curve samples may also offer an advantage.

A minority of AUSPIG practitioners are equipped with load cell hardware to capture climate data. Those with hardware face difficulty in reformatting the frequency of data captured to meet AUSPIG's hourly Min & Max requirement. An in-house utility application is available to reformat logged data but is difficult to use. In practice logged data processed by the utility is more commonly physically graphed, visually extrapolated and then manually entered into AUSPIG. AUSPIG supports a Climate file (Min & Max Temperature, Humidity & Air speed data) import procedure but it is seldom used in practice. This file is a simple space delineated text file.

Presently AUSPIG does not support any import facility to acquire feed or pig weight variables specifying the growth response curve. The growth curve is of higher priority than climate to improve the rate of adoption, but obviously more difficult to capture in practice.

There is an import facility to upload a comprehensive range of Reproductive, Housing and Fixed and Variable Cost variables that is rarely used in practice. It is quicker & easier to manually enter data as it is not supported by international herd recording software and there is incomplete compliance from Australian herd recording programs (MIPS & PigMania)).

The Windows version of AUSPIG was released in March 2003 and is presently undergoing field evaluation. The DOS version is more widely used at present and the length of the migration process is presently unknown.

Both DOS and Windows versions support file export facilities to output AUSPIG Model Data Sets, Genotypes, Buyers and Climate data.

AUSPIG Windows version 4 supports a comprehensive range of Standard and "User Defined" report types that may be saved in text file formats and as such are intentionally available for third party access (eg Spreadsheets and Word processing).

The Expert System that presides over the growth model is not fully automated and requires user intervention to fine tune and is thus not yet suitable for real time automated decision making within an integrated production control system. Clear caveats within the AUSPIG manual; "the AUSPIG System is intended to support decision-making, and not to substitute for a competent decision maker" support this notion and leave scope to assume that a substantial effort may be required to address this issue.

10.2 METAFARMS "I-PRODUCTION" SYSTEM

This system is not yet commercially available in Australia. Bob Hitchens (PigTales agent) has attempted to trial the system but due to technical difficulties, has been unable to get the system up and running. As such the product should be regarded as a prototype. Initial enquiries indicate that the system was largely developed for "in house purposes" (data & document management within a veterinary practice) and international market penetration is in the very early stages and regarded as minimal.

The product concept however is very sound and deserves description to capture a probable future direction for web based data management systems.

"i-Production" is the closest to an integrated management system discovered in this commercial review. However this system is mainly concerned with data communication and not so much with control functions. It attempts to develop an umbrella repository to collate a dynamic array of data sources that can be web based or site based or a mixture of both.

A Microsoft SQL server provides the platform for database storage. The overall system design resides within a System Map Database that identifies all data sources / sites and their relationships (eg Sheds & trucks). An Integration server stores the rules used to integrate data sources. An Automation server controls task execution to acquire and transform data. Data-Connectors provide the mechanism to integrate external data sources eg Herd Recording Program (only PigCHAMP is mentioned). A Portal Administrator manages user security permissions to hide or reveal system components upon login. SwiftKnowledge is a database sorting engine that can output to an Excel Server for customized reporting.

