Final Report

P.PIP.0772 – Leap4Beef – Industry Beef Boning Automation
Learnings from Program and Recommendations for Ongoing Development

Project code: P.PIP.0772

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Abstract

The Teys-MLA Beef Boning Automation program commenced in 2018 as a collaborative program between MLA and Teys Australia. Its purpose was to develop the world's first automated beef boning system, leveraging lamb boning automation. For the industry, this was an opportunity to revitalise Australia's competitive status domestically and abroad, to improve boning accuracy and efficiency, and to deal with the increasing difficulty of labour shortages which only became more apparent through the pandemic of COVID-19. For MLA, this was an opportunity to develop a system with specifications and price appropriate for widespread adoption.

This report summarises key learnings, highlights pivots in development approaches to delivering program strategy and makes recommendations for the next stages of the program.

Milestone reports document detailed technical design outcomes and should be referred to in building out next technical development activities.

Executive Summary

The Teys-MLA Beef Boning Automation program commenced in 2018 as a collaborative program between MLA and Teys Australia. Its purpose was to develop the world's first automated beef boning system, leveraging lamb boning automation. For the industry, this was an opportunity to revitalise Australia's competitive status domestically and abroad, to improve boning accuracy and efficiency, and to deal with the increasing difficulty of labour shortages which only became more apparent through the pandemic of COVID-19. For MLA, this was an opportunity to develop a system with specifications and price appropriate for widespread adoption.

Teys and MLA agree that these challenges are becoming more critical to the Australian industry. Both organisations continue to support this program of work, the opportunities it can provide to the whole Australian beef industry supply chain and acknowledge the increasing challenges successful automation will address in order to remain globally competitive.

A test, learn and pivot approach has been applied through the program to date. Review of the research and development undertaken to date has provided important learnings around how best to continue the program to achieve commercial success and widespread industry adoption. Both companies recognise a pivot in structure, funding and contracting is required to enable the remaining research and development to get through the commercial prototype phase.

Teys will not continue their role as decision-makers and lead contractor but will continue to support the testing and validation of prototypes as one of a few industry representatives. It has been acknowledged that the business drivers to run successful meat processing operations are in conflict with the test and learn methods required to create new automation innovations. Managing unchartered innovation to tight commercial deliverable timelines stifles the explorative methods and inventive concepts necessary to research and develop a new technology.

This report summarises key learnings, highlights pivots in development approaches to delivering program strategy and makes recommendations for the next stages of the program management.

Milestone reports document detailed technical design outcomes and should be referred to in building out next technical development activities.

The industry benefit to be achieved by a successful program was proven very robustly in the work to date and will likely deliver the following financial benefit:

Benefit per head: $29 ~ $65

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1 Background

The intention of this program has been to produce a world first automated beef boning system. MLA and Teys developed a novel concept, x-ray enabled (DEXA) beef boning process layout, which leverages existing x-ray enabled lamb automation successes. Lamb automation's benefits of improved consistency and accuracy, along with labour savings were expected to flow through to beef boning automation. Prior to this program of work MLA contracted Scott Automation to deliver three bodies of scoping work, summarised under the following projects:

- P.PSH.1204
- P.PSH.0911
- P.PSH.1199

1.1 Research and development vision

The original strategy document summarised the vision for this program as a *"proposed overarching strategy of a Beef Automation Program titled "Leap for Beef" and how it will closely align and support other MLA key strategies such as Objective Measurement (OM) and Digital Strategy (DS), with an anticipated five-to-seven-year horizon development and adoption process. The strategy will build from the learnings of the now successful 'LEAP' Lamb Boning Automation".*

1.2 Program Objectives

The strategy document presented key development elements to achieve the program objectives:

"The concept will utilise sensing and automation technologies in an innovative, modular approach to beef boning. Ex-ante Cost Benefit Analysis (CBA) data has shown the proposed plan has the potential to improve accuracy of cutting lines and provide important transparent carcase data such as Lean Meat Yield. The strategy describes 'stand-alone' boning or packing modules that incorporate objective carcase measurement (OCM) and objective primal measurement (OPM) technology to provide an integrated transformational solution from the start of the boning room to the packing load out area and enabling the distribution of carcase data to the benefit of supply chain."

The component technologies that successfully automated lamb boning were expected to apply to beef boning. The program designated forequarter, hindquarter and middle automation as separate activities. It aimed to process the remaining parts through manual cutting methods.

Beef carcase specifications, cutting lines and boning room processes would require a new system. Because this system would process a whole side of beef, the program vision re-imagined the way a beef side was disassembled and presented coming into the boning room.

The system design approach was separated into modules, addressing each cutting line before bringing modules together as a system. The intention was to reduce risk of failure. The development pathway of one cutting line would not impact other cuts. It would mean development and delivery could be incremental, rather than deliver a single integrated install of all modules. Modules may be automated, or operator assisted depending on automation and sensing complexity. Vision & sensing capability would drive or assist a cutting/boning mechanism. Materials handling capability would transfer product between modules and hold the product for cutting/boning with stability. The development of each module required these capabilities be developed concurrently.

The system would cut, trim and pack primals in future by the addition of new modules.

The first part of this program was to understand where the value would be extracted by a final system.

1.3 Program Pivot Now Required

Teys have been the single processor and joint collaborator with MLA on this program. Given the heavy focus on processing skills and commercial processing application, Teys carried the major responsibility for program direction. This brought with it strong commercial skills in running successful processing businesses and associated capital contractual arrangements.

It has been recognised that commercial contracting requires a different set of drivers, management processes and thinking styles to enable research and development that will eventually result in the best commercial systems.

It has been mutually agreed between MLA and Teys that a different program structure is required while R&D is still being tested, if the best automation solutions for industry are going to be achieved.

This document summarises the program activities and learnings to date and provides recommendations on how to use those learnings as the program pivots and prepares for the next stages of development.

2 Contract Structure and Objectives

In the initial scoping stages of this program, Teys had provided a global request for tender to all companies that have experience in food industry engineering and automation. Many of these companies have a track record of automation in the pork, poultry, and seafood industries where the uniformity of carcases is very reliable. No company except Scott Automation responded to the tender with any interest. This reflects the challenging nature of automating beef breakdown due to the high variability in carcase conformation, market requirements and diverse cutting specifications.

Given the bold nature of this program the work scope and deliverables were difficult from the outset.

