Australian Government
Department of Agriculture, Fisheries and Forestry

Rural R&D for Profit Program 18-04-019

Developing and Commercialising Advanced Measurement Technologies and Feedback Systems into Globally Competitive Australian Meat Value Chains (ALMTech II)

Final Report

5 April 2023

Abstract

This final report of the ALMTech II project (July 2019—April 2023) concludes that it has either delivered or over-delivered on all but two of its scientific and industry outputs. The two outputs that were partially achieved are: 1) a first commercial prototype for identifying offal condemnation has yet to be deployed, despite significant progress with an operation prototype towards that goal; and 2) only one of the targeted two installations of a live animal 3D imaging system in a feedlot has been achieved.

The project has been consistent with the Rural Research & Development for Profit Program objective to realise significant productivity and profitability improvements for primary producers.

The project has been a collaboration driven by the Commonwealth's Department of Agriculture, Fisheries and Forestry (DAFF) and three Research & Development Corporations (RDCs)—Meat & Livestock Australia (MLA), the Australian Meat Processor Corporation (AMPC) and Australian Pork Limited (APL)—in partnership with commercial companies, State departments and universities.

ALMTech II focused on enhancing the Australian beef, lamb and pork industries' ability to respond to market demands and capture value-chain price differentials, via advanced objective measurements of red meat quality and quantity. In the Australian beef industry these price differentials represent an opportunity to capture an estimated $130 million per year from producers supplying cattle that better meet company and consumer requirements, with similar opportunities in lamb and pork. Advanced measurements and feedback will enhance the transparency of trading across the livestock value chain. By 2040, it is estimated that ALMTech (I & II) will have generated a net present value (NPV) of $858 million net benefits to the beef, lamb, and pork industries in Australia.

ALMTech II supported the development and commercialisation of technologies to provide beef, lamb and pork producers with advanced measurements of two key attributes that influence the value of livestock: lean meat yield (LMY) percentage and eating quality (EQ). Within abattoirs, these technologies needed to be adaptable to pre- or post-chill deployment, robust in an abattoir environment, and capable of operating at the processing fastest chain speeds. On-farm, objective measurement technology costs became more crucial given that farms generally cannot achieve the same "economy of scale" through-put available to abattoirs.

The first commercial Dual Energy X-ray Absorptiometry (DEXA) imaging systems have been installed, calibrated, and monitored in six lamb abattoirs and one beef abattoir. Commercial prototypes for a 3D cattle imaging camera, a hand-held microwave fat depth scanner for both live and carcase lamb and beef, and a Frontmatec beef rib-eye grading camera have been developed and deployed. Furthermore, the PorkScan Mk2 carcase imaging system has been installed and calibrated in two commercial pork abattoirs.

ALMTech's Industry Calibration Working Group (ICWG) has facilitated industry's calibration and adoption of new technologies and traits by defining their measurement methodologies, error tolerances, accreditation processes and auditing systems for the Australian Meat Industry Language and Standards Committee (AMILSC). The ICWG introduced three new traits for the lamb and beef industries to trade upon, each of which has been endorsed by the AMILSC and are now included in the AUS-MEAT language: lamb carcase lean, fat, and bone percentage based on computed tomography as the reference standard; lamb chemical intramuscular fat percentage (IMF%), and beef IMF%.

Introduction of the new lamb chemical IMF% trait notably resulted in an ALMTech II collaborator, Gundagai Meat Processors (GMP), launching a world-first lamb pricing grid, which pays producers a premium for LMY and IMF% while providing feedback on animal health at an individual carcase level. This was also a first in terms of providing a commercial signal back to producers that balanced the two genetically antagonistic traits of LMY and EQ, through DEXA and IMF% measurement.

The project has liaised with supply chains to integrate device outputs into industry decision-making systems and to create new and enhanced genetic tools (e.g. Estimated Breeding Values and Indexes) to select for LMY% and EQ. ALMTech II also delivered tools to enable processors to better define the true market value of carcases by optimising market-specific carcase allocation, based upon predicted cut weights prior to carcase fabrication. This has been done via development of a Beef Value Calculator (BVC), a Lamb Value Calculator (LVC) and a Carcase Optimisation Tool (COT).

At this project close-out, it is appropriate to focus on adoption gaps to ensure the project's legacy is maximised. We foresee the need for ongoing industry support. In particular, we recommend the creation of an industry-supported collaborative group that would provide a coordinated experimental structure to support the ongoing development and accreditation of measurement technologies. This group would also support the AMILSC to continuously review the existing accreditation standards, providing evidence to update them when required and, most importantly, to support the broader industry to implement and make use of data stemming from the technologies that ALMTech I & II has supported. Without this support, it is possible that extensive adoption of enhanced measurement will be markedly delayed.

Executive Summary

This ALMTech II Final Report concludes that the project has either delivered or over-delivered on its scientific and industry outputs, with the exception of two outputs being partially delivered: The partially achieved outputs are: 1) a first commercial prototype for identifying offal condemnation has yet to be deployed, despite significant progress with an operation prototype towards that goal; and 2) only one of the targeted two installations of a live animal 3D imaging system in a feedlot has been achieved

Notable achievements across the life of ALMTech include:

- Supporting the installation, calibration, and monitoring of commercial dual energy x-ray absorptiometry (DEXA) systems in six lamb abattoirs and one beef abattoir, enabling the development and launch of the world-first value-based pricing grid for lamb by Gundagai Meat Processors.
- Introducing three new traits for the lamb and beef industries to trade upon, each of which has been endorsed by the Australian Meat Industry Language and Standards Committee (AMILSC) and are now included in the AUS-MEAT language; including proposed error tolerances, accreditation processes and auditing systems:
    - Lamb carcase lean, fat, and bone% based on computed tomography as the reference standard;
    - Lamb intramuscular fat percentage (IMF%); and
    - Beef intramuscular fat percentage (IMF%).
- Introducing conversion equations for transforming beef IMF% into the equivalent visual marbling scores used by Meat Standards Australia (MSA) and AUS-MEAT, which have been endorsed by AMILSC, pending final acceptance by the MSA Pathways committee.
- Introducing a new set of accreditation standards for camera-based technologies to predict rib-eye traits such as Fat Colour, Meat Colour, Rib Fat Depth, Eye Muscle Area, and MSA and AUS-MEAT marble scores, including specification of error tolerances, the accreditation process, and the auditing system, which have been endorsed by AMILSC.
- Undertaking industry evaluation of the first commercial prototype of a hand-held microwave fat-depth scanner for lamb and beef in live animals and carcases, at a commercial beef feedlot, and Dardanup Butchering Company and WAMMCO, respectively.
- Installing and evaluating hardware for 3D imaging of live cattle at the Tullimba feedlot.
- Supporting the commercialisation and accreditation of the Frontmatec Q-FOM beef loin-eye grading camera, the first commercial deployment at a commercial abattoir. Three additional abattoirs have commenced pre-commercial trials.
- Supporting the installation and calibration of the PorkScan Mk2 carcase imaging system in two commercial pork abattoirs.
- Supporting the development and evaluation of novel and emerging devices employing different technologies for estimating EQ (especially IMF%), including the SOMA Optics S-7090 device, an Optical Coherence Tomography probe, the Trinamix portable Near Infra-Red device, and a nuclear magnetic resonance (NMR) scanner for both beef and sheep carcase IMF% measurement.
- Investigating the potential of the Rapiscan dual-view Multi-Energy X-ray Absorptiometer (MEXA) augmented with hyperspectral imaging for rapid, non-invasive, in-line detection and assessment of offal defects. This technology is showing promise for other propositions, such as grass- versus grain- meat authentication, though these propositions require further validation.

- Investigating the value of measuring eye muscle dimensions in lamb carcases and collating MSA data from lambs processed in the Meat & Livestock Australia (MLA) Resource Flock projects, pending full genetic analysis of these data.
- Supporting the development and refinement of a Beef Value Calculator (BVC), a Lamb Value Calculator (LVC) and Carcase Optimisation Tool (COT) to enable processors to define carcase value more accurately and optimise market-specific carcase use, based upon predicted cut weights before fabrication.
- Liaising with supply chains to integrate device outputs into commercial decision-making systems and to create new and enhanced genetic tools to select for LMY% and EQ.
- Publishing 18 peer-reviewed papers in a special edition of the prestigious international journal, *Meat Science* (2021). This, together with an additional 24 peer-reviewed publications in international journals and 41 peer-reviewed conference papers, demonstrates the world-class quality and recognition of the research conducted by the ALMTech program. The ALMTech team are currently compiling another suite of peer-reviewed papers for publication in another special edition of *Meat Science* (2023).
- Providing scientific presentations and extension of ALMTech research and development at national and international conferences, field days, industry workshops and training events.
- Providing technical support adoption and optimise the application of various objective measurement technologies across several beef and lamb supply chains.
- Providing career development and industry engagement for 2 early career scientists, 17 post-doctoral fellows, 6 doctor of veterinary medicine students, 8 PhD students, 2 Honours students and 10 research scientists/assistants, including several emerging and future research leaders.

Contents

Abbreviations

Acronym	Description
AAAS	Australian Association of Animal Sciences
ACBH	Australian Cattle and Beef Holdings Pty Ltd
ACC	Australian Country Choice
AGBU	Animal Genetics and Breeding Unit
ALC	Australian Lamb Company
AMILSC	Australian Meat Industry Language and Standards Committee
AMPC	Australian Meat Processor Corporation Ltd
APL	Australian Pork Limited
ASBV	Australian Sheep Breeding Value
BCR	Benefit Cost Ratio
BIN	Beef Information Nucleus
BVC	Beef Value Calculator
COT	Carcase Optimisation Tool ('Optimiser')
CRC	Co-operative Research Centre
CT	Computed Tomography
DPIRD	Department of Primary Industries and Regional Development
DAFF	Department of Agriculture, Water and the Environment
DJPR	Department of Jobs, Precincts and Regions Victoria (previously DEDJTR)
DEXA	Dual Energy X-Ray Absorptiometry
DPI NSW	Department of Primary Industry NSW
EC	Executive Committee
EMA	Eye Muscle Area
EQ	Eating Quality
ICWG	ALMTech Industry Calibration Working Group
IMF	Intramuscular Fat
IP	Intellectual Property
ISC	Integrity Systems Company
HSI	Hyperspectral Imaging
KPI	Key Performance Indicator
LDL	Livestock Data Link
LMY	Lean Meat Yield
LVC	Lamb Value Calculator
MDC	MLA Donor Company
MINTRAC	National Meat Industry Training Advisory Council Ltd
MLA	Meat & Livestock Australia Ltd
MSA	Meat Standards Australia
MU	Murdoch University
NCMC	Northern Cooperative Meat Company
NIR	Near-infrared
NPV	Net Present Value
OM	Objective Measurement
pHu	Ultimate pH
PRIPCC	Progress Review, Intellectual Property and Commercialisation Committee
R&D	Research and Development

ROI	Return On Investment
SARDI	South Australian Research and Development Institute
SC	Steering Committee
SAR	Scott Automation and Robotics
UAdel	University of Adelaide
UMelb	University of Melbourne
UTS	University of Technology Sydney
WAMMCO	Western Australian Meat Marketing Co-operative Ltd
WTP	Willingness To Pay

1 Introduction

1.1 Project rationale & objectives

The project's Activity Work Plan (**Appendix 7.0**) and Monitoring & Evaluation Plan (**Appendix 7.1**) highlight the project's research activities, in terms of scientific and industry outputs, along with a series of indicators of success (effectiveness, impact, appropriateness, efficiency and legacy). This final report evaluates the project's research activities and outputs in terms of these indicators.