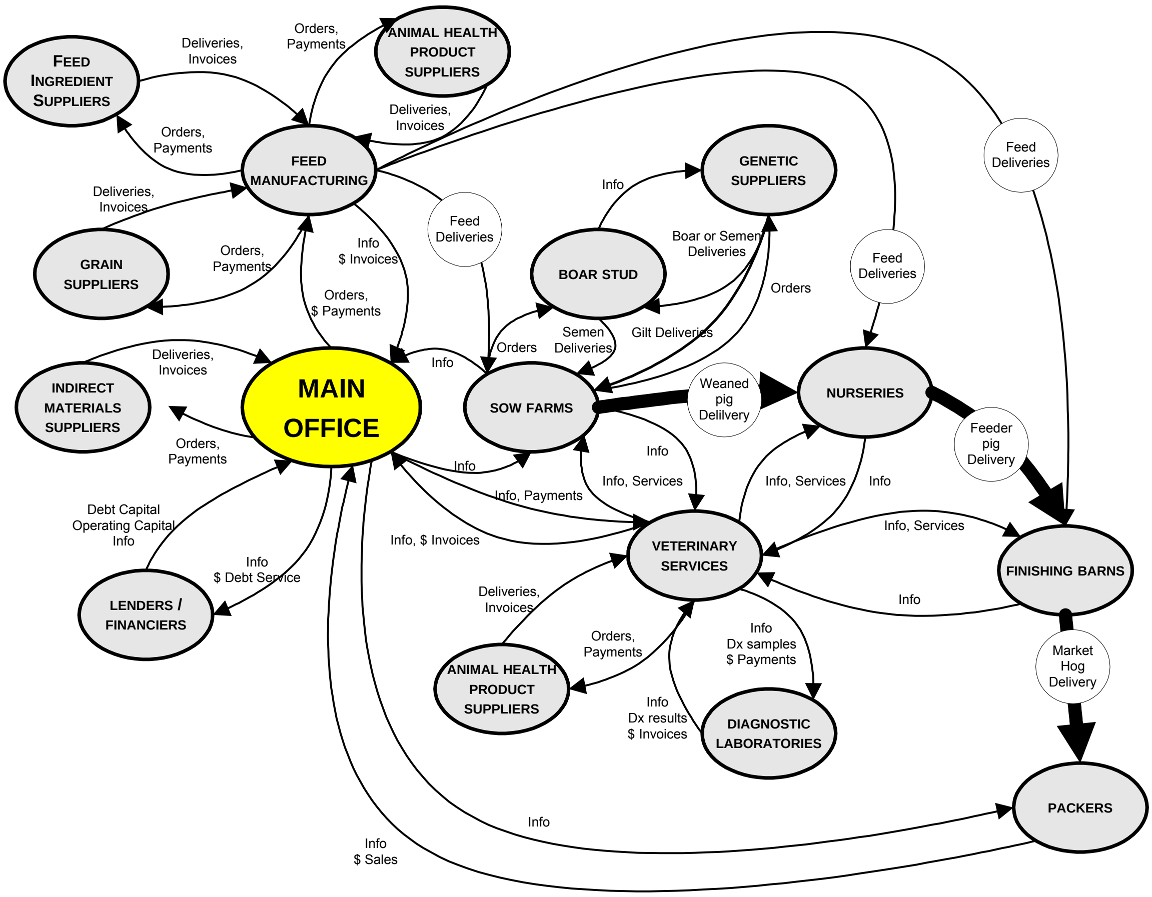

Figure 9. Concept of the Metafarms system

In a sentence, it's a large database that uses Microsoft's platform to plug into various data sources to effectively fast track development. As such it is most valuable for research purposes but there is an associated risk of data overload. By comparison, currently available smaller independent systems suffer from report overload resulting in less than 20% of capacity being utilised in practice. This proposed system is exposed to a ten-fold risk of redundant capacity. A process of report and chart automation is mentioned but the actual detail is lacking and intimates that personalized reports are instantly provided in real time claiming to "deliver the right information to the right people".

The diagram above was sourced from the Metafarms web site (www.metafarms.com) and describes the potential components of an integrated data capture system.

10.3 PIGBLUP

PIGBLUP is a genetic model currently used by 11 Australian breeding herds comprising approximately 7,500 nucleus sows supplying genetic improvement material to 40% (estimate) of the Australian commercial sector.

HM BOOT (<5000 sows) support Import / export interfaces with PIGBLUP. The interface file specification format is available in the public domain at: http://agbu.une.edu.au/PIGBLUP/herd2.html

Pedigreed and performance data (reproduction, production and carcase if available) is exported from herd recording programs to PIGBLUP which returns Estimated Breeding Values (EBV's) for various traits. These EBVs for individual traits are then combined into a $EBV which is the basis for selection decisions. Information about EBVs is returned to herd recording programs to report and service selection processes of future breeding stock.

Given that approximately 30% of pig growth is explained by genotype there is potential value in incorporating some assessment of genotype within the decision making processes embodied within a PLF system.

Direct PIGBLUP users could potentially improve the accuracy of genetic modelling by incorporating "sensor" production data (eg feed intake). Additional information available from improved electronic recording devices could be used to improve models for existing traits and/or develop new traits that better describe performance in commercial environments. Automated access to climatic data may also assist in the assignment of contemporary groups.

PIGBLUP interfaced herd recorders could also potentially utilize EBV data sourced from their genetic suppliers to predict genetic potential of commercial pigs and their requirements to reach full production capacities in a given environment. Similarly, other herd recording programs could support this interface if warranted.