The contract between MLA and Teys took an innovative approach where the specific outputs, timeframes and cost allocations were not specific. This is in contrast to the normal MLA contracting process where very specific deliverables are agreed with fixed time frames and milestone outputs. Given the dynamic nature of the research and development that was to be undertaken, this would support the agile and dynamic development.

MLA-Teys Contract

MLA entered a collaborative agreement with Teys to host the Leap4Beef program in their processing plants, and facilitate the design, development, installation and commissioning of an automated beef primal cutting system. Solutions were to:

- prioritise automation of beef boning,
- consider risk and commercial rewards as drivers,
- consider the broader industry processing environment,
- address the majority of industry requirements for adoption purposes,
- undertake as many of the 12 beef side cutting lines as possible, and
- automate support processes as needed.

The collaborative agreement did not put a time constraint on the solution, nor specifications, except the '12 beef side cutting lines'. These cutting lines encompass the whole beef side focusing on primal cutting.

Teys then engaged subcontractors as required to deliver on these objectives.

Research and Development room

The sub-contract to build the Research and Development room required to support the program of works and prototypes was under development at the time that the global request for automation contractors was being undertaken. After the room had been completed, Scott technology was assembling a response to the RFP and had contributed a lot of initial scoping ideas that built on their earlier pre-program projects with MLA and from cutting trials they undertook with Teys in the R&D facility.

Teys-Scott Sub-Contracts

Teys engaged Scott Automation to perform the engineering design and development of this program. This contracting was the result of the detailed scoping work that Teys and Scott Automation had undertaken earlier in the program.

The objectives of their contracts were to:

- complete Part 1 prototype scoping of the robotic cutting system within 2 years
    - The purpose of this contract was to test a range of hypothesis and pre-prototype cutting, handling and visioning approaches
    - The findings from this research would then feed into a second stage design and build contract
- complete Part 2 – Develop commercial prototypes within 2 years
    - The purpose of this contract was to develop knife and fork prototypes from Part 1 work, then to
    - Adapt knife and fork results into commercial prototypes that would be installed and operational at the end of the contract to:
        - process 400 sides an hour, and
        - deliver other specifications for the final system.

During the scoping of the first Scott's contract, it was not clear which development options should be prioritised to build first.

Both Teys and MLA identified that there needed to be a robust methodology to firstly prioritise the research and then to manage the various streams of research. A number of engineering consultancy firms were asked to submit project management methods including HAZOP style methodologies. Greenleaf was also asked to meet with Teys and Scott Automation, understand the challenges in proceeding to a first stage contract, and present a methodology for managing the design innovation.

Teys-GLE Sub-Contracts

The complexity of beef automation requires strong project management and leadership. A rigorous research and development method was required. An initial contract helped establish the Program and design methodology (described in the methodology) and formed a steering committee to oversee the design process.

A second contract provided the business case analytics and detailed plant and benefit cost analysis required to support the prioritisation of design options and to test commercial viability. Part of this contract involved very detailed trials on plant around product, carcase and processing specifications. Results from these trials was then used to inform, challenge and test design concepts delivered under the Scott's contracts.

3 Program Methodology

Some parts of the program methodology have been very effective. Based on learnings to date in the program other aspects now require a pivot to enable the best outcomes for industry. The various aspects are described in this section and will underpin recommendations on how to move forward.

3.1 Industry involvement

Teys were responsible for the design, progress and outcomes of this R&D program. A lot of time and energy has been invested over the past 4 years to achieve many learnings. Deep consideration of the program and the significant work still required to achieve much-needed beef automation for most Australian processing configurations prompted Teys to make the following statements:

Beef processors are excellent adopters of technology. They assess the value of the technology to their business by observing proven systems in other locations, assess the ability to adapt the technology to their company's constraints, install in a short timeframe with detailed service provider contracts, and executed to limit downtime and integration delays. They:

- *contract the necessary parties to apply an existing solution to their process,*
- *work with the necessary parties to adapt the solution to their particular use-case as a plant,*
- *do it in a timely manner to get back to production as soon as possible.*

Based on the R&D program's learnings, Teys believe beef processors using these methods are not suited to lead R&D programs and create new systems. Research organisations like MLA, AMPC and their associated service providers have the mindset required to test things in ways that explore many unclear options to find the best solution. Part of this mindset requires appetite to fail quickly and often to get to workable solutions. Processors don't tolerate this, which is why they are successful at what they do. The challenge is in building a program of works maintaining input from processors to deliver commercial priorities and application, but managed using an R&D mindset.

3.2 System design

The Greenleaf program design employed an effective R&D approach in conjunction with Teys and built on an overarching leadership framework to regulate the process on Teys' financial metrics, described below.

3.2.1 Test & learn model – Greenleaf program design

The Design, Test & Learn process is an iterative, design-led development process. Figure 4 summarises the process and manages the three work motivations in Figure 1.

Product Design Model – target processing plant, livestock type and market requirement variations. Bookends each design phase and helps set KPIs when component builds start. Underpins the success measures applied through each Design and Develop phase.

Test & Learn trials – build foundational capabilities that enable future-state automation, also achieving commercial deliverables in the short term.