As per the project's administrative structure (detailed in **Section 2.3**), this report was firstly developed by the project's Executive Committee, comprising the Program Leaders, which is chaired by ALMTech Chief Investigator, Professor Graham Gardner. It was then reviewed and edited by the project's Progress Review, Intellectual Property and Commercialisation Committee (PRIPCC), consisting of independent chairperson Alan Bell (Professor Emeritus of Animal Science, Cornell University) and independent technical expert Professor John Thompson, along with representatives from MLA, AMPC, and APL. Finally, this report was reviewed and edited by the project's Steering Committee, chaired by Richard Apps (MLA), consisting of representatives from AMPC, APL and key industry stakeholders including three independent producers and three representatives of the meat processing sector (one from JBS, one from WAMMCO and one from Woolworths). The inclusion of both livestock producer and processor representatives provided oversight and guidance on priorities along the value chains.

1.2 Project background

The inaugural 4-year project, ALMTech I (June 2016—July 2020), generated enormous momentum for objective carcase measurement by supporting development of new technologies for measuring LMY% and EQ traits. Key collaborators included 22 Australian industry bodies and 18 research provider organisations, plus 10 international technology providers / research organisations.

DAFF accepted the ALMTech I Final Report and commended the project for achieving all of its scientific and industry outputs. The full report is available at the following website: www.mla.com.au/research-and-development/reports/2020/grant-agreement-rnd4profit-15-02-031-advanced-measurement-technologies-for-globally-competitive-australian-meat-value-chains/.

Technologies measuring LMY% were developed for use on-farm as well as within abattoirs. On-farm devices for live animals included 3D imaging cameras for cattle and microwave back-fat scanners for cattle and sheep. In abattoirs, the technologies for measuring carcase LMY% and fatness included a 3D imaging camera for beef, a microwave fat-depth scanner for lamb and beef, and the PorkScan-Plus system. A cornerstone of ALMTech I was supporting the calibration and installation of DEXA systems in two commercial lamb abattoirs and one commercial beef abattoir to predict carcase LMY%. Support for these devices and installations in a further three commercial lamb abattoirs has continued in ALMTech II.

ALMTech I also supported the development of a suite of technologies for predicting EQ traits in beef and lamb carcases, including loin eye cameras that required a cut surface, and probe and nuclear magnetic resonance technologies that did not require a cut surface. The probe technologies included two intramuscular needle-probe designs using differing applications of

spectral imaging to measure hot or cold carcase IMF% in both lamb and beef. Six loin-eye cut surface technologies were investigated: the Frontmatec Q-FOM, E+V, Meat Imaging Japan and TenderSpec. The E+V camera was successfully installed in one beef abattoir and, under Teys leadership, achieved AUS-MEAT accreditation. The Frontmatec Q-FOM camera was successfully calibrated, progressed to manufacture, and continued in ALMTech II with Meat Standards Australia (MSA) and AUS-MEAT accreditation and commercialisation.

ALMTech I investigated the potential of the Rapiscan dual-view multi-energy x-ray absorptiometer (MEXA) augmented with hyperspectral imaging, and the Rapiscan RTT110 CT scanner, for rapid, non-invasive, in-line measurement of carcase composition and offal condemnation assessment under commercial conditions. This has progressed in ALMTech II to a pre-commercial prototype ready for testing with collaborating supply chains.

The project team worked closely with supply chain partners to integrate the data made available from ALMTech I's new technologies into MLA's Livestock Data Link online feedback system and other proprietary systems owned by individual processors. This included linkage to genetic databases and the development of new and enhanced genetic tools to select for LMY% and EQ traits on-farm. The project also ensured the compatibility of all devices with the MSA EQ prediction system, in part by developing uniform accreditation protocols. ALMTech I developed data-to-decision packages to help industry use data from the new technologies. A Lamb Value Calculator (LVC) tool was enhanced, while a Beef Value Calculator (BVC), and Carcase Optimisation Tool (COT) were developed to enable processors to define the true value of carcases and to optimise market-specific carcase use, based upon predicted cut weights prior to carcase fabrication. These carcase value calculators are publicly available at the following website: www.mla.com.au/extension-training-and-tools/creative-commons-licenses/.

ALMTech I established the Industry Calibration Working Group (ICWG), which produced the ICWG Traits Manual to document trait definitions, and the methods and technologies for their measurement. The ICWG's major achievements were the development of new accuracy and accreditation standards, endorsed by the Australian Meat Industry Language & Standards Committee (AMILSC), for AUS-MEAT accreditation of cut surface cameras.

An economic analysis reported that ALMTech I generated a discounted Net Present Value of $383 million and an estimated Benefit-Cost Ratio of 4:1.

Given this success, DAFF invited the project team to submit a re-bid to extend funding of the ALMTech project. This application was successful, and henceforth the 4-year ALMTech II project (July 2019—April 2023) was structured to support the full commercialisation of technologies supported and developed in ALMTech I.

ALMTech II attracted even greater industry commitment than ALMTech I—in terms of number and breadth of partners, and both in-kind and cash contributions—including several new commercial participants from the feedlot, processing, and retail sectors, illustrating ALMTech's alignment with stakeholder needs. Additionally, the relevant industry Peak Industry Councils have positively engaged with and supported the project.

2 Methodology

The project was divided among a series of sub-programs, described in **Section 2.1** below, which also became a key part of our governance, described in **Section 2.3**. Activities and outputs, described in **Section 2.2**, were assigned to each of these sub-programs and formed the basis of the subsequent Key Performance Indicators (KPIs) developed at the project's Annual Review each financial year.

2.1 Programs

ALMTech II had the following programs / sub-programs, similar to the structure of ALMTech I:

- **Program Executive**
  - **E.1**: Undertake project initiation, project planning and management
  - **E.2**: Undertake communication and extension activities
  - **E.3**: Undertake industry liaison and value estimation
  - **E.4**: Undertake monitoring and evaluation, including general management of technology calibration
- **Program 1**: Develop lean meat yield (LMY) measurement technologies, both on farm and in the abattoir
  - **1.1**: Develop live measurement of lean meat yield (LMY)
  - **1.2**: Develop carcase measurement of LMY (direct)
  - **1.3**: Develop carcase measurement of LMY (indirect)
- **Program 2**: Develop eating quality (EQ) measurement technologies in the abattoir
  - **2.1**: Commercialise two technologies for grading eating quality in beef carcases and two technologies for grading eating quality in lamb carcases
  - **2.2**: Develop and validate new eating quality (EQ) technologies
- **Program 3**: Align these technologies with automation
  - **3.1**: Develop a commercially deployable automated solution for measuring offal condemnation
- **Program 4**: Enhance producer feedback systems and genetic tools using new measurements from these technologies
  - **4.1**: Develop data flow to industry information delivery systems
  - **4.2**: Develop data flow to industry genetic evaluation systems
- **Program 5**: Align data into decision systems to enhance profitability
  - **5.1**: Enhance carcase value tools
  - **5.2**: Enhance data decision tools
  - **5.3**: Enhance supply chain engagement

2.2 Activities & outputs

ALMTech II had the following activities and outputs, as per the Activity Work Plan (**Appendix 7.0**). The scientific (**S**) and industry (**I**) outputs have been cross-referenced to the project's research activities. Refer to **Sections 3.1 and 3.2** for further details on these scientific and industry outputs.

Activity 1 – Undertake project initiation

Activity 2 – Undertake project planning and management

Activity 3 – Undertake communication and extension, including industry liaison and value estimation

S(ix)	Work strategically with international partners to publish and collaboratively expand this research creating a sustainable base to continually refine and update the objective technologies and enhance grading credibility.
S(x)	Develop early career (Post-Doctoral fellows) and trainee scientists (PhD/Masters) to leave a legacy of scientific and technical capacity into the future.
S(xi)	Produce 15 refereed publications in international scientific journals to internationally underpin the integrity and acceptability of the key scientific and industry objectives and outputs.

Activity 4 – Undertake monitoring and evaluation, including general management of technology calibration

I(v)	Produce standardised calibration systems that are internationally recognised to underpin the integrity of the new objective carcase measurement technologies, to be adopted by 2023.

Activity 5.1.1 – Develop live measurement of lean meat yield (LMY)

S(i)	Support the commercialisation of a live animal 3D imaging system for measuring lean meat yield through installation into two commercial beef feedlots.
S(vii)	Develop at least two new measurement technologies for lean meat yield to be deployed either in abattoirs or on-farm. Technologies may include 3D imaging coupled with hyperspectral tissue depth measurements, microwave fat depth, and rapid computerised tomography systems.
I(i)	Develop reliable technologies operating within feedlots, or mobile units for use in the seedstock sector for assessment of carcase LMY, to be commercialised by 2023.

Activity 5.1.2 – Develop carcase measurement of LMY (direct)

S(ii)	Support the commercialisation of DEXA systems for measuring LMY through installation into five lamb abattoirs, and one beef abattoir. This may also provide the capacity for directing future automated deboning in beef and enhance current systems in lamb.
I(ii)	Develop reliable technologies operating at line speed for assessment of carcase LMY, to be fully commercialised and implemented within the processing industry by 2023.

Activity 5.1.3 – Develop carcase measurement of LMY (indirect)

S(iii)	Support the commercialisation of the PorkScan-Plus imaging system for measuring LMY through installation into two commercial pork abattoirs.
S(vii)	Develop at least two new measurement technologies for LMY to be deployed either in abattoirs or on-farm. Technologies may include 3D imaging coupled with hyperspectral tissue depth measurements, microwave fat depth, and rapid computerized tomography systems.
I(ii)	Develop reliable technologies operating at line speed for assessment of carcase LMY, to be fully commercialised and implemented within the processing industry by 2023.

Activity 5.2.1 – Commercialise two technologies for grading eating quality (EQ) in beef carcases and two technologies for grading EQ in lamb carcases

S(iv)	Support the commercialisation of cameras for measuring factors affecting EQ (i.e. intramuscular fat, pH, colour) through installation into two lamb abattoirs and two beef abattoirs.

I(iii)	Develop reliable technologies operating at line speed for assessment of carcase EQ attributes, to be fully commercialised and implemented within the processing industry by 2023.

Activity 5.2.2 – Develop and validate new EQ technologies

S(vi)	Develop at least two new measurement technologies for factors affecting EQ (i.e. intramuscular fat, pH, colour) including near infra-red spectroscopy, computerized tomography and hyperspectral imaging.
I(iii)	Develop reliable technologies operating at line speed for assessment of carcase EQ attributes, to be fully commercialised and implemented within the processing industry by 2023.

Activity 5.3 – Develop a commercially-deployable automated solution for measuring offal condemnation

S(v)	Support the development of a commercially deployable automated solution for assessment of offal condemnation and other carcase defects. The prototype would provide key diagnostics prior to manufacture for individual carcase fabrication and marketing options.
I(iv)	Deploy first commercial prototype equipment for identifying offal condemnation by 2023.

Activity 5.4.1 – Develop data flow to industry information delivery systems

I(vii)	Analyse impediments to feedback and data flow and deploy solutions to ensure enhanced feedback to producers.

Activity 5.4.2 – Develop data flow to industry genetic evaluation systems

I(viii)	Develop and implement three new or improved genetic products or tools that are clearly focused on Value Based Pricing (VBP) for beef, lamb or pork.

Activity 5.5.1 – Enhance carcase value tools

S(viii)	Deploy algorithms within two abattoirs that translate the carcase/meat quality measurements into VBP (a combination of lean meat yield and eating quality) and novel pricing mechanisms up and down the supply chain.

Activity 5.5.2 – Enhance data decision tools

I(vi)	Link objective carcase measurement with data capture, storage, dissemination and management systems for use up- and down-stream within the value chains to maximise communication and profit and be implemented by the 10 value chain partners.