10.4 PIGCHAMP

PigCHAMP reports a user base of 3500 clients from 55 countries and is regarded as the dominant international market leader. PigCHAMP services approximately 50,000 sows in Australia. Recent developments have seen PigCHAMP capture additional market share via competitive acquisitions (PigTales, EasyCare v1 & Porks2). PigCHAMP version 5 is identical to PigWIN and represents an alliance between these two major international software houses. PigCHAMP v5 is simply PigWIN re-badged by a change of logo and colour scheme, the structure and functionality is identical. This merger is clearly targeted at providing PigCHAMP with a windows upgrade without the associated development time and costs.

Thus all explanatory information documented herein referencing PigWIN applies equally to PigCHAMP (BarnCHAMP = PigPAD).

PigCHAMP developments have been more recently focused at establishing their web based "Vision" recording system. Production data is entered directly on to PigCHAMP's Vision website via a browser interface. The Vision concept is also available to DOS PigCHAMP v

4.10 users via a free Vision Upload utility that transports three DOS data files to the same internet site.

The marketing intent is to migrate users to web based systems by providing benefits only accessible from the web site (SPC analysis, real time comparative benchmark reports and any other new report types as there are developed).

This site also supports a data download facility that enables a remote consultant to download client data for uploading into the consultants PigCHAMP installation for expert evaluation and interpretation.

DOS PigCHAMP versions 2.x, 3.x and 4.x do not support export interfaces to PigPulse, Auspig or PigBlup. Similarly, these versions do not support any import interfaces to service automatic data capture devices or systems.

10.5 PIGWIN HERD RECORDING SYSTEM

PigWin has adopted a modular approach to package a suite of optional program components. The growing (PigGAIN - optional) and breeding (PigLITTER - optional) herds are serviced in separate independent modules which are accessed via the parent module (PigMAIN – mandatory).

The PigPAD module provides for electronic data entry and recall for all PigWIN modules. Apart from PigPAD there are no direct data import facilities to acquire production inputs electronically.

It is presently unknown if the PigPAD interface is proprietary or is it in the public domain. That is, if it is accessible and documented, could it be used by third party data sources to upload data into PigWIN?

Both Modules provide extensive reporting flexibility and support CSV file saving formats. PigLitter supports a comprehensive export facility to PrimePulse that is presently being reviewed to also service PigGAIN. PigGAIN also supports an ASCII Price Matrix import and export facility.

Personal communication with PigWIN has indicated that their research into electronically acquiring production data from data capture devices is a straight forward simple task. But it is presently impractical to address due to a myriad of data formats and structures that vary by source. Until an industry standard exists, this work is very unlikely to proceed.

PigWin adopts an open table format and adheres to a policy of servicing functionality appropriate only for their core business of herd recording and analysis, and then addressing extraneous client requests via import and export interfaces (XML format).

10.6 REVIEW OF MAJOR HERD RECORDING SYSTEMS

PigTails services approximately 40,000 sows via direct installations or indirect bureau services. The bureau service clients tend to migrate to independent client installations that remain reasonably steady. PIGMANIA is relatively inactive and services a contracting base of 20 to 25,000 sows (predominantly <1000 sow herds). MIPS services a steady base of 116 clients holding approximately 30,000 sows and tends to attract 100 – 600 sow herd size clients.

MIPS and PigMANIA both service interfaces to BLUP, AUSPIG and PigPulse. PIGMANIA also services an APIDIF import / export facility that acts as a complete data dump for all records within the system. The Australian Pig Industry Data Interchange Format (APIDIF) is fully documented and enables comprehensive two way communication between any applications supporting the standard. This format is in fact an extension of the BLUP interface format. PIGMANIA is the only application supporting the standard that was first released in 1994. The standard is comprehensive and designed to accommodate expansion to service emerging data sources.

MIPS and PIGMANIA both support a return interface from BLUP that conveys EBV's and environmental trend data. MIPS uses Microsoft Access data base format, PIGTALES uses a Clipper driven DBase 4 file format and PIGMANIA uses a proprietary format. Although the known formats are accessible by third party developers, the database design documentation is proprietary and required to expedite interface development. Personal communication with these software houses indicates a cooperative nature given mutual benefits.

10.7 HARDWARE PACKAGED SOFTWARE

Some of the hardware systems now contain sophisticated analysis and reporting software that are worth mentioning separately. These software packages are incorporating more of the data management functionality than some of the nominal farm management packages.