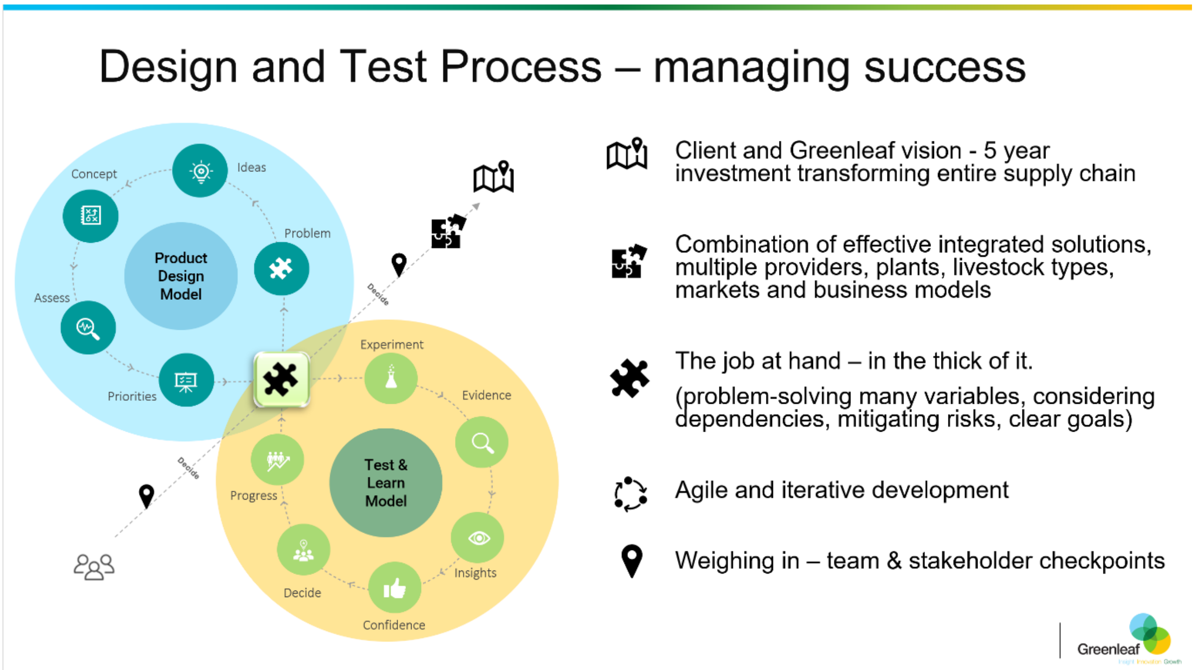

Figure 1: The Greenleaf Test & Learn Model

An iterative process like this needs a lot of effort. It should only be used when solving a difficult, valuable challenge. Beef automation is very much one of these challenges. A pathway is required that consolidates disparate but valid perspectives across industry. A two-stage process of diverging and converging (Product Design Model, and Test & Learn Model) turns over all options and possibilities for innovative approaches. Before focusing on one method of value creation, this process may go through many repetitions, or iterations.

This two-stage process is described in Figure 2. The first defines “Where to play”, identifying the opportunity spaces that could create the greatest value. Then in the second stage, the testing of prototypes that help define “How to win” and test whether the design hypothesis is viable through a range of experiments.

Outputs from experiments either give confidence to proceed with more detailed design, or based on quick failures, identify new problems, ideas and concepts around how to solve them and prioritise the next set of priorities to go and test. There should also be some flexibility for ideation and pivoting during each set of experiments as required.

An unknown design presents the challenge of budgeting for an unknown timeline. It needs to explore and uncover all major challenges and find viable ways to overcome all of them, which requires multi-faceted approaches, repeated failures and finding insight in failure. This is the key difference between:

- operational excellence mindsets, focused on efficient time to implementation.
- design led innovation mindsets, focused on uncovering many risks and a design to overcome

3.3 Program management

3.3.1 Motivations for success

Sound principles have driven success and will maintain progress toward the long-term vision. They maintain design scoping, contracting, project developments, unknown risks and deliverables.

Three key work motivations managed the beef automation strategy and its program of work. These are summarised in Figure 2 and underpinned by a commercial focus applied to all activities.

Motivation A – overarching leadership of the program-by-program host(s). This oversight guards the design process and principles which are followed for success. Processes are put in place to lead and manage the program. Motivation A will be influenced by the organisational mindsets leading the program.

Motivation B – value propositions per automation and performance target. Considers the value propositions for each automation capability and performance targets across variables to achieve a commercial outcome. This discipline prioritises development of components based on the likelihood and value it could deliver.

Motivation C – use cases. Considers the environment of system operation, plant configurations, and broader industry drivers that will impact commercial success.

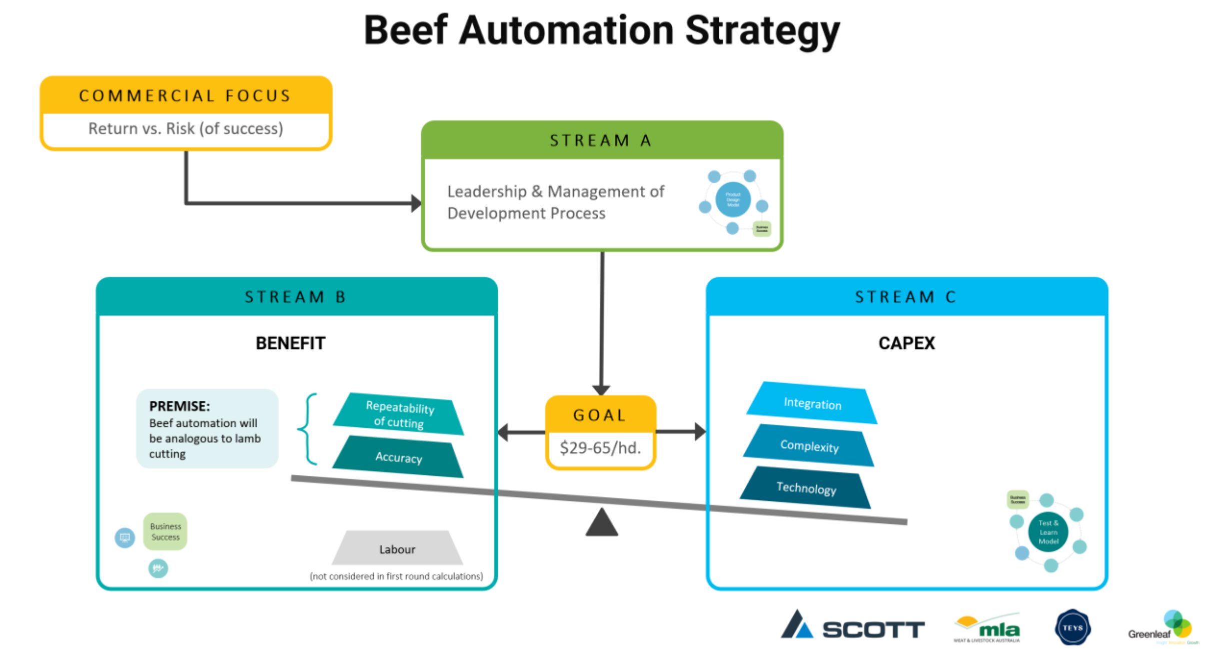

Figure 2: Interaction between the three work motivations driving the value proposition for each investment pathway

3.3.2 Commercial focus

Each module to be developed was presented according to its potential to demonstrate benefit and achieve commercial Key Performance Indicators (KPI's), prior to development. These KPI's addressed a range of criteria including risk mitigation, economic reward, critical path and development timeline prior to being designed and developed. Figure 3 provides an example of the value proposition scoping that underpinned each project design phase and assessment and revision of the subsequent mid-project performance results.