Activity 5.5.3 – Enhance supply chain efficiency and engagement

I(ix)	Deploy software systems to optimise sorting of raw materials to best meet customer specifications for finished products that utilise yield and eating quality data generated for carcases and primal cuts, thereby capturing productivity and profitability benefits.

2.3 Governance & contracting

The project was administered via the following structure:

1. The **Executive Committee (EC)** comprised of the Program Leaders and was chaired by ALMTech Chief Investigator, Professor Graham Gardner. The EC met monthly to discuss the progress of each program and general project operational matters while undertaking extension activities and developing newsletters, publications, and quarterly reports (for the PRIPCC and the Steering Committee) and performance reports (for DAFF).

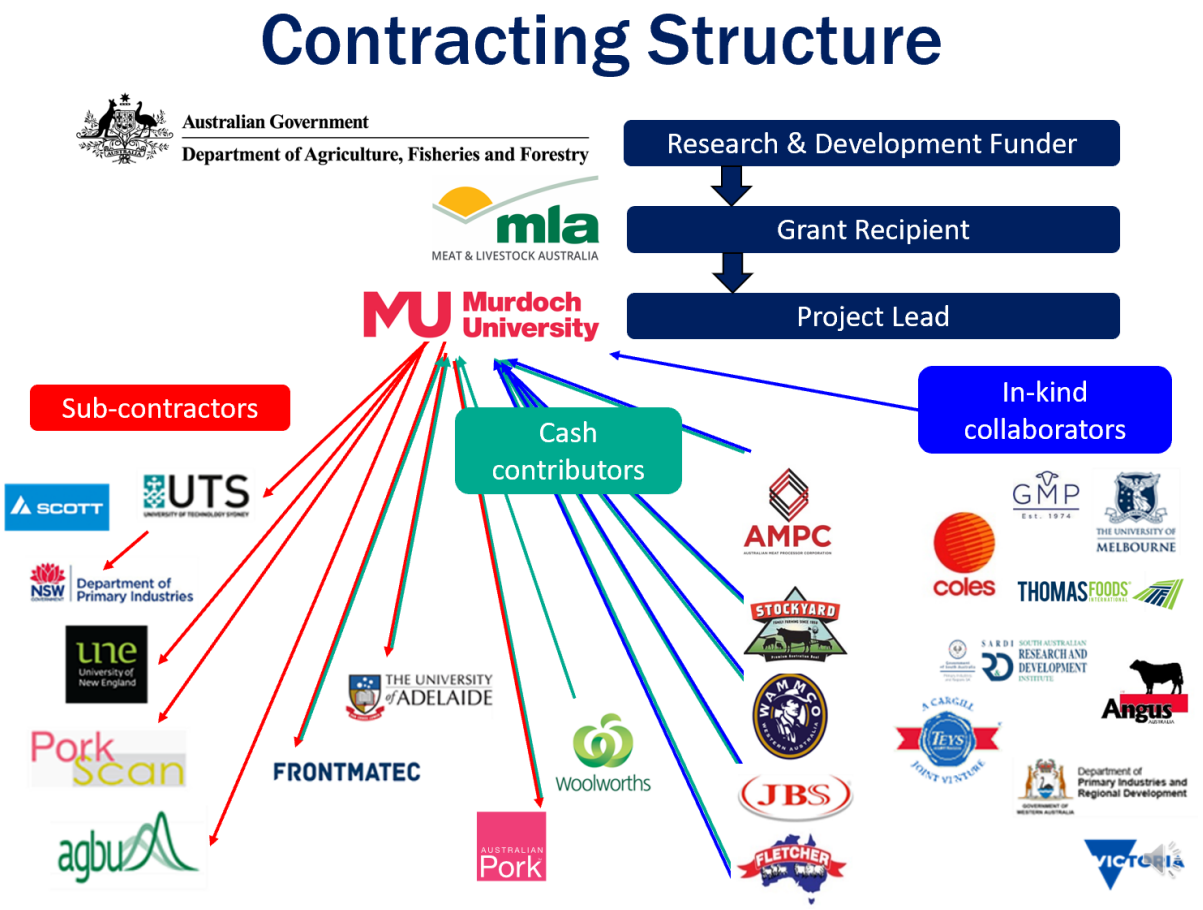
2. The **Progress Review and Intellectual Property and Commercialisation Committee (PRIPCC)** consisted of independent members Professor Emeritus Alan Bell (committee chair) and Professor John Thompson along with representatives from MLA, AMPC, and APL. This group of technical experts met quarterly to provide feedback to the Steering Committee and the Executive Committee regarding the progress of each program, as documented in the quarterly and performance reports.

3. The **Steering Committee (SC)** was chaired by Richard Apps (MLA) and included representatives from key stakeholders plus three independent producers, who met quarterly to provide broad scrutiny of the project delivery and direction, as documented in the quarterly and performance reports. The inclusion of livestock producers, supermarket and meat processor representatives provided oversight and guidance on priorities along the value chain.

4. An **Industry Calibration Working Group (ICWG)** was chaired by Professor Graham Gardner. The ICWG met as required to develop trait and calibration standards associated with the new technologies, documenting these in a dynamic report known as the ICWG Traits Manual to provide technical recommendations to industry.

5. The **ALMTech Annual Review** was a three-day forum to review progress and develop the ALMTech Annual Operational Plans. It convened key stakeholders, the Executive Committee, the PRIPCC and the Steering Committee to review the project's progress over the previous year against the designated KPIs, and to propose work plans for the following financial year. In both 2020 and 2021, the ALMTech Annual Review was held as a virtual conference with speakers providing talks in MP4 format followed by interactive Zoom sessions.

The project was contracted according to the following structure:



2.4 Location of project activities

The location of project activities is listed as follows:

Name & type of site	Postal address	State	Postcode
Meat & Livestock Australia (project partner site)	PO Box 1961, North Sydney	NSW	2059
Murdoch University (project partner site, laboratory)	School of Veterinary and Biomedical Sciences, Murdoch	WA	6150
Australian Meat Processor Corporation (project partner site)	PO Box 6418, North Sydney	NSW	2059
Australian Pork Limited (project partner site)	2 Brisbane Avenue, Barton	ACT	2600
PorkScan Pty Ltd (project partner site)	2 Brisbane Avenue, Barton	ACT	2600
University of Adelaide (project partner site)	Roseworthy Campus, University of Adelaide	SA	5371
Woolworths (project partner site)	1 Woolworths Way, Bella Vista	NSW	2153
JBS Australia (project partner site, field site)	PO Box 36, Altona North	VIC	3025
Teys Australia (project partner site, field site)	Building 3 Freeway Office Park, 2728 Logan Road, Eight Mile Plains	QLD	4113
Fletcher International Exports (project partner site, field site)	Locked Bag 10, Dubbo	NSW	2830
Gundagai Meat Processors (project partner site, field site)	PO Box 100, Gundagai	NSW	2722
Stockyard (project partner site, field site)	PO Box 1170, Toombul	QLD	4012
WAMMCO (project partner site, field site)	PO Box 4059, Victoria Park	WA	6979
Primary Industries and Regions South Australia (project partner site)	GPO Box 1671, Adelaide	SA	5001
DPI NSW (project partner site)	PO Box 865, Dubbo	NSW	2830
DEDJTR (project partner site)	124 Chiltern Valley Rd, Rutherglen	VIC	3685
DPIRD (project partner site)	Baron-Hay Court, South Perth	WA	6151

University of New England (project partner site, laboratory)	Meat Science Building - W48, School of Environmental & Rural Science, University of New England, Armidale	NSW	2351
University of Melbourne (project partner site)	Faculty of Land and Food Resources, The University of Melbourne, Parkville	VIC	3010
University of Technology Sydney (project partner site)	PO Box 123, Broadway	NSW	2007
Frontmatec Group (project partner site)	Albuen 37, 6000, Kolding, Denmark		
Angus Australia (project partner site)	Locked Bag 11, Armidale	NSW	2350
Scott Automation and Robotics (project partner site, laboratory)	Unit R / 10-16 South Street, Rydalmere	NSW	2116
Thomas Foods International (project partner site, field site)	Level 2, 170 Fullarton Road, Dulwich	SA	5065
Coles (project partner site)	Level 2, M9 800 Toorak Road, Hawthorn East	VIC	3123

3 Project outputs

The ALMTech II Activity Work Plan (**Appendix 7.0**) defined a series of scientific and industry outputs. The following sections outline the final status of these outputs at the close of the project. Detailed outcome reporting is contained in the Technical Reports by Program (**Appendix 7.11**).

3.1 Scientific outputs

ALMTech II had the following eleven scientific (**S**) outputs, as listed in bold text. The final status at the close of the project is provided below each respective output. ALMTech II has either delivered or over-delivered on ten of these eleven scientific outputs, with **S(v)** still having a way to go before arriving at a commercially deployable solution.

S(i)	**Support the commercialisation of a live animal 3D imaging system for measuring lean meat yield through installation into two commercial beef feedlots.**
	ALMTech II has partially delivered on this scientific output by supporting the commercialisation of one live animal 3D imaging system for measuring LMY% through installation into the Tullimba NSW beef feedlot. Although not a 3D imaging system, a hand-held microwave fat-depth scanner has been deployed at the Conargo feedlot in Deniliquin NSW. A microwave measured fat depth combined with weight can be used to predict LYM%. This output is detailed in the "Sub-program 1.1 Summary Report" (**Appendix 7.11**).
S(ii)	**Support the commercialisation of DEXA systems for measuring lean meat yield through installation into five lamb abattoirs and one beef abattoir. This may also provide the capacity for directing future automated deboning in beef and enhance current systems in lamb.**
	ALMTech II has delivered on this scientific output. DEXA systems for measuring lean meat yield have been installed into six lamb abattoirs: JBS Brooklyn, JBS Bordertown, Gundagai Meat Processors, Frew Foods International, TFI Tamworth, and WAMMCO Katanning. Additionally, a Nuctech system has been installed at Wagstaff. A DEXA system for measuring lean meat yield has been installed in one beef abattoir at Teys Rockhampton. ALMTech II has provided abattoirs with resources to compare DEXA with E+V yield estimation carcase surface imaging system. Automation has become seamless at the JBS lamb plants in Brooklyn and Bordertown. Other non-automated DEXA systems have been considered for driving automation, with the challenge being hot-to-cold image comparisons. This output is detailed in the "Sub-program 1.2 Summary Report" (**Appendix 7.11**).
S(iii)	**Support the commercialisation of the PorkScan-Plus imaging system for measuring lean meat yield through installation into two commercial pork abattoirs.**
	ALMTech II has delivered on this scientific output by supporting the commercialisation of the PorkScan-Plus imaging system for measuring lean meat yield through installation into two commercial pork abattoirs: Linley Valley Pork WA and Big River Pork SA. In terms of P2 prediction, this task is nearing completion. In terms of LMY% prediction, we have undertaken a broader project to compare Autofom, Hennessey and PorkScan Mk1 and 2 against a CT gold standard measure, to provide scientific rigour to this output. This output is detailed in the "Sub-program 1.3 Summary Report" (**Appendix 7.11**).