10.7.1 Infomatic

Used by the SKOV and Big Dutchman systems, this software is comprised of the following modules:

- Climate. This module monitors the environmental sensors attached. Monitoring, reporting and graphing functionality is included.
- Production. This module collects data for water consumption, feed consumption, mortality and weight gain. This data can also be used in analysis functions.

Data can be imported from CSV files and exported in the same manner for use in 3rd party programs.

10.7.2 Barn Report/Barn Watch

Used by the Farmex and Dicam systems, the Barn Report software is used to analyse the data stored on the web server where it is uploaded from the monitoring hardware. This software has numerical and graphical reports for data analysis. Additional data can be imported and graphed from CSV files and exported in the same format.

The Barn Watch software produces exception reports from the collected data to notify the user of anomalies for possible user intervention. This can also be customised for a cost per exception to show the user how much the problem is costing them.

10.7.3 OMNI-Feed

Used by the Phason Omni system this software monitors feed usage and relates it to herd management information to provide details about per animal consumption. Numerous reports and charts are available to interpret the data. Import and Export options are not available.

10.7.4 C-Central

This software is developed for use with the Chore-time hardware system. This software allows remote access and remote control of hardware. Multiple farm locations allowed. Graphical representation of one section, one shed, or farm at a time. Import/Export options unknown.

10.7.5 DailyWeigh

This software is used by Osborne systems as the heart of their WeightWatcher Growth Management System. Growth curves, weight info, weight distribution graphs each day, phase feeding reports, weight prediction. Import/Export available to and from CSV files.

10.8 PRIMEPULSE REVIEW

PrimePulse is a generic Statistical Process Control program that interfaces to industry data sources (predominantly Herd Recording Programs). The primary objective of this program is to identify significant shifts in performance to initiate managerial intervention processes. The key strength of the program is that it is fully automated and can sense the presence of a new data file, processes it and output its findings without any input required by the user.

The diagram below relates data sources that PrimePulse MAY access:

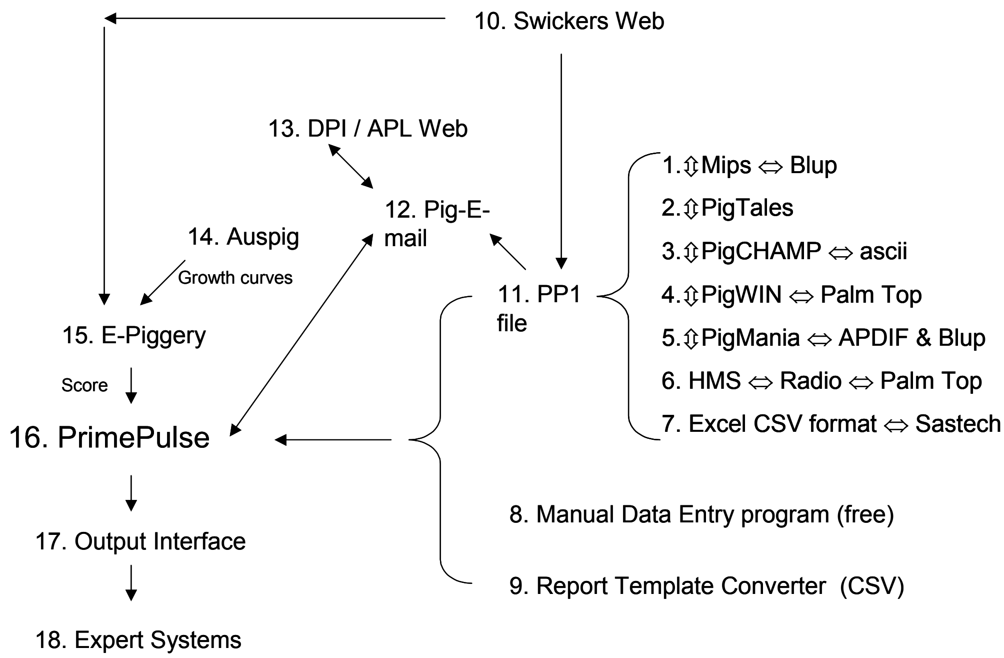

Figure 10. PrimePulse data pathways

1 to 5 are proprietary Herd Recording Programs

1. MIPS is a data entry only program, no upload facility. It does support an export interface to PIGBLUP (reproductive event data collated by sow of origin, eg sow ID 23D, farrowed 11/01/2003, 10 born live, 2 dead etc) and AUSPIG (performance and financial records).
2. PigTales data entry only, no upload facility.
3. PigCHAMP has an upload facility for reproductive data only (thus can poach data from other programs) – interface specification is documented within the user manual.
4. PigWIN – is modularised and services reproductive data in an independent system to growth data. Has interface to PalmTOP hardware for on site data entry that can upload into the parent installation eg office or home. Note PigCHAMP v 5.0 is PigWIN re badged.
5. PigMANIA – manual data entry only. Developed APIDIF to service DOS data migration to Windows 6+ years ago. Australian Pig Industry Data Interface Format was used for the purpose and was incorporated into software in the brave hope that it would be adopted as the standard and enable an "open database" environment enabling

clients to freely interchange between herd recording systems. Not adopted by anyone else to my knowledge. It is an extension upon the PIGBLUP Interface format (predominantly reproduction data), and is structured to enable ease of extension to service emerging data sources.

6 HMS – Herd Management System is QAF's (Bunge) in house recording system. They have developed their own handheld data capture devices for reproductive data that is relayed by radio towers to the head office computer (not in line of sight).

7. Excel CSV format is used to capture data from any spreadsheet. Sastech is a program used within most abattoirs to capture data from the kill chain eg carcase weight & fat depth. Sastech can output to Excel and some abattoirs use Excel to email Kill data to clients. We can provide VBA modules that can be imported into any Excel spreadsheet to output data in PP1 format.

8. PigIn is a manual data entry program (freely distributed) that is a standalone installation that can be used to enter any paper based data source. It outputs a PP1 file format for import into PrimePulse

9. Report Template Converter is a utility program that can read any asci file and reformat it into PP1 format – this functionality has been incorporated into PrimePulse. Custom Templates have to be developed for each asci file format encountered.

10. Swickers (Kingaroy abattoir) is going online with a client intranet to download carcass data files to clients in the form of 1) raw carcass data, 2) summarized consignment statistics that are provided in PP1 format.

11. PP1 file is a PrimePulse proprietary data file format that is freely available in the public domain and used to convey "sample" data for generic analysis within PrimePulse. It is a normalized flat file data table in comma separated format – very simple for layman use (eg via excel).

12. Pig-E-Mail is a communications program (free) that 1) conveys data files via email to DPI or directly to a web site (developed for an APL group demo project), and 2) receives & presents slide shows depicting the results of data analysis returned from the DPI bureau service.

13. DPI / APL web site – a database of files sent / received with client password protections and constraints.

14. AUSPIG – supports file saving facilities in ascii formats that are readily accessed by third party programs (but constrained by constant version upgrade maintenance to respond to changes in file formats). Growth Curves could be imported into E-Piggery via this means.

15 E-Piggery – A what if production model that interfaces with PrimePulse to apply financial weightings to physical production changes detected. Designed to automatically assign financial weightings to a wide range of production variables and output these to a "score file" imported by PrimePulse.

16. PrimePulse – a generic Statistical Process Control system that automates the analysis of an infinite number of traits to identify significant shifts in performance and outputs these “issues” to a database that is automatically interrogated by a system of exception rules to prioritise issues for intervention. These outputs are saved to file for other applications to utilize.

17. PrimePulse OutPut Interface, designed but not yet developed, intended to return information to source programs (suppliers of data) for further action eg Reproductive Expert Systems to automatically provide advice to rectify the situation.

18. Expert Systems – an interface to Reproductive expert system has been jointly specified. This specification is generic and could service any other purpose – eg invoke an AUSPIG simulation to re formulate diets upon detecting a summer fall in voluntary feed intake.

APPENDIX C – EFITA ABSTRACT

BASE-Q PROJECT – STEP TOWARDS INFORMATION RICH LIVESTOCK FARMING

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In Australia during the last few years an intensive air quality (AQ) related research program have been in place, as it was realised that air quality could potentially and quite severely effect animal health (Skirrow *et al.*, 1995). Since the late nineties a number of articles has been published highlighting the importance of this area of research (Banhazi and Cargill, 1998; Banhazi and Cargill, 1999; Cargill and Banhazi, 1998). Overseas publications also confirmed the importance of optimal air quality (Donham, 1989; Wathes *et al.*, 1983; Wathes *et al.*, 1998) and apart from production aspects, Occupational Health and Safety (OH&S) aspects of sub-optimal air quality was also highlighted by a number of studies (Donham, 2000; Donham *et al.*, 2000).