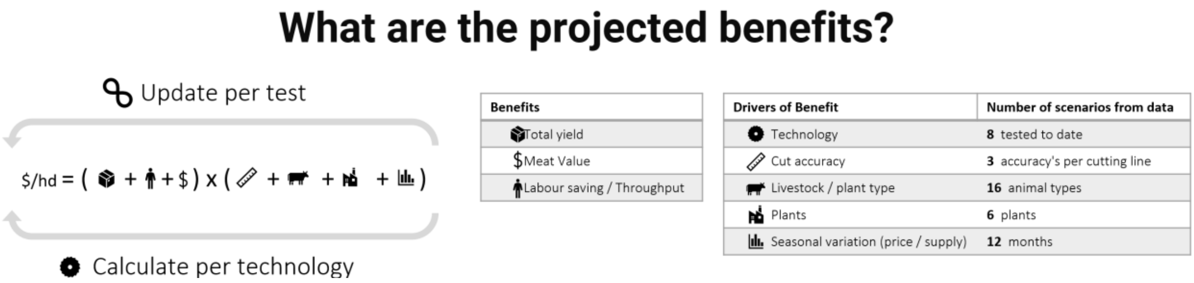

Figure 3: (Concept) Commercial metrics for design criteria and development risk management

A multi-variable assessment methodology (Figure 3) was adopted to prioritise investment for risk reduction of a final commercial system.

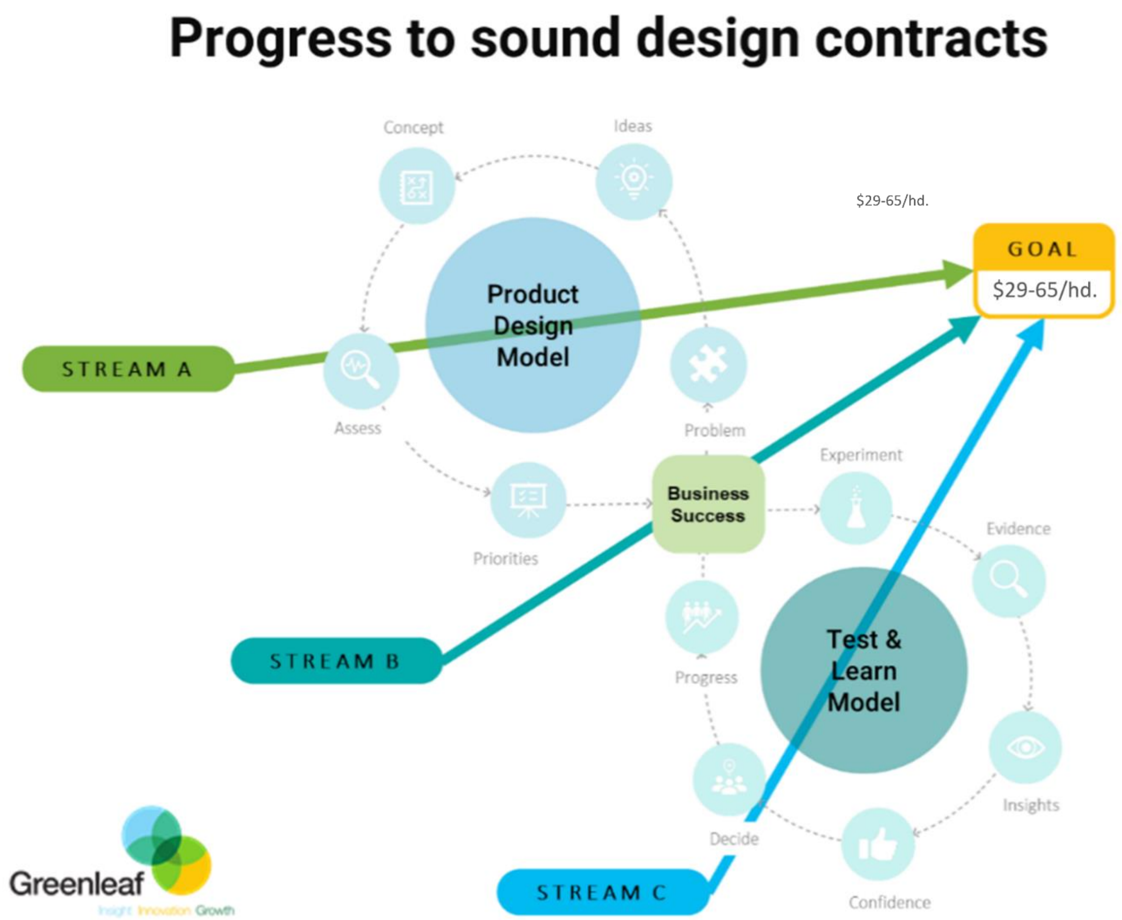

Figure 4: Test & Learn – Iterative development process

A clear set of targeted outcomes are agreed for each stream pathway, which refers back to commercial deliverables but maintains the flexibility of the design process. This flexibility is to generate many different ideas, keeping within the structure of the process. This structure is necessary to design, test, and learn and pivot, acknowledging unidentified unknowns and pursuing multiple approaches to a solution. It uses the following process in Figure 4:

a. problem definition,
b. generating ideas,
c. developing reasonable concepts,
d. assessing them for likelihood, and
e. prioritising them, which leads into
f. experimentation,
g. to validate by the evidence produced in the experiments, from which
h. insights into the problem and how the solution mis/matches it, which then give
i. confidence as to the solution's effectiveness, where we decide between solutions and
j. give the go-ahead to progress.

Or alternatively where evidence does not give confidence to proceed, repeat the process based on new problem definitions.

4 Findings and Results

4.1 Using the test & learn method

The process and principles of the test & learn method must be adhered to and guarded, particularly in the exploratory stages of a project. A number of possible design pathways were developed that needed to be tested during the project. The intention was to prioritise these, and through experimentation, narrow down the possible design pathways to those that provided the best results. Figure 5 visualises a partial adherence to the process.