S(iv)	**Support the commercialisation of hyperspectral cameras for measuring factors affecting eating quality (i.e. intramuscular fat, pH, colour) through installation into two lamb abattoirs and two beef abattoirs.**
	ALMTech II has over-delivered on this scientific output by supporting the commercialisation of the following devices: Frontmatec Q-FOM, MEQ, MIJ, MasterBeef, and VIAScan CAS. All of these devices have received AUS-MEAT accreditation for a range of MSA and AUS-MEAT beef rib eye traits; and as a result have been deployed to various companies (Australian Country Choice, JBS, Teys, Greenhams, John Dee) for commercial integration trials as part of private or industry-funded projects. In lamb, MEQ and SOMA Optics devices have been accredited for chemical IMF% and are currently being utilised by several processors to undertake MSA benchmarking and/or underpin pricing grids (Gundagai Meat Processors, JBS Brooklyn, JBS Bordertown, V&V Walsh, Fletcher International, Australian Lamb Company, Frew Foods International). In addition, a hyperspectral camera has been installed on the Scott LEAP system at JBS Brooklyn, which is outputting IMF% values. This output is detailed in the "Sub-program 2.1 Summary Report" (**Appendix 7.11**).
S(v)	**Support the development of a commercially deployable automated solution for assessment of offal condemnation and other carcase defects. The prototype would provide key diagnostics prior to manufacture for individual carcase fabrication and marketing options.**
	ALMTech II has progressed R&D addressing this scientific output. However, there is still a way to go before arriving at a commercially deployable prototype, both in terms of a technical solution and in terms of commercial viability in a processing plant. Several technologies have been tested to deliver this outcome. ALMTech has supported the development of a commercially deployable automated solution, for assessment of offal condemnation and other carcase defects, as a combination of short-wave infra-red (SWIR) and multi-energy x-ray absorptiometry (MEXA). Rapiscan have successfully developed MEXA sensing hardware and are progressing with their MEXA dual-view offal inspection scanner, integrated with a hyperspectral surface camera. This upgraded dual sensor unit, which is operating continuously at The University of Sydney, can differentiate diseased samples identified by meat inspection at an abattoir from non-diseased samples in various beef offal's. A second global commercial hyperspectral camera solution used for detecting defects in pork and chicken, is being modified for fast-tracked application in beef processing. A feasibility study run by MLA's Integrity Systems Company has tested market opportunities, focusing on animal health and eating quality, engaging three NH Foods facilities plus the Northern Co-operative Meat Company Ltd (NCMC). Frew Foods International and Gundagai Meat Processors also have data on the value of offal defects. The value propositions and final design elements of a commercial offal sortation solution will be further developed in a series of processor demonstrations and with industry consultation which will continue post-ALMTech.
S(vi)	**Develop at least two new measurement technologies for factors affecting eating quality (i.e. intramuscular fat, pH, colour) including near infra-red spectroscopy, computerised tomography and hyperspectral imaging.**
	ALMTech II has over-delivered on this scientific output by supporting the development of three new measurement technologies for factors affecting eating quality (i.e. intramuscular fat, pH, colour): optical coherence tomography (OCT), nuclear magnetic resonance (NMR) and hyperspectral imaging. This output is detailed in the "Sub-program 2.2 Summary Report" (**Appendix 7.11**).
S(vii)	**Develop at least two new measurement technologies for lean meat yield to be deployed either in abattoirs or on-farm. Technologies may include 3D**

	imaging coupled with hyperspectral tissue depth measurements, microwave fat depth, and rapid CT systems.
	ALMTech II has over-delivered on this scientific output. • ALMTech's low-cost, hand-held microwave device for measuring back fat depth is in use, both on carcases in commercial abattoirs and on live animals in feedlots, in both lamb and beef. The device and its algorithms have undergone several iterations of refinement. Industry personnel around Australia have been trained by ALMTech to use the device. A commercial prototype has been deployed at a beef feedlot. The next phase is the full commercial integration of this device with supply chain partners. • Scott Automation and Robotics DEXA systems for measuring lean meat yield have been installed into six lamb abattoirs: JBS Brooklyn, JBS Bordertown, Gundagai Meat Processors, Frew Foods International, TFI Tamworth, and WAMMCO Katanning. A DEXA system for measuring lean meat yield has been installed in one beef abattoir at Teys Rockhampton. A Nuctech DEXA has been installed and calibrated at Wagstaff's lamb abattoir. • ALMTech has supported the commercialisation of the PorkScan-Plus imaging system for measuring lean meat yield through installation into two commercial pork abattoirs: Linley Valley Pork WA and Big River Pork SA. • In terms of commercializing a live animal 3D imaging system for measuring lean meat yield, as mentioned in **S(i)**, ALMTech has supported the installation of such a system into the Tullimba NSW beef feedlot. This output is detailed in the "Sub-program 1.1 Summary Report", "Sub-program 1.2 Summary Report" and "Sub-program 1.3 Summary Report" (**Appendix 7.11**).
S(viii)	**Deploy algorithms within two abattoirs that translate the carcase/meat quality measurements into VBP and novel pricing mechanisms up and down the supply chain.**
	ALMTech II has over-delivered on this scientific output. Pricing (linked to both producer pricing and wholesale primals pricing) is associated with accuracy in the estimation of saleable meat yield (SMY) and EQ. Market access or product differentiation (linked to both producer pricing and wholesale pricing) is associated with offal defect detection. • **Data integration.** ALMTech has worked closely with supply chain partners to integrate the data made available from ALMTech supported technologies into Meat & Livestock Australia's Livestock Data Link online feedback system and other proprietary systems owned by individual processors. This has included linkage to genetic databases and the development of new and enhanced genetic tools to select for LMY% and EQ on-farm. • **MSA compatibility.** ALMTech has ensured the compatibility of all devices with the MSA EQ prediction system, in part by developing uniform accreditation protocols. • **Carcase value calculators.** ALMTech has developed data-to-decision packages and in-plant business rules to help industry use data from the new technologies, including a Lamb Value Calculator (LVC) and a Beef Value Calculator (BVC). The LVC and BVC enable processors to define the true value of carcases and to optimise market-specific carcase use, based upon predicted cut weights prior to carcase fabrication. ALMTech then went a step further and developed an industry-first Carcase Optimisation Tool (COT) for use by lamb processors. The COT utilises the complete package of ALMTech's cut weight prediction algorithms and is currently being applied across four lamb supply chains (Greenstock/Woolworths, FFI, GMP and Coles) to: i) evaluate actual boning room outcomes 'post-hoc' against predicted 'most profitable optimised'

	scenarios; and ii) compare proposed boning plan changes against current plans. These carcase value calculators are publicly accessible from: www.mla.com.au/extension-training-and-tools/creative-commons-licenses/. • **Greenstock / Woolworths supply chain.** This supply chain has deployed an algorithm developed by ALMTech to predict shortloin fat cover, which is being used by the company to sort carcases to cut plans that better reflect the value to Woolworths' domestic lamb retail market. This algorithm is informed directly by the DEXA prediction of whole carcase fat. This represents the first commercial application of DEXA for in-plant sortation that increases both boning room yield and labour efficiency. • **Frew Foods International (FFI) supply chain.** This supply chain has deployed an algorithm developed by ALMTech that accurately predicts the fat score of lambs. The increase in accuracy compared to manual palpation is allowing the business to improve carcase sortation outcomes, particularly for carcases at the fatter end of the spectrum. Improved sortation is leading to improved boning room yield and labour efficiency. • **Gundagai Meat Processors (GMP) supply chain.** This supply chain has implemented a value-based payment grid for lamb, taking advantage of 'first mover' opportunities to utilise carcase yield and eating quality as mechanisms to shape the future supply of lambs to underpin the development of their own premium branded products. This output is detailed in "Program 5 Summary Report" (**Appendix 7.11**).
S(ix)	**Work strategically with international partners to publish and collaboratively expand this research creating a sustainable base to continually refine and update the objective technologies and enhance grading credibility.**
	ALMTech II has over-delivered on this scientific output by working strategically with 11 international research providers and 12 international commercial companies. Refer to **Section 4.3** (International collaborators) for a complete list. Professor Gardner has also been invited as an international reviewer on the Meat Technology Ireland board, a group with a similar mandate in Ireland to ALMTech in Australia. A notable achievement has been the selection of a suite of 18 peer-reviewed papers for publication in an open-access special edition in the discipline's premier international journal *Meat Science* (2021). This demonstrates that the research undertaken by ALMTech scientists is of world-class standard. This special edition focused upon the development, calibration and validation of technologies that measure traits influencing meat eating quality, or carcase fat and lean composition. The publications describe the various technologies being developed, how these devices are being trained upon common gold-standard measurements, and how their outputs are being simultaneously integrated into existing industry systems. The publications also outline how this enhances the industry uptake and adoption of these technologies, and how this is further accelerated by education programs and strategic industry investment into their commercialisation. The special edition papers are available from: www.sciencedirect.com/journal/meat-science/special-issue/1069L13ZRCC in open access format, making journal articles available to readers at no cost. They can also be found in **Appendix 7.11** (Sub-program E.2 Communication and extension activities; KPI 2.3). The ALMTech team are currently compiling another suite of peer-reviewed papers for publication in an open-access special edition in the discipline's premier international journal *Meat Science* (submissions due 30th May 2023).
S(x)	**Develop early career (Post-Doctoral fellows) and trainee scientists (PhD/Masters) to leave a legacy of scientific and technical capacity into the future.**

	ALMTech II has over-delivered on this scientific output. The project has established a new network of scientists from universities and research institutes across Australia, and trained 2 early career scientists, 17 post-doctoral fellows, 6 doctor of veterinary medicine (DVM) students, 8 PhD students, 2 Honours students and 10 research scientists/assistants. Refer to the list of early career and trainee scientist contributions to the ALMTech project (**Appendix 7.4**). A notable strength of the ALMTech research team has been our continued ability to extend research to non-technical industry audiences, through presentations at field days, industry workshops, training events, and Zoom-based webinars, which have been delivered to date across all states of Australia in a truly national outreach program, and internationally, even during COVID-19 restrictions. Refer to the Extension Activity Log (**Appendix 7.6**). The ALMTech project website, www.almtechau.com, has recently been redeveloped and is gaining interest from our industry audiences.
S(xi)	**Produce 15 refereed publications in international scientific journals to internationally underpin the integrity and acceptability of the key scientific and industry objectives and outputs.**
	ALMTech II has over-delivered on this scientific output. As mentioned in detail under scientific output **S(ix)**, a notable achievement has been the selection of a suite of 18 peer-reviewed papers for publication in a special edition in the discipline's premier international journal *Meat Science* (2021). The ALMTech team also have submitted an additional 24 papers for publication in peer-reviewed international journals and 41 peer-reviewed conference papers. We have also been invited to submit another special edition in the journal *Meat Science* in 2023.

3.2 Industry outputs

ALMTech II had the following nine industry (**I**) outputs, as listed in bold text. The final status at the close of the project is provided below each respective output. ALMTech II has either delivered or over-delivered on eight of these nine industry outputs, with **I(iv)** still having a way to go before arriving at a first commercial prototype.