It was realised, that accurate, low-cost monitoring of airborne pollutants is therefore essential if appropriate air quality improvement strategies are to be implemented. Furthermore it was also established that an easy-to-use air quality measurement kit is not available at present. Therefore a project was designed and funded by the Australian Pork Limited (APL) to select, develop and consolidate low cost measurement techniques for detection of airborne pollutants, as well as to establish the appropriate organisational structure and **data management system** for these measurements to be carried out on a routine basis.

As a first step in the project, a methodological review was undertaken on current practices used for low cost air pollutant measurement techniques on commercial farms. This information was used to establish in-principle recommendations for the environmental quality measurement instruments and related the data management systems required. The current prototype kit consists of two airtight boxes and a number of hardware components. Inhalable and respirable particle concentrations are measured using a TH#107CD 18-194A air pump connected via Dutch manufactured (Euro-Glass Pty. Ltd.) "Venturi-tubes" to two cyclone filter heads (for respirable particles) and two Seven Hole Sampler (SHS) filter heads (for inhalable dust) and operated at flow rates of 1.9 and 2.0 l/min respectively (Wathes *et al.*, 1998). An infrared sensor is used to measure CO2 levels, while the sensor used to measure NH3 is a thin-film polymer based technology (Fotis, 2002; Phillips *et al.*, 2001). Temperature and humidity data are recorded in buildings using temperature and humidity sensors connected to the dataloggers used to store the gas concentration information. Data were easily transferred from the dataloggers into the associated BASE-Q software/database. The BASE-Q software, with its enhanced data handling and reporting functions, greatly increased the efficiency of the system. Concentrations of the different airborne pollutants are automatically calculated and graphed using a special graphical output.

The new BASE-Q air quality monitoring and data management system has a number of advantages, when compared with traditional air quality instrumentation and data management systems. Both the size and weight of the monitoring hardware were significantly reduced in order to improve ease of installation, labour efficiency and transport. The monitoring equipment was simplified and encased in a waterproof enclosure to improve ease of operation and disinfection. The special software developed greatly simplified data input, improved data management and the reporting functions of the system. Due to these structural improvements of the hardware used and the enhanced data management software developed, the labour input required for operating the system was reduced and therefore the cost of air quality monitoring minimised. These improvements will enable producers and industry consultants to undertake air quality measurements routinely on farms and therefore reduce the Occupational Health and Safety risks for workers and potentially improve animal health and production efficiency.

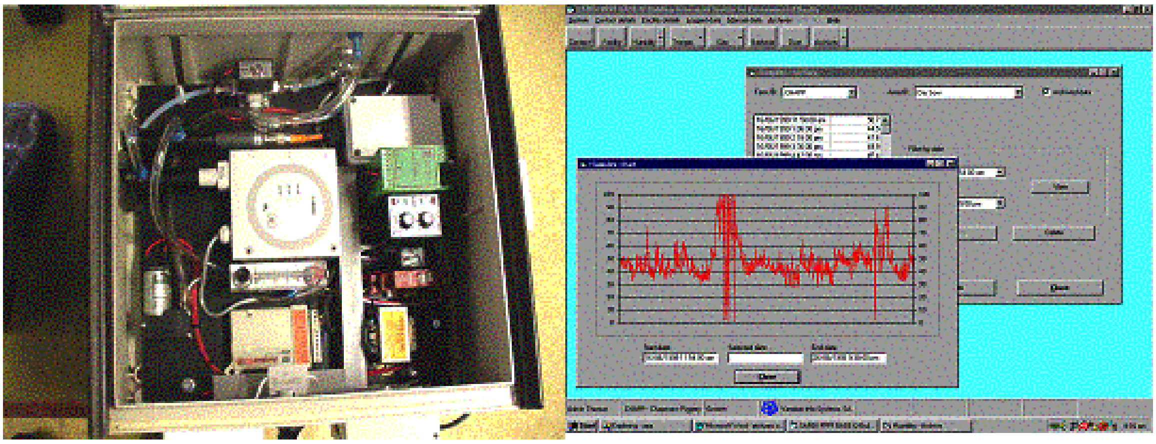

Figure 11 . Monitoring instrumentation and reports generated by the BASE-Q system.

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