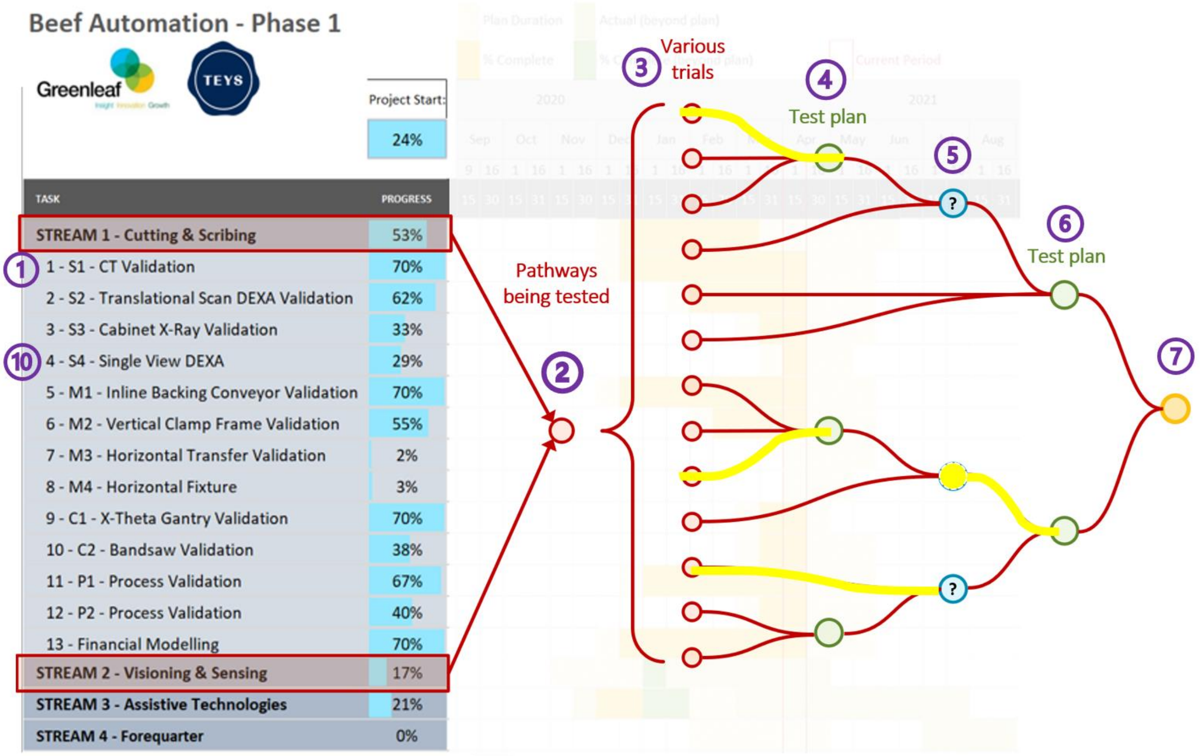

Figure 5: Visualizing Test & Learn Breakdown

The tests to be undertaken for Stream 1 are listed next to point 1 in the figure. Each test experiment is depicted in point 3 through 6 to explore the design possibilities and determine the best ways to overcome identified challenges and achieve the best design solution at point 7. To satisfy contract timeline drivers, a likely pathway visualised in Figure 5was chosen while ignoring the others points.

Point 2 of

①

②

Figure 6 reports that accelerating R&D by this method ignores potentially valuable options. When chosen, the test & learn process was further shortened by concentrating assumptions about the pathway into a summary statement in point 1 of

Figure 6.