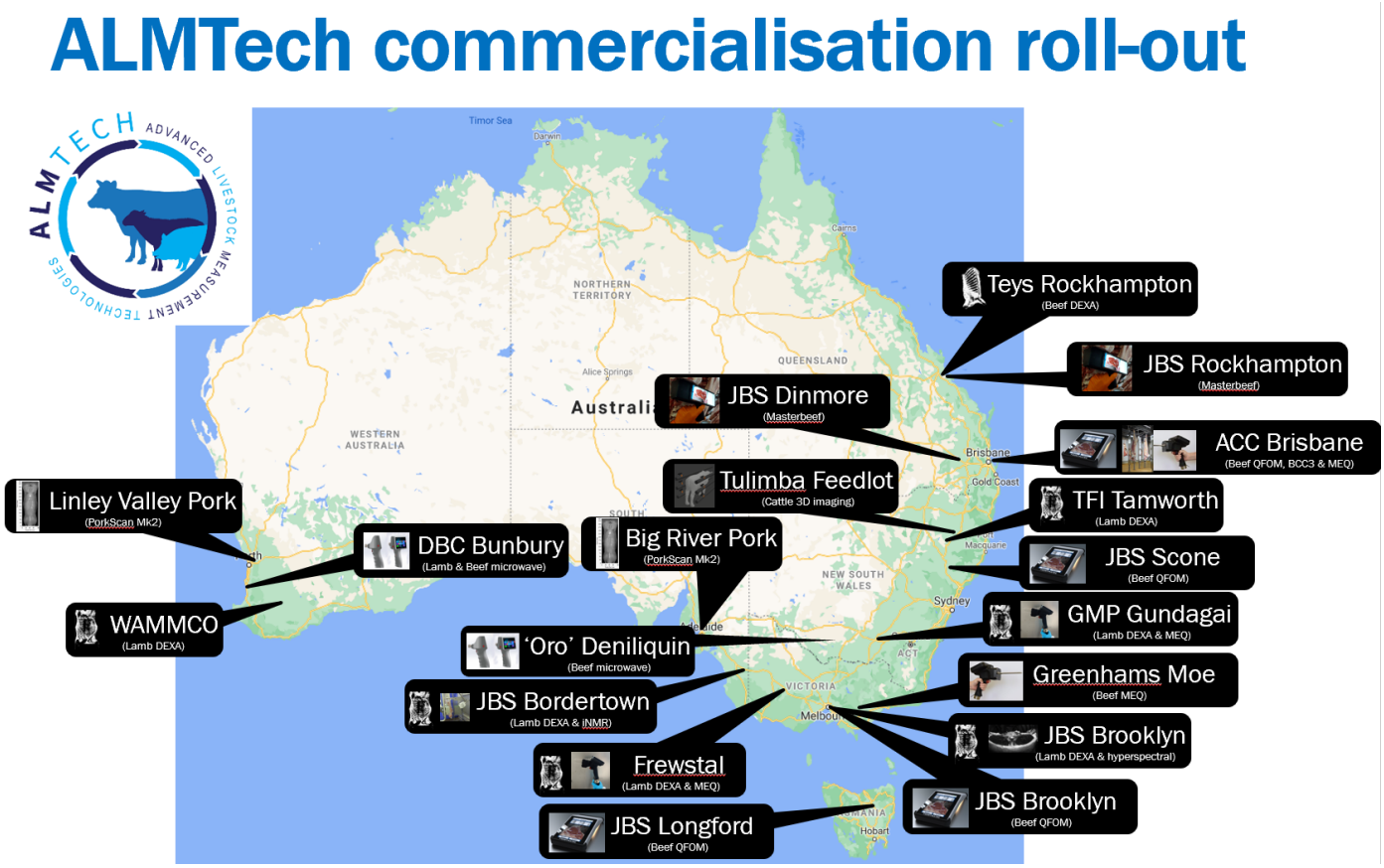
I(i)	**Develop reliable technologies operating within feedlots, or mobile units for use in the seed-stock sector for assessment of carcase lean meat yield, to be commercialised by 2023.**
	ALMTech II has delivered on this industry output, via live animal 3D imaging and hand-held microwave technology, both in beef; refer to the commentary in scientific output **S(vii)**. This output is detailed in the "Sub-program 1.1 Summary Report", "Sub-program 1.2 Summary Report" and "Sub-program 1.3 Summary Report" (**Appendix 7.11**).
I(ii)	**Develop reliable technologies operating at line speed for assessment of carcase lean meat yield, to be fully commercialised and implemented within the processing industry by 2023.**
	ALMTech II has delivered on this industry output, based upon the commentary in scientific outputs **S(i)**, **S(ii)** & **S(iii)**. This output is detailed in the "Sub-program 1.2 Summary Report" (**Appendix 7.11**).
I(iii)	**Develop reliable technologies operating at line speed for assessment of carcase eating quality attributes, to be fully commercialised and implemented within the processing industry by 2023.**
	ALMTech II has delivered on this industry output, based upon the commentary in scientific output **S(iv)**. This output is detailed in the "Sub-program 2.1 Summary Report" (**Appendix 7.11**).
I(iv)	**Deploy first commercial prototype equipment for identifying offal condemnation by 2023.**
	ALMTech II has progressed with this industry output but has not met the 2023 target for a first commercial prototype. A pre-commercial upgraded dual sensor operating at The University of Sydney can differentiate diseased samples from non-diseased samples in various beef offals. In-kind processor partners have been identified to demonstrate the pre-commercial prototype in a plant in early 2023. There has been an expression of interest from Australian Meat Inspection Services to convene a meat inspection review in early 2023 to determine the value proposition of disease sortation and how the offal defect solution would effectively work commercially.
I(v)	**Produce standardised calibration systems that are internationally recognised to underpin the integrity of the new objective carcase measurement technologies, to be adopted by 2023.**
	ALMTech II has delivered on this industry output, rolling out new traits for IMF% and LMY% in sheepmeat, IMF% for beef, and beef camera grading standards. For each of the devices that obtain AMILSC accreditation, we have developed calibration standards, as part of the AMILSC requirements. ALMTech II has also progressed towards a NATA-accreditation process for laboratories measuring IMF%. This output is detailed in the "Sub-program E.4 Summary Report" (**Appendix 7.11**).
I(vi)	**Link objective carcase measurement with data capture, storage, dissemination, and management systems for use up- and down-stream within the value chains to maximise communication and profit and be implemented by the 10 value chain partners.**
	ALMTech II has over-delivered on this industry output, via implementation by more than 10 value chain partners: Frew Foods Interntion, Woolworths, Gundagai Meat

	Processors, Coles, Fletcher, Stockyard, WAMMCO, Thomas Foods International, Australian Lamb Company, Australian Country Choice, Kilcoy, Greenhams, Dardanup Butchering Company, and AMG. ALMTech has worked closely in this regard with the Integrity Systems Company (who provide integrity and information systems for the red meat value chain), the Livestock Data Link advisory group (who integrate new data into industry feedback systems), MyMSA, Sheep Genetics and BREEDPLAN. ALMTech's research PCs installed at WAMMCO, Frew Foods International and Gundagai Meat Processors have provided in-plant problem solving and information interrogation/exploration. Installations at JBS Bordertown and Brooklyn are nearing completion. This output is detailed in the "Sub-program 4.1 Summary Report", the "Sub-program 4.2 Summary Report" and the "Program 5 Summary Report" (**Appendix 7.11**).
I(vii)	**Analyse impediments to feedback and data flow and deploy solutions to ensure enhanced feedback to producers.**
	ALMTech II has delivered on this industry output, based upon the commentary in scientific output **S(viii)**. In lamb, this is evidenced via the Greenstock / Woolworths, Gundagai Meat Processors (GMP) and Coles supply chains, as well as recent progress at WAMMCO. GMP have deployed a bespoke producer portal to provide feedback on objective measurements including carcase weight, LMY, IMF% and disease / defects at the individual carcase level. Livestock Data Link (LDL) remains the most widely available platform for processors to supply carcase feedback to producers, including access to management advice to improve carcase compliance to specifications. LDL is undergoing significant redevelopment by MLA's Integrity Systems Company to further improve the platform's delivery capability across the industry. In beef, EQ devices (for example, ACC and JBS utilising the Frontmatec Q-FOM beef grading camera) inform the MSA model. In pork, price signals and feedback are linked through PorkScan. This output is detailed in the "Sub-program 4.1 Summary Report" (**Appendix 7.11**).
I(viii)	**Develop and implement three new or improved genetic products or tools that are clearly focused on VBP for beef, lamb, or pork.**
	ALMTech II has delivered on this industry output. Objective measurement technology can be used to deliver genetic gains and benefits to industry, namely via breeding for better LMY% (underpinned by DEXA) and MSA-level EQ (in terms of shear force and IMF%). ALMTech II has completed the genetic validation of 7 new genetic tools for the sheep industry: 1. DEXA was validated as an accurate genetic prediction of CTlean and thus LMY breeding values. 2. MEQ was validated as an accurate genetic prediction of IMF and thus IMF breeding values. 3. A preliminary validation of SOMA indicates that it will also be an accurate genetic prediction of IMF%. 4. Preliminary validation of genomic flock benchmarking in Terminal sheep was conducted and demonstrated accurate results. This provided sufficient evidence to support ongoing development of this product. 5. Preliminary validation of genomic flock benchmarking in Maternal sheep was also conducted and demonstrated accurate results. This provided sufficient evidence to support ongoing development of this product. 6. Analysis of eye muscle dimension data suggests the need for a new definition of these traits, which is likely to lead to new eye muscle width or area traits for sheep. 7. A new model for improved analysis of the shear force trait was also defined and validated for use by Sheep Genetics.

	ALMTech II has also examined the value of using carcase data from industry ram breeding (seedstock) flocks to build upon an industry sheep reference population in Australia. This work concluded that commercial seedstock data can be used if data collection is accurate and consistent with industry standards and this enables new models to work with industry flocks to provide genetic resource flock data. ALMTech II has also continued to work with BREEDPLAN to evolve the EQ traits away from marble score toward IMF%, which will be captured from the new beef rib-eye cameras. In a similar vein, work has commenced to validate the use of DEXA in beef and the development of a LMY breeding value for beef. This output is detailed in the "Sub-program 4.2 Summary Report" (**Appendix 7.11**).
I(ix)	**In collaboration with commercial providers, deploy software systems to optimise sorting of raw materials to best meet customer specifications for finished products that utilise yield and eating quality data generated for carcases and primal cuts, thereby capturing productivity and profitability benefits.**
	ALMTech II has delivered on this industry output, using its suite of tools developed by the team to engage effectively with lamb and beef processors to identify opportunities to improve carcase processing performance to meet consumer requirements. • The Lamb and Beef Value Calculators have continued to extend their reach to new processors, including Gathercoles, Tallangatta Meat Processors, Bindaree Beef, and Tasmanian Quality Meats. • The Carcase Optimisation Tool is being actively applied at the strategic level in four lamb supply chains (Greenstock/Woolworths, FFI, GMP and Coles) to identify opportunities to improve processing outcomes. • A new tool, Meat Logic, has been developed and evaluated at two lamb processing sites with the intent to use whole-of-plant data to predict, monitor and review processing performance, informed by the use of real-time carcase yield predictions (e.g. from DEXA, microwave or other yield measurement devices), combined with cut weight predictions sourced from ALMTech's cut weight algorithm database. • In beef, EQ devices (e.g. ACC utilising Frontmatec Q-FOM beef grading camera) inform the MSA model, therefore enhancing a system that already exists. This output is detailed in the "Program 5 Summary Report" (**Appendix 7.11**).

3.3 Map of Australia-wide commercialisation

Implementation of ALMTech-supported technologies across Australia is progressing well. The figure below illustrates this roll-out, although the number of sites increases each month; hence, upon reading, this figure is likely to be outdated. This distribution illustrates the national reach of the ALMTech project and the excellent connection that the team have maintained with industry partners.



3.4 Key Performance Indicator achievements

Refer to the following table for the list of project activities and their descriptions, cross-referenced against the relevant Key Performance Indicators (KPIs) spanning the life of ALMTech II, and the Appendices to refer to for the related content that documents these KPI achievements.