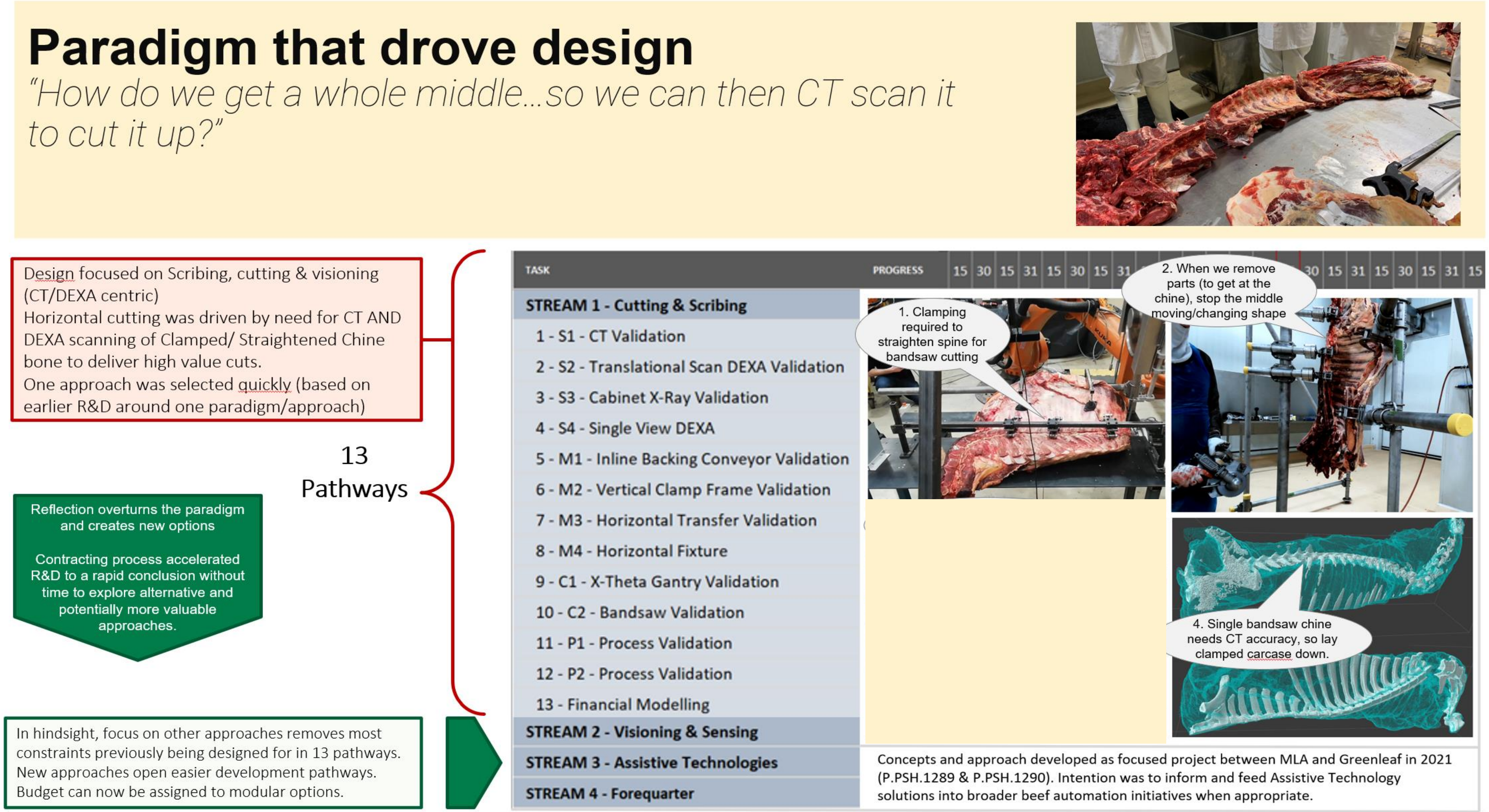

Figure 6: Test & Learn iterating through the CT scan paradigm

4.2 Development dependencies constrain useful iteration

Each part of the equipment used in an automation module is closely connected. One part's function determines what is required of each other part, and so decisions have impacts beyond the design problem being posed. Materials handling development demonstrated this. Care should be taken that decisions for an element like CT-scanning do not have a one-way impact on other decisions.

The program pre-projects found the highest value in the side components in Figure 7. This broken down side would be simple to chine with a robot-driven bandsaw, driven by a CT scan. But the brisket, flank, ribcage, leg and shoulder would need to come off first. So, with the goal of achieving bandsaw chining eventually, these components with the lower value would be developed first. This was an unnecessary constraint, since other methods of chining, as in Figure 9, had not been tested through the test & learn iterative process before narrowing down on the bandsaw.

Figure 7: Beef side 'Middle' - Pre-program conclusions

It was found that the spine was stiff, and its curvature, shown in Figure 8, made bandsaw cutting difficult. The process to develop spine straightening and clamping before scanning was lengthy and detailed. This was only necessary because bandsaw chining, enabled by CT-scanning, was pursued. Figure 10 also demonstrates the impact a material handling system could have on CT-scan data. Materials handling clamps passing through the CT scanner produced artifacts and poor image quality, yet took a long time to trial and design, all under tight contract deadlines. The straightened spine was entirely for the benefit of the bandsaw.

Figure 8: Beef side spine curvature (left) and twist (right)

4.3 Expertise creates blind-spots in the iterative process

Scott has great expertise in cutting methods. This was demonstrated through this project's development. This followed the test & learn process in generating ideas, evaluation, experimentation and making the decision to proceed.

Scott also developed ideas in the field of cutting lines and the techniques to perform them. However, the test & learn process was cut short to bandsaw chining as discussed previously. Cutting techniques like Figure 9 were not tested, despite potentially negating the need for CT technology and spine straightening.

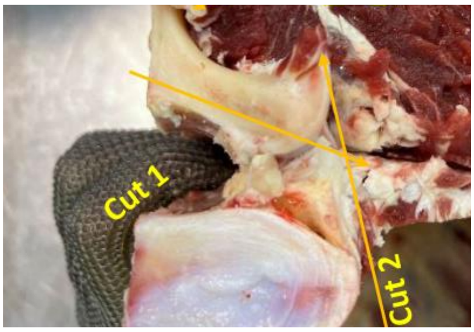

Figure 9: Alternate Chining Method, performed without spine straightening

4.4 Commercial deliverables require first-try-success

Teys and Scott had a contract which specified the date of system delivery, and what the system would achieve. This was a different mandate to the scope of the Teys-MLA contract and caused Scott to focus on development of one vision technology – CT-scanning. To meet their contract conditions, they attempted development to use it for all cuts. Seen in Figure 10, the chine bone remains clear with an aviation CT-scanning system, but the rib and meat definition are lost in the middle.

Figure 10: Sample scan image of prepared side + Aluminium beam and two plastic beams. From Milestone 13 Report

Alternate technologies were not developed to a point of confidence due to commercial obligations, and so the test & learn process broke down. There was no comparison of CT with other potential solutions until late in the program. Had more time been allowed, this pivot would have enabled a potentially more effective development pathway.

4.5 Deviation from original contract intent

The original contract specified development of a modular system. But the breakdown of the iterative, test & learn process in vision and scanning development meant CT-scanning was to be the cornerstone technology of the final system. To support the use of this technology as the only vision system for all cuts until all 12 lines were complete, a single, fixed-side system was pursued. Scanning as much of the carcase with a CT-scan required a materials handling system to hold the side without its shape changing during transfer and cutting. This need departed the system from a modular design to a single, fixed-side system. Future modules would need to operate through this fixed-side method, or occur separately, after the system had finished processing.

4.6 Findings

4.6.1 Motivations for success

Motivation A – overarching leadership of the program by Teys, MLA and Industry. This oversight ensured design principles were followed for success through the initial stages of the program. As discussed through this report, processors' priorities for development and delivery of a system are not intended to support R&D. This is shown through the rushed introduction of commercial deliverables leading to the development process breaking down.

Motivation B – value propositions per automation and performance target. Middle and loin cutting, as part of 'middle' cutting, deliver 84 % of total benefit. The program has prioritised these cuts to capture the value. However, bandsaw chining requires that the leg, shoulder, brisket, rib cage and flank comes off the carcase first. The program chose to develop modules in the order of operation, automating the boning room in order from marshalling to packing. Because of this, although the middle cutting was 'prioritised' it would be developed last.

Another option was to manually perform the other cuts, then feed the broken downside into the automated chining and loin cutting modules to prioritise that development. Still another option was to test if another cutting method could change the order the cuts would need to be performed in, to perform loin and chine cutting earlier in the process.

Motivation C – broader industry integration considerations. Due to commercial installation pressures in contracting, ROI was calculated and presented for the Teys Rockhampton installation. This supported the programs Internal Rate of Return targets but did detract from considering integration with other plant sizes and configurations.

Reverting to a single system design did limit consideration of brown-field installations. A single system which requires a specific configuration or order of operations cannot be installed by processors who'd like to install part of the system or have an installation which is progressive or has a different order of operations.

4.6.2 Contract

The Teys-MLA contract was suitable for the purpose of this program. It was broad in definition, giving Teys the freedom needed to develop the system. Teys did initiate the need for a structured test & learn process to underpin this lose scope. This proceeded well during the early stages of the project. However, at the point where subcontracted work needed to narrow to final design the test and learn process shifted to a fixed timeline contract with a fixed throughput per hour, but was still unclear in the hurdles, learnigns and pivots that were still required.

By contrast, the Teys-Scott contract was detailed, specific on timelines, and included technical specifications for deliverables. These constraints are important, but when so much exploration is still undefined, fixed timeframes to deliver commercial prototypes limits design options. This restricted their freedom to design, develop and deliver.

Learnings from the Lamb Leap Automation journey show there were many iterations of the system concepts over a number of years before confidence and commercial traction was gained with industry. Teys and MLA were trying to acieve this same outcome in a much more compressed time frame in the subcontract with Scott Automation, which did not lend itself to proper exploration of alterantive development streams.To meet commercial timelines, the structured process was rushed.. The result was an imbalance in the technical developments across different disciplines and problem spaces. Given the enormity of the Beef automation development objectives that still needed to be considered, a more realistic timeframe on development that allowes for alternative and opposing solutions to be presented as evolving priorities (i.e. emerging commercial deliverables) is still required at this point in development. A structured approch to development of well defined component capability still allows strict contracting. Deliverables against component development, testing and assessment of commercial viability becomes very specific and enables the next stage of contracting and development to proceed, using the new knowledge gained from the previous work. The timeframe for commercial adoption becomes less defined, but the deliverables at each stage become much tighter and more specific.

The Teys-GLE contract was adequate to determine the responsibilities of project management, both to scope program direction and continue management. With such broad objectives as 'oversee the design process' and 'provide the business case analytics … and benefit cost analysis' there was room to be adapted to the progress of the program in general. But given the bulk of the investment was with Scott Technology, and their obligation to deliver tight financial metrics, there was limited ability to re-direct fixed contract deliverables.

4.6.3 Program value opportunity

The final output of this program was to achieve commercial installation with a benefit estimated at between $29 and 65/hd. Sensitivity analysis of market price fluctuations are accounted for within the program. Changes in pricing of secondary cuts impacts on the value delivered from cut accuracy, as does the combination of cutting specifications by market and carcase type. Return on investment is updated after each experiment, driving the design towards commercially viable options.

The progression of R&D towards successful commercial automation are expected to deliver the following benefits:

1. The middle in Figure 7 (of which the loin cutting, and middle are most significant) holds 84 % of the capturable value for automating beef cutting processes
2. The capturable value of beef automation is mostly found in driving accuracy improvements
3. Continually tightening labour availability make beef automation even more significant so assistive technologies for shoulder and hindquarter boning should be a key part of the future program of work

5 Future program recommendations

5.1 Contracts

Contracts need to direct iterative, agile development – Reinforces program managers encouraging broad thinking in technical staff/advisors. Achieves a complete enough view of the relevant technologies, systems and processes to support MLA's goal of a portfolio of technologies for continued R&D within the program that will (with further R&D) result in commercially viable solutions relevant to a wide enough section of industry.

Contracts need structured development methods – Methods need to be used consistently to prevent bypassing potentially beneficial ideas, accountable assessment of likelihood for success, or generating incomplete or untrue insights. The stage of progression through the method must be documented. It is possible that a person with multiple project roles may confuse where different capabilities are in the test & learn figure-8 (e.g., vision at the ideas stage, but cutting at the experiment stage) and make wrong decisions by brushing over important insights.

Contracts need to follow the model of the Teys-MLA contract – For an R&D program, this requires a clear statement of intent, not outcome. It must consider commercial drivers, industry adoption, general production parameters (e.g. the beef side 12 cutting lines), and other enablers or considerations (e.g. handling and sortation where it delivers a direct benefit). If there are clear activities that support the intent of the program, these need to be required of the contractor (e.g., establish a BBA R&D room for Phase 1 and for subsequent phases).

Do not engage service providers in fixed time, fixed deliverable agreements – at least in the early stages of R&D where too many unknowns get missed to meet the contract. When engaging service providers, their effectiveness and output should be managed by a method other than a whole-of-project deadline. Short-term contracts with short-term deadlines could manage development in an iterative cycle and support contract variations with a smaller decision impact. This delivers and enforces short-term progress without stifling the long-term flexibility of the test & learn model.

Commercial-ready contracting stifles early design iterations – Scott Automation were capable in design, and their methods of addressing technical details were effective. However, their contract with Teys was delivery of a commercially installed system. The contract delivering Part 2 of the automation program was due 12 months after preliminary R&D (a short timeframe for an R&D program). The first design concepts required first-try-success to meet the timeline. It was feasible but did not allow for unforeseen challenges that arose, all of which were surmountable. It led to unhelpful design constraints and a tunnel-visioned technical focus from the outset. Other more superior approaches were identified late in the program and by external parties but ignored due to tight timelines. A more iterative contracting process with shorter timeframes, allowance for pivoting after each deliverable, and integration of other external design approaches will enable the learnings to date in the program to build into a very effective set of modular beef automation solutions.

Multiple and conflicting design approaches stimulate innovation – having multiple service providers working independently on similar problems challenges group think. Doing this in a way that enables the sharing of learnings across service providers towards the first of a 2+ stage project can uncover creative solutions that none of the providers imagined. The program is still at a base level of understanding that would benefit from this level of creative exploration.

5.2 Program management

Steering committee should not expect processor leadership to be effective – (at least while initial concepts are being tested). The Leap4Beef program should have processor input around technical, operational and commercial requirements but be managed by MLA and project management providers. There should be consultative input from industry, and design input from service providers. This controls the introduction of commercial priorities. There should be many service providers engaged to complete work on each part of the system separately. This promotes the introduction of new ideas and reduces the risk of the program being restricted to one company's paradigm of development. It may also introduce new players to be industry service providers, promoting healthy market competition.

To iterate the importance of industry input (not program leadership) – Service providers should not be left to design and develop without a robust level of industry technical input in defining the processors operational constraints. Many times, in this program, technical knowledge and constraints have had to be driven very firmly in conflict with designers to adjust their paradigms that would have otherwise produced very smart designs, but less than acceptable outcomes.

The current development method and set of motivations is effective - The program should use the test & learn method. Its effectiveness to progress development systematically and develop a broad range of capabilities is necessary for the program's success. Its connection of commercial and practical environments with technical requirements prevents developing a fantastic system with no end user. Contracts can be pursued with multiple service providers to find a solution independently of each other, and those solutions can be brought under the umbrella of the program for comparison and assessment.