Activity	Description	Key Performance Indicators (KPIs)	Refer to
1	**Undertake project initiation**	**1.1**	• Activity Work Plan (**Appendix 7.0**)
2	**Undertake project planning and management**	**1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 3.3**	• Monitoring & Evaluation Plan (**Appendix 7.1**) • Communications Plan (**Appendix 7.2**) • Risk Assessment Spreadsheet (**Appendix 7.3**) • Annual Operational Plans (**Appendix 7.10**)
3	**Undertake communication and extension, including industry liaison and value estimation**	**1.4, 1.5, 2.3, 2.4, 3.4, 3.5**	• Project website (www.almtechau.com) • Early Career & Trainee Scientists (**Appendix 7.4**) • Newsletter Archive (**Appendix 7.5**) • Extension Activity Log (**Appendix 7.6**) • Media & Publications Log (**Appendix 7.7**) • Intellectual Property Register (**Appendix 7.8**) • Economic Evaluation Report (**Appendix 7.9**)
4	**Undertake monitoring and evaluation, including general management of technology calibration**	**1.6, 2.5, 3.6**	• Technical Reports by Program (**Appendix 7.11**)
5.1.1	**Develop live measurement of lean meat yield (LMY)**	**1.7, 1.8, 1.9, 1.10, 2.6, 2.7, 2.8, 2.9, 3.7, 3.8, 3.9, 3.10**	• Technical Reports by Program (**Appendix 7.11**)
5.1.2	**Develop carcase measurement of LMY (direct)**	**1.11, 1.12, 1.13, 2.10, 2.11, 2.12, 2.13, 3.11, 3.12, 3.13**	• Technical Reports by Program (**Appendix 7.11**)
5.1.3	**Develop carcase measurement of LMY (indirect)**	**1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19**	• Technical Reports by Program (**Appendix 7.11**)
5.2.1	**Commercialise two technologies for grading eating quality in beef carcases and two technologies for grading eating quality in lamb carcases**	**1.21, 1.22, 1.23, 1.24, 1.25, 1.26, 2.20, 2.21, 2.22, 2.23, 2.24, 3.20, 3.21, 3.22, 3.23**	• Technical Reports by Program (**Appendix 7.11**)
5.2.2	**Develop and validate new eating quality (EQ) technologies**	**1.27, 1.28, 1.29, 2.25, 2.26, 2.27, 2.28, 3.24, 3.25, 3.26, 3.27**	• Technical Reports by Program (**Appendix 7.11**)
5.3	**Develop a commercially deployable automated solution for measuring offal condemnation**	**1.30, 1.31, 1.32, 2.29, 2.30, 3.28**	• Technical Reports by Program (**Appendix 7.11**)
5.4.1	**Develop data flow to industry information delivery systems**	**1.33, 2.31, 3.29**	• Technical Reports by Program (**Appendix 7.11**)
5.4.2	**Develop data flow to industry genetic evaluation systems**	**1.34, 2.32, 2.33, 3.30**	• Technical Reports by Program (**Appendix 7.11**)
5.5.1	**Enhance carcase value tools**	**1.35, 2.34, 2.35, 2.36, 2.37, 3.31, 3.32**	• Technical Reports by Program (**Appendix 7.11**)
5.5.2	**Enhance data decision tools**	**1.36, 2.38, 2.39, 3.33, 3.34**	• Technical Reports by Program (**Appendix 7.11**)
5.5.3	**Enhance supply chain efficiency and engagement**	**1.37, 1.38, 1.39, 2.40, 2.41, 2.42, 2.43, 3.35, 3.36, 3.37**	• Technical Reports by Program (**Appendix 7.11**)

3.5 Contribution to program objectives

ALMTech II's ambition is to realise significant productivity and profitability improvements for primary producers, via the following objectives:

- Provide beef, lamb and pork producers with access to more accurate descriptions of the key attributes that influence the value of their livestock: LMY% and EQ; and compliance to market specifications, delivered via advanced measurement technologies, in synergy with abattoir automation where appropriate;
- Enhance feedback systems to provide producers with new information that enables improved decisions on breeding and compliance to market specifications;
- Deliver new tools and data to processors that can be used by producers to improve the rate of genetic gain and processing efficiency, while optimising their capacity to allocate product to the most valuable market end-point, thereby increasing the wealth of the value chain participants;
- Capitalise on the co-operation of industry stakeholders to maximise effective decision making, reduce risk and optimise profit for all partners;
- Develop an early-stage prototype of objective measurement equipment for offal condemnation; and
- Develop and improve these technologies and systems to increase competitiveness and profitability in the Australian meat value chain.

The ALMTech Economic Evaluation Exit Report (**Appendix 7.9**) estimates the most likely economic value of the ALMTech I and ALMTech II projects combined to the Australian beef, sheep meat, and pork industries. These estimates consider the accuracy, reliability, and commercial usability of the various Objective Measurement (OM) technologies and their adoption rates.

As detailed in the ALMTech Economic Evaluation Exit Report, summing each annual benefit out to 2040 as reflected in the assumed adoption profile, accounting for estimated user costs and discounting back to 2023, the estimated NPV for net benefits for the beef industry scenarios (prior to accounting for R&D costs) is $123 million, for the sheep meat industry scenarios is $538 million, and for the pig meat industry scenarios is $197 million. Aggregating these measures across the three industries gives an estimated NPV of net benefits of $858 million, accounting for ongoing user costs but prior to accounting for R&D investment costs. Adjusting MLA and APL R&D costs to real 2020 values and summing across the three industries generates a discounted cost aggregate of $128 million. Therefore, the overall OM theme of work has resulted in a discounted net benefit of $730 million with an estimated benefit to cost ratio (BCR) of 6.7:1. These values are quite consistent with the returns from other large R&D programs in the livestock industries, such as the Cooperative Research Centre for Beef Genetics Technologies.

The estimated NPV of net benefits of $858 million is somewhat higher than that estimated at the end of ALMTech I ($510 million). Partly, that difference is due to the re-inclusion of the benefits and costs from animal health related outcomes, although with the 70% discount due to attribution concerns that benefit is quite small now. Additionally, new scenarios have been included, although their contribution is minor. The base equilibrium values have also been changed to better reflect current industry conditions, and while prices in all the meat markets are much higher, numbers are lower, so the adoption profiles start from lower values than in the economic evaluation report conducted at the end of ALMTech I. The main contributor to the difference is the change in the adoption profiles. Whenever future values are brought closer to the current period, the principles of discounting ensure that the NPVs will be higher. The willingness-to-pay by end users for better information, which enables better decisions, can only be captured if there are suitable incentive systems in place to facilitate these better decisions.

The implementation of the value-based trading system by GMP is a great start, but other value-based marketing systems must be implemented in parallel to the implementation of the new technologies to enable the full range of the potential benefits to be captured and transmitted up and down the relevant value chains.

4 Collaboration

4.1 Australian industry collaborators

Most crucial to the project have been our Australian industry collaborators. Engagement with these collaborators has been formally and informally structured at numerous levels, with examples including the following:

a) In most cases, experimental work undertaken by ALMTech to support development of technologies has been done within abattoirs and on the farms of our collaborating industry partners. This has provided them with a first-hand experience of the technologies being tested and has been a crucial mechanism to create a commercial needs-driven focus and enhance future adoption.
b) The private companies who invested cash into the ALMTech II project included JBS Australia, Frontmatec, Woolworths, Fletcher, Stockyard and WAMMCO. These companies had representatives on the Steering Committee and formally provided direction for the experimental work and subsequent implementation.
c) We had producer representatives from the sheep meat industry, the grass-fed beef industry and the beef feedlot industry who also sat on our Steering Committee and formally provided direction for the experimental work and subsequent implementation.
d) Companies who actively supported the ALMTech project—particularly those with an expressed intent to adopt a new measurement technology or enhance their producer feedback—were offered quarterly, confidential supply-chain meetings. These included a selection of key ALMTech personnel with a knowledge of the technologies of interest to that business. Within those meetings, the business case and practical logistics of adopting new measurement technologies was established.
e) The companies described in d) above, as well as representatives from MLA, AMPC, MSA, commercial partners, State departments of primary industries, and all ALMTech personnel, also participated in twice-yearly national supply-chain meetings. These were used as discussion forums across a range of topics relevant to enhancing LMY% and EQ within the livestock industries.

These collaborative activities created an extensive industry network. The companies involved, and examples of their collaboration, included:

- Meat & Livestock Australia (project partner) – accessing Resource Flock, Beef Information Nucleus R&D herds, and producer feedback portals
- Australian Meat Processing Corporation (project partner) – accessing extensive processor network
- Australian Pork Limited (project partner) – accessing extensive processor and producer network
- Teys Australia (project partner, field site) – abattoir testing of beef DEXA, E+V grading camera, MEQ probe
- JBS Australia (project partner, field site) – abattoir testing of lamb DEXA, hyperspectral lamb grading camera, Lamb Value Calculator
- Thomas Foods International (field site) – processing MLA Resource Flock
- Gundagai Meat Processors (field site) – abattoir testing of lamb DEXA, MEQ probe, Lamb Value Calculator, Carcase Optimisation tool
- Frew Foods International (field site) – abattoir testing of lamb DEXA, MEQ probe, Lamb Value Calculator, Meat Logic
- Western Australian Meat Marketing Co-operative Limited (field site) – installing DEXA; processing MLA Resource Flock

- Northern Cooperative Meat Company (field site) – understanding the potential to use whole-of-supply chain data to optimise enterprise performance; time of grading of IMF investigation; supply chain data exploration
- Bindaree Beef (field site) – abattoir testing of hyperspectral cameras and microwave scanners.
- Stockyard (field site) – testing of various devices.
- Fletcher (field site) – abattoir testing of various devices.
- Prestige Foods (field site) – abattoir testing of hyperspectral cameras
- Woolworths (field site) – retailer testing of Lamb Value Calculator
- Coles (field site) – retailer testing of Lamb Value Calculator
- Angus Australia – Beef Information Nucleus R&D herd
- Herefords Australia – Beef Information Nucleus R&D herd
- Harvey Beef (field site) – abattoir testing of hyperspectral cameras
- John Dee (field site) – Beef Information Nucleus R&D herd processing, and abattoir testing of hyperspectral cameras and 3-D imaging system
- Australian Lot Feeders Association (ALFA) – R&D planning
- Australian Brahman Breeders Association – Beef Information Nucleus R&D herd
- Santa Gertrudis Australia – Beef Information Nucleus R&D herd
- Droughtmaster Stud Breeders' Society – Beef Information Nucleus R&D herd
- Australian Lamb Company – abattoir testing of Lamb Value Calculator
- Integrity Systems Company – value chain network via integrity and information systems
- Livestock Data Link advisory group – integration of new data into industry feedback systems
- AUS-MEAT – accreditation of new grading technologies
- Meat Standards Australia – integration of new grading technology outputs into the MSA language
- Australian Meat Industry Language and Standards Committee – approval of new grading traits and language standards for beef grading cameras, and alternate lamb and beef technologies
- MEQ – technology development collaboration in Resource Flock and Beef Information Nucleus herds

4.2 Australian research collaborators

The project brought together a network of scientists distributed across universities and research institutes across Australia. In many cases, these networks did not previously exist and have entrenched collaborative activities that will extend beyond the term of the project. These organisations included:

- Murdoch University (project partner)
- University of New England (project partner)
- Animal Genetics and Breeding Unit (project partner)
- University of Adelaide (project partner)
- University of Technology Sydney (project partner)
- Department of Primary Industries NSW (project partner)
- AgBiz Solutions (project partner) – meat industry supply chain analyst
- SunPork (project partner)
- PorkScan (project partner)
- University of Melbourne (project partner)
- University of Sydney (project partner)
- Department of Jobs, Precincts and Regions Victoria (project partner)
- Department of Primary Industries and Regional Development Western Australia (project partner)
- South Australian Research and Development Institute (project partner)

- Health 4 Wealth
- Sheep Co-operative Research Centre
- Sheep Genetics
- Meat Standards Australia
- Enhanced Abattoir Surveillance (EAS) program. This included data collection with Thomas Foods International (Lobethal), and collaboration with GMP on collection methodology and analysis.

4.3 International collaborators

Our international collaborators have been crucial to the outputs of the ALMTech project. We actively sought international partners who were interested in developing their own technologies, specifically tailoring them to the Australian livestock industries. This has markedly diversified the technologies that we have tested and introduced numerous companies with a track record of successful commercialisation to the Australian livestock industry. In other cases, our collaboration provided an ideal forum in which to critique our own innovation program by contrasting it with that of other countries that are active in this space, with AgResearch New Zealand and Meat Technology Ireland being prime examples. These collaborators included the following:

Research providers

- AgResearch (New Zealand) – in addition to the aforementioned Meat Science Special Edition, ALMTech collaborated over hyperspectral and nuclear magnetic resonance work, and their INNERVISION service, which offers commercial CT scanning for breeding stock evaluation, research and veterinary diagnostic purposes
- Meat Technology Ireland – an organisation similar to ALMTech (Prof. Gardner is a member of their scientific peer review panel).
- Sheep Ireland
- Meat Promotion Wales
- INRA National Institute for Agricultural Research (France)
- United States Department of Agriculture USDA – genetics
- Texas Tech University (United States of America)
- Obihiro University (Japan)
- China Agricultural University
- International Sheep Genomics Consortium
- AUS-MEAT

Commercial companies

- Scott Automation and Robotics (New Zealand – project partner)
- AbacusBio (New Zealand) – Sheep Improvement Limited
- Signet Breeding Services (United Kingdom)
- Rapiscan (United Kingdom)
- Frontmatec (Denmark)
- E+V (Germany)
- Farm Animal Imaging FAIM – now a European CT consortium
- TenderSpec (United States of America)
- NH Foods (Japan) – abattoir testing of Beef Value Calculator
- SOMA Optics (Japan)
- MIJ: Meat Imaging Japan
- Nuctech (China)

5 Extension & adoption activities

5.1 Engagement

Arguably the most crucial mechanism of industry engagement within the ALMTech project has been the design of experimental work undertaken in direct collaboration with the industry end-user of the technology. Excellent examples include supporting the installation and testing of the lamb and beef DEXA systems within commercial abattoirs, coupled with the installation of research PCs run in parallel, enabling the research team to remotely access and test equipment operating in commercial settings. This provided collaborating industry partners with a first-hand experience of the technologies being tested, along with analytical support to suggest ways of utilising and reporting the new data generated. This ensured that the full benefit of these systems was being utilised, while also providing case studies to encourage future adoption at other sites. Another excellent example has been the processor support for experiments accrediting beef rib-eye trait technologies. These labour-intensive and disruptive experiments could not progress without the commitment of processor partners. Indeed, the COVID-19 travel restrictions highlighted the strength of these relationships, with several experiments undertaken on behalf of ALMTech by industry staff located on-site. The success of this engagement strategy has been illustrated by the number of new participants from the feedlot, processing, and retail sectors who installed objective measurement technologies and integrated them into their businesses.

The ALMTech project team extended their engagement to include non-technical industry audiences, as demonstrated through the Extension Activity Log (**Appendix 7.6**), which lists the team's presentations at field days, industry workshops, training events and webinars. These industry presentations were delivered across all states of Australia in a truly national outreach program, and internationally.

Additionally, the formal activities coordinated through Program 5 have been entirely focused upon supply chain engagement. These activities include national Supply Chain Group meetings, confidential company-based supply chain meetings, and training workshops delivered through the producer networks of MLA and our key collaborating processor partners. Engagement with both producer and processor representatives provided oversight and guidance on priorities along the value chain, via accurate, credible, and transparent information that had been validated by independent industry representatives.

5.2 Appropriateness

Indicators that illustrate ALMTech's alignment with industry stakeholder needs include:

- Expanded support from ALMTech I to ALMTech II of new commercial participants from the feedlot, processing, and retail sectors.
- Expressed interest from producers and processors in ALMTech's work via attendance at engagement activities, as per the Extension Activity Log (**Appendix 7.6**).
- Regular invitation of ALMTech's ICWG to the AMILSC, to present upon new traits to integrate into the industry trading language, and experimental designs for the testing of new technologies.
- Uptake by collaborating industry partners of the lamb and beef DEXA systems, coupled with the installation of research PCs.
- Expressed demand from processors in the beef industry for improved methods of determining marbling in beef. This was well demonstrated by the number of companies who collaborated to test and install loin eye cameras.

- Expressed demand from processors in the lamb industry for a measure of EQ, enabling them to roll-out an individual carcase grading system (MSA Mk2). This was well demonstrated by the number of companies who collaborated to test and install IMF% measurement technologies.
- Uptake by supply chains to integrate device outputs into commercial decision-making systems.
- Positive engagement from the relevant industry Peak Councils, the National Meat Industry Training Advisory Council (MINTRAC) and the Australian Meat Industry Council (AMIC). The latter have undertaken a series of online workshops and created a series of training modules structured around ALMTech outputs.

5.3 Adoption

To increase the likelihood of adoption, the project incorporated numerous strategies to enhance the integration of the new technologies into industry. Firstly, the R&D was undertaken in collaboration with supply chains, resulting in direct implementation of technologies at completion of the experimental work – DEXA being a key case-in-point. Secondly, significant effort was devoted to integrating the resulting data flow into existing industry data platforms and feedback systems, such as MLA's Livestock Data Link (LDL) feedback system and other proprietary feedback systems. This included linkage to genetic databases and the development of new and enhanced genetic tools stemming from the new measurements, which were delivered through the well-established BREEDPLAN and Sheep Genetics programs. Thirdly, significant effort was focused on developing data-to-decision packages that helped industry generate profit from the new measurements. Lastly, to facilitate the compatibility of technologies to existing infrastructure, some investment was focused on automation, given the potential dual roles for many of the sensing technologies.

6 Lessons learnt

6.1 Conclusions

A key success of the project has been the efficiency achieved through the central coordination of the development, calibration, and validation of new objective measurement technologies, which has ultimately accelerated their speed-to-market. Wherever possible, this testing has been undertaken across genetically defined resource flocks and herds, integrating as many technologies as possible in parallel. The use of common animal resources has ensured the following:

- Reduced experimental costs through the utilisation of pre-existing resource herds and flocks. Simultaneous deployment of many measurement technologies across the same animals further enhances this efficiency.
- Maximised phenotypic and genotypic ranges within the sample population across which technologies are being calibrated and validated. Commercial flocks/herds are generally less variable, thus easier to predict.
- Direct comparison of different technologies that are attempting to predict the same trait.
- Using genetically defined animals has enabled predictions from measurement technologies to be directly uploaded into genetic databases, and the seamless assessment of their capacity to inform new or enhanced genetic tools.

Specifically, ALMTech II has either delivered or over-delivered on ten of its eleven scientific outputs and eight of its nine industry outputs. The outstanding outputs, **S(v)** and **I(iv)**—both with respect to an automated solution for assessing offal condemnation and other carcase defects—have progressed but still have a way to go before arriving at a technical solution that is commercially viable in a processing plant.

The project progressed through the COVID-19 pandemic, despite restrictions to travel and abattoir access. The project team turned challenges into newfound opportunities by productively refocusing their efforts into analysing data, planning experiments, and writing papers, while fortifying their vast network of Australia-wide and international collaborators, with several experiments undertaken on the team's behalf by industry staff located on-site. However, there were inevitable delays, most notably linked to the commissioning of a portable Computed Tomography (CT) device, now anticipated to be operational by mid-2023. Although this activity was not funded by ALMTech, the delayed commissioning of the portable CT particularly affected progress with validation of the beef DEXA system and 3D imaging system at Teys Rockhampton, which will now take place beyond the life of ALMTech II. Nonetheless, we have achieved the related scientific output **S(ii)** thanks to the roll-out and calibration of numerous lamb DEXA systems across Australia in addition to the beef DEXA system at Teys Rockhampton, calibrated simply via data captured off-site, and through manual bone-out data. Once it has been commissioned, the portable CT device will go a step further by providing a robust and transportable calibration of the beef DEXA and other lean meat yield prediction systems.

6.2 Recommendations

A *What Next After ALMTech?* workshop session during the 2022 Annual Review asked attendees to consider what ALMTech currently provides to industry and what gaps will be evident once ALMTech ends. Attendees arrived at an exhaustive list of 73 potential activities and research and development projects that could exist beyond ALMTech—many heavily adoption focused—which attendees anonymously ranked in priority order. The top 12 potential research and development projects were:

Rank	Potential R&D Projects
# 1	Live animal measurements of lean meat yield and eating quality
# 2	Support for / acceleration of the adoption of current ALMTech technologies
# 3	Development of new commercially important traits that describe aspects of carcase value
# 4	Support for data integration from technologies across the industry
# 5	Support for the adoption of in-abattoir tools such as the Lamb Value Calculator / Beef Value Calculator / Optimiser / Meat Logic
# 6	Continued support to develop industry capability of producers, agents and advisors through training
# 7	Continued Intramuscular Fat % work to inform AUS-MEAT and MSA marble score
# 8	Continued ALMTech support for centralised technology development and commercialisation
# 9	Capability building in terms of postgraduate, postdoctoral and career pathway development
# 10	Coordinated experiments specifically focused on optimising the value of the Resource Flock and BINS kills
# 11	Support for the use of data flow from objective measurement into genetic evaluation
# 12	Continued Industry Calibration Working Group and its associated Traits Manual; continued support for AMILSC, AUS-MEAT and the Supply Chain task force

The workshop highlighted an ongoing need for an industry-aligned collaborative group to provide a central, coordinated experimental structure to support the development, accreditation, and commercialisation of future objective measurement technologies. It also identified the following range of research ideas, which represent the core of a potential future project for the livestock industry RDCs to consider.

Potential new traits to be developed include:

- Oleic acid % or unsaturated fat % or fat softness – beef
- Marble fineness – beef
- Fresh shear force – lamb & beef
- Circularity of eye muscle area – beef
- Distribution of IMF% in striploins and other cuts – beef
- AUS-MEAT marble scores 10 to 15 – beef

Potential issues to solve regarding technology transfer and adoption include:

- Integrating technology into commercial practice
- Managing technology software and hardware updates
- Deciding business rules around new technologies
- Developing producer adoption programs
- Providing value proposition of new technologies for clients

Potential issues to solve regarding carcase and live animal evaluation include:

- Determining value of knowing grading outcome (other than pH and rib fat) at slaughter
- Determining shear force of fresh meat
- Measuring IMF% more accurately in live animals for genetics and days-on-feed optimisation
- Determining the value of carcase yield to on-farm efficiency and CN30
- Ongoing work in traceability

Potential issues to solve regarding genetic improvement include:

- Determining the genetics of offal and animal health

- Using DNA technology to find genetic outliers

Potential issues to solve regarding animal health include:

- Developing new carcase measures of livestock wellbeing

Potential technologies and tools to be developed include:

- NMR lamb IMF% hot
- NMR beef IMF% hot
- NMR beef & sheep live IMF%
- LEAP hyperspectral – lamb IMF%
- Ultrasound – live IMF%

7 Appendix

7.0 Activity Work Plan

7.1 Monitoring & Evaluation Plan

7.2 Communications Plan

7.3 Risk Assessment Spreadsheet

7.4 Early Career & Trainee Scientists

7.5 Newsletter Archive

7.6 Extension Activity Log

7.7 Media & Publications Log

7.8 Intellectual Property Register

7.9 Economic Evaluation Report

7.10 Annual Operational Plans

7.11 Technical Reports by Program

Please note that the following Technical Reports that have been marked as '**CONFIDENTIAL**', due to commercially sensitive content, have been withheld from the public version of the **ALMTech II Final Report** and reside in the full version as archived with Meat & Livestock Australia.