Program managers must be invested in the logic of technical development decisions – Technical team members cannot have carte blanche to pursue or ignore development pathways, particularly where they do not have expertise in all the solution areas their decisions impact. For example, deciding to pursue brisket scribing with scissors but ignoring reciprocating saws. Program managers must be included in these decisions and determine what is worthwhile.

Program managers must understand the timing of the introduction of stakeholders, processes and other elements – If these elements are introduced too early, development is stifled by increased numbers of opinions, consideration of irrelevant factors, and potentially premature go/no-go decisions. Industry adoption needs to be revisited during the design stage. This will require input from a wider group of companies. In turn, this will require structure and a method for engaging processors in the next stages of the program for more industry adoption focus and less plant install focus.

5.3 System design

A modular system is needed – Many processors will install some, but not all system modules and nearly all requiring integration to brown-field sites.

Early development must consider a balanced development of all technology capabilities – Technical capabilities should be developed evenly within disciplines (e.g. vision systems: camera vs. CT) and between disciplines (e.g., vision systems vs. cutting systems) to compare immature with immature and mature with mature capabilities. These findings will all have an impact and contribution when integrated in later stages.

System design needs to be informed by technical possibility - System design should take place after and concurrently with technical development, to prevent early work (on dependent systems) being lost when antecedent technologies mature to be unusable. The program should refocus on a modular system design. The principle was good, and much of the learnings from this program will feed directly into such an approach. As with any strict process, test & learn processes can be applied sensibly. As a project progresses the test & learn method shifts from technologies to module configurations. The ongoing work builds on the process that was followed early on. Ideas have already been scoped repeatedly and insights have been validated.

5.4 Technical development

The solution needs to begin by addressing primal and whole-of-side cutting lines - The current program contract found which of the 12 cutting lines gave the highest value. This value should be reiterated to drive development priorities. This will allow secondary cuts to be addressed in a future program once these significant cuts are functionally automated. Note that this program should not be a repetition of the lamb LEAP program – some processors have said it this way, 'you cut lamb, you bone beef'.

"You cut lamb. You don't cut beef, you bone beef."

When Teys asked for project tenders from the international market, the lack of response from companies which have automated chicken and pork in particular indicated that beef automation is new and challenging. Therefore, the initial focus on cutting lines needs to be careful and well considered.

High-value, low risk cutting lines need to be prioritised in development order - Error! Reference s ource not found., point 3 recommends beginning with the Loin & Chine specifically. It also recommends that existing, proven technologies are expected to be functional, which lowers the risk of their development.

Program delivery needs well-rounded, broad-reaching technical development - The program should investigate a broad range of technologies, processes, and synergies. This not only ensures a complete survey of possible solutions, but also serves to streamline future research by eliminating impractical or ineffective solutions, presented as a portfolio. Existing, proven (for industry application) technologies should be favoured to avoid protracted development, but there is no reason to restrict technologies which have not been proven in our industry if they can be tested quickly and repeatably. As difficulty arises, the test & learn model would complete scoping of the difficulties and begin testing of alternate methods. This would have allowed feedback between cutting techniques, vision techniques and handling techniques for assessment of the whole solution.

Self-diagnostic questions are needed – Differences of opinion, or variations from the expected process, rather than driving and stifling development, are a good opportunity to check the pulse, and ask questions:

- Have we rushed parts of the development methodology, OR overlooked design options due to our paradigms?
- What is the purpose of this prototype? Why is it different from previous prototypes?
- Do we have a plan to address *wide-spread adoption*? When will we address it?
- Do we have a time planned into this program to improve *efficiency* of the system?

Cobotics provides a high-value solution to boning labour issues – Cobotic solutions can be implemented with reduced visioning requirements and different expertise to automation. Therefore, they may be developed with a quicker timeline than full automation, may solve issues which automation does not have the fidelity for, and may be developed in parallel with automation which spreads risk and increases richness of the technical teams and problem-solving input.

5.5 Technical knowledge

Add to the portfolio of knowledge developed by the program to-date - The technical knowledge developed in this program will continue to be useful. It does not need to be rehashed except where documentation is lacking. Cutting methods has developed into a significant body of work, but application of those cutting methods on various cuts may still need to be explored, as an example.

As outcomes of the Teys-Scott contract, we have gathered new understanding of:

- Carcase movement (post-cut, carcase transfer, clamping, horizontal vs. vertical)
- Carcase characteristics (spine stiffness and shape, physical dimensions and variation)
- Cutting methods (blade types, shapes, motion)
- Visioning (CT-scanning, colour-based marking)
- Breakdown process

The program needs to safeguard these learnings and build on them.

Note that a large amount of technical detail has been documented in milestone reports and progress documents during the project and will be useful in support the next stages of development.

CT technology needs to be developed last in visioning – Its data quality is outweighed by its associated design challenges. As a technology, it has been developed extensively through the program to-date without the ability to deliver commercially. Other technologies and automation approaches using those technologies can achieve similar or better (lower cost/better ROI) results. These whole of solution design approaches should be tested to determine if they have less rigorous challenges for system integration.

5.6 Benefits to industry

Return on Investment is less than 3 years - This program can provide a processor $29/head benefit, up to $65/head. The specific benefit per head is plant dependent, and dependent upon the cost of install, so any further detail requires a tailored analysis. The challenges still to be solved are in identifying and delivering the best designs to extract that value.

6 Conclusions

As the program continues, it needs to use the methods intended in the original Teys-MLA contract, with changes in stakeholder management, a more structured approach to the test & learn process that is not rushed through tight delivery timeframes that have undefined challenges, and a return to modular system design.

The program to-date has delivered highly useful, specialised expertise in some capabilities, and the program going forward should complement that expertise with many concurrent service providers such as assistive technology for shadow boning. Next stages of work should consolidate the learnings to date and priorities development of some needed capabilities with a modular approach.

Program management should continue by MLA in collaboration with AMPC and with the input of a number of processors and service provider. It is recommended that a dedicated project management service provider manage the groups of service providers and present the results of their development to the steering group. The key requirement of this oversight is the consolidation of learning and positive challenge of approaches from multiple service providers with different or complementary capabilities towards commercial solutions.

An effective program will deliver at least $ 29/hd and up to $65/hd depending on plant and market configurations.

7 Table of Figures