Program Executive

Sub-program E.2 Communication and extension activities

KPI 2.3 Meat Science Journal Special Edition 2021 Papers

1. Objective measurement technologies for transforming the Australian & New Zealand livestock industries
2. Objective grading of eye muscle area, intramuscular fat and marbling in Australian beef and lamb
3. A global calibration model for prediction of intramuscular fat and pH in red meat using hyperspectral imaging
4. Robustness of hyperspectral imaging and PLSR model predictions of intramuscular fat in lamb *M. longissimus lumborum* across several flocks and years
5. Non-invasive spectroscopic and imaging systems for prediction of beef quality in a meat processing pilot plant
6. Long term performance of near infrared spectroscopy to predict intramuscular fat content in New Zealand lamb
7. Intramuscular fat prediction of the semimembranosus muscle in hot lamb carcases using NIR
8. Association between visual marbling score and chemical intramuscular fat with camera marbling percentage in Australian beef carcasses
11. Towards real-time assessment of intramuscular fat content in meat using optical fibre-based optical coherence tomography
12. Prediction of consumer palatability in beef using visual marbling scores and chemical intramuscular fat percentage
13. The potential for dual energy X-ray absorptiometry to predict lamb eating quality
14. Dual energy X-ray absorptiometry predicts lamb carcass composition at abattoir chain speed with high repeatability across varying processing factors
15. Using dual energy X-ray absorptiometry to estimate commercial cut weights at abattoir chain-speed
16. Lean meat yield estimation using a prototype 3D imaging approach
17. Ultrawide band microwave system as a non-invasive technology to predict beef carcase fat depth
18. Prediction of lamb carcase C-site fat depth and GR tissue depth using a non-invasive portable microwave system
19. Capturing lean distribution in lamb carcases is of more value to the processor than the breeder

20. A prototype rapid dual energy X-ray absorptiometry (DEXA) system can predict the CT composition of beef carcases

Sub-program E.4 General management of technology calibration

Sub-program E.4 Summary Report

KPI 3.6 A carcase composition trait for sheep meat grading technologies

KPI 3.6 A suggested change for accreditation experiment guidelines for cut surface grading technologies

KPI 3.6 Accreditation of destructive or fixed-installation technologies predicting beef rib-eye traits

KPI 3.6 Accreditation standards for cut surface camera grading technologies

KPI 3.6 Accuracy and accreditation standards for IMF% devices in beef

KPI 3.6 Accuracy and accreditation standards for IMF% devices in lamb

KPI 3.6 Amendments to the accreditation standards for IMF% in sheep meat

KPI 3.6 Appendix 3. Analysis of grader accuracy **CONFIDENTIAL**

KPI 3.6 Appendix 6. Transforming IMF% into AUSmb & MSAmb

KPI 3.6 Development of homogeneous, stable meat reference materials for beef & lamb across a range of CL levels - Milestone 1

KPI 3.6 Development of homogeneous, stable meat reference materials for beef & lamb across a range of CL levels - Milestone 2

KPI 3.6 Development of homogeneous, stable meat reference materials for beef & lamb across a range of CL levels - Milestone 3

KPI 3.6 Development of homogeneous, stable meat reference materials for beef & lamb across a range of CL levels - Milestone 4

KPI 3.6 A carcase composition trait for sheep meat grading technologies

KPI 3.6 Amendments to the accreditation standards for IMF% in sheep meat

KPI 3.6 Repeatability of chloroform Soxhlet calibrated laboratory based NIR determination of chemical fat% in beef

KPI 3.25 Variation of intra-muscular fat within the M. longissimus lumborum of lamb

KPI 7.1 Updated validation performance of lab-based NIR spectroscopy method against chloroform Soxhlet extraction for determination of chemical fat in lamb & beef

Program 1

Sub-program 1.1 Develop live measurement of LMY

Sub-program 1.1 Summary Report

KPI 1.16 Continued improvement of the MiS operating system and algorithm

KPI 2.6 Validation of a prototype microwave device to measure fat depth at the rib and P8 sites

on live cattle and validate against the corresponding ultrasound and abattoir measurements

KPI 2.7 Ability of live microwave scanning in sheep to predict whole body fat composition as determined by live DEXA scanning

KPI 2.7 Report on antenna and probe design for portable microwave system

Sub-program 1.2 Develop carcase measurement of LMY (direct)

Sub-program 1.2 Summary Report

KPI 3.11 AUS-MEAT accredited lamb DEXA algorithm performance

KPI 3.11 DEXA Bone detection algorithm for lamb carcases

KPI 3.11 Initial analysis of lamb DEXA predicting GR tissue depth

KPI 3.11 Lamb DEXA accreditation submission to AMILSC on behalf of Scott Automation and Robotics

KPI 3.11 Standardised methodology for sampling & image analysis, & validation resource data for CT as the calibrating standard for LMY measurement

KPI 3.11 WAMMCO DEXA calibration

KPI 3.12 Bridging of beef DEXA images to provide LMY feedback

KPI 3.12 DEXA prediction of lean beef trim

KPI 3.12 Potential for applying DEXA prediction as feedback at the Teys Rockhampton abattoir

KPI 3.13 The value of precise cut weight prediction in the optimisation of lamb carcase processing

KPI 3.13 DEXA rack weight prediction at WAMMCO Katanning **CONFIDENTIAL**

Sub-program 1.3 Develop carcase measurement of LMY (indirect)

Sub-program 1.3 Summary Report

KPI 1.14 PorkScan Plus + predicting ultrasound P2 **CONFIDENTIAL**

KPI 1.19 3D imaging in beef carcase LMY

KPI 1.20 Capability of integrated hyperspectral and 3D imaging cameras to determine subcutaneous fat depth and cover

KPI 2.17 Report on the ability of a microwave device to predict rib fat and P8 fat depth in beef carcases

KPI 2.17 On-farm and abattoir suitability of microwave scanner system design

KPI 2.17 Report on the ability of a prototype microwave device to predict multiple traits in lamb

KPI 3.14 Compare objective carcase measurement technologies for pig classification systems

KPI 3.14 PorkScan AutoFom Hennessy CT report **CONFIDENTIAL**

Program 2

Sub-program 2.1 Commercialise technologies for grading EQ in beef & lamb carcases

Sub-program 2.1 Summary Report

KPI 3.21 Report on the integration of a hyperspectral camera with Scott's LEAP system and MSA Mk II lamb grading model **CONFIDENTIAL**

KPI 3.22 Report on AUS-MEAT accreditation of performance of the MasterBeef system **CONFIDENTIAL**

KPI 3.22 Report on AUS-MEAT accreditation of performance of VIAScan CAS **CONFIDENTIAL**

KPI 3.22 Report on impact of environmental factors (i.e., bone smear, temperature) on prediction of lamb cut surface traits by a hyperspectral camera (prior to LEAP installation) **CONFIDENTIAL**

KPI 3.22 Report on the calibration and validation of the Frontmatec commercial camera in beef **CONFIDENTIAL**

KPI 3.22 Report on the desktop calibration repeatability and validation of a hyperspectral camera (prior to LEAP installation) **CONFIDENTIAL**

KPI 3.22 Report on the precision and accuracy of the Frontmatec grading camera against AUS-MEAT camera accreditation requirements **CONFIDENTIAL**

KPI 3.24 Report on AUS-MEAT Accreditation of SOMA predicting chemical IMF% in lamb **CONFIDENTIAL**

KPI 3.24 Report on the validation performance of the MEQ probe to predict IMF% in MLA Resource flock lambs **CONFIDENTIAL**

Sub-program 2.2 Develop & validate new EQ technologies

Sub-program 2.2 Summary Report

KPI 1.28 Measuring lamb meat stiffness using optical coherence elastography **CONFIDENTIAL**

KPI 2.25 Report on a plan for the calibration and validation of the commercial OCT prototype **CONFIDENTIAL**

KPI 2.25 Report on a plan for the validation of the SOMA NIR device in lamb **CONFIDENTIAL**

KPI 2.25 Report on PLS and Machine Learning for the ASD NIR prediction of IMF in lamb **CONFIDENTIAL**

KPI 2.25 Report on the updated calibration and validation of the SOMA NIR device for IMF% in lamb **CONFIDENTIAL**

KPI 2.26 Report on the initial calibration performance of Optical Coherence Tomography predicting chemical IMF% lamb **CONFIDENTIAL**

KPI 3.24 Report on the independent validation and repeatability of the SOMA device **CONFIDENTIAL**

KPI 3.24 Report on the relationship between fatty acid profile and consumer sensory scores

KPI 3.26 Report on the ongoing validation and repeatability of the MasterBeef system for measuring IMF% in lamb **CONFIDENTIAL**

KPI 3.26 The association of DEXA images with lamb eating quality

KPI 3.26 Ultrasonic assessment of intramuscular fat percentage in beef and lamb loins at 37ºC

KPI 3.27 Report on calibration and initial validation of devices predicting IMF% and other traits in pork

Program 3

Program 3 Summary Report

KPI 2.29 Rapiscan RTT-110 system upgrade accuracy validation CONFIDENTIAL

KPI 2.30 Livestock offal inspection and sortation with multi-sensor platforms in abattoirs CONFIDENTIAL

Program 4

Sub-program 4.1 Develop data flow to industry information delivery systems

Sub-program 4.1 Summary Report

Sub-program 4.2 Data flow to industry genetic evaluation systems

Sub-program 4.2 Summary Report

KPI 2.32 Genetic analysis of MIJ traits in beef and their potential to manipulate IMF traits genetically **CONFIDENTIAL**

KPI 3.30 Analysis of eye muscle dimension data sourced from direct carcase measures and those obtained from CT images

KPI 3.30 Genetic analysis of DEXA measured lean meat yield

KPI 3.30 Preliminary genetic parameters and viability of microwave predictions of carcase C-site fat depth

KPI 3.30 Report on the preliminary analysis of model refinement for the genetic evaluation of shear force in lamb

KPI 3.30 Value of data from commercial ram breeders' flocks as an industry reference population for Australian sheep

Program 5

Program 5 Summary Report

Sub-program 5.1 Enhance carcase value tools

KPI 2.34 Reverse engineering the Carcase Optimisation Tool to determine lamb value

KPI 2.36 Re-analysis of beef carcase pricing data with less variation in yield in carcases analysed

KPI 2.43 Lamb Carcase Optimisation Tool Cut Tree Hierarchy

KPI 3.31 A framework to ensure data integrity to support the commercial implementation of dual-energy X-ray (DEXA) systems and data use in red meat processing

KPI 3.31 Commercial use of DXAFat% in-plant to predict shortloin fat cap depth and sort lamb carcases to minimise fat trimming **CONFIDENTIAL**

KPI 3.31 Development of an integrated prediction algorithm for carcase fat using DEXA installed on the hot slaughter chain to support real-time sortation decisions by Frew Foods International **CONFIDENTIAL**

KPI 3.32 Case study on the implementation of GMP's value-based pricing grid for lambs **CONFIDENTIAL**

KPI 3.33 Summary of yearly, monthly, daily and between and within lot variation in MSA carcase data

KPI 3.33 Value-based pricing system based on carcase yield and eating quality traits

KPI 3.34 Capacity of the LVC to predict cut weight using DEXA lean estimates in a commercial environment at GMP **CONFIDENTIAL**

KPI 3.34 A case study in carcase optimisation in a domestic supply chain **CONFIDENTIAL**

Sub-program 5.2 Enhance data decision tools

KPI 2.39 The tactical model in optimization of boning room management

KPI 3.33 Beef primal cut weight prediction from diverse breed crosses

Sub-program 5.3 Enhance supply chain efficiency and engagement

KPI 2.42 PGS Mentoring Lamb Compliance

KPI 3.35 Final Report of The Supply Chain Group – 2020 to 2022

KPI 3.36 Benchmarking flock performance within a value-based payment grid for lamb - a producer case study **CONFIDENTIAL**

KPI 3.36 Adoption through Supply Chain Engagement

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