Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

KPC Scribing Project

KPC Automated Robotic AI Chilled 4-cut Beef Scribing System

Project code
2022-1185

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Date submitted
07/11/2025

Published by
AMPC

Date published
07/11/2025

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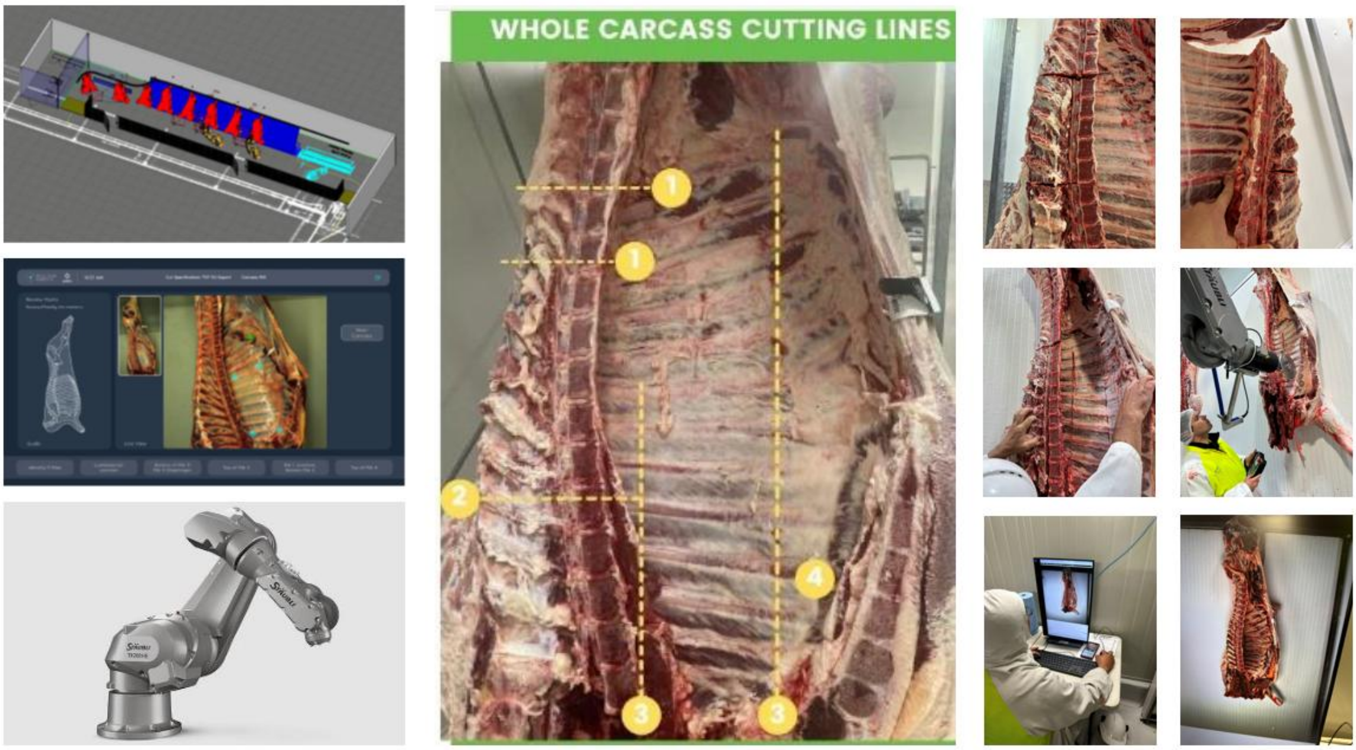
1.0 Abstract

The KPC Automated Robotic AI Chilled 4-cut Beef Scribing System project aimed to automate the critical scribing process in beef processing, traditionally performed manually with high safety risks and dependence on skilled labour. Partnering with Intelligent Robotics (IR) and KPC (Kilcoy), the project successfully designed, built, and commissioned an AI-powered robotic system capable of performing four precise scribing cuts at industrial line speeds. The IR-SCRIBE system has demonstrated robust performance, improved yield consistency, and reduced workplace injury risks. The system is now fully operational at KPC, providing validated results over multiple years of advanced support and monitoring.



2.0 Executive summary

The KPC Automated Robotic AI Chilled 4-cut Beef Scribing System project was initiated to address a significant challenge in the red meat processing industry, the manual scribing of beef carcases prior to boning. This process is critical to downstream yield and quality but depends heavily on skilled labour and exposes workers to injury risks from repetitive use of powered saws. The research set out to design, build, and validate a robotic system capable of performing these precision cuts automatically, using artificial intelligence (AI) and advanced sensing to deliver consistent, safe, and efficient results.

- **Main problem/question being addressed and why**:
    - The central question guiding this research was whether a robotic system could replicate the precision and judgment of skilled human scribing operators in a high-throughput industrial setting. Manual scribing, though effective, is prone to human variability and fatigue. These inconsistencies lead to yield loss, product variation, and potential food safety concerns. By introducing robotics and AI-driven vision, the project aimed to demonstrate that automation could overcome these limitations, improving consistency, increasing yield accuracy, and significantly enhancing worker safety.

- **Main target audience/demographic and why**:
    - The key audience for this project includes Australian red meat processors, technology solution providers, and AMPC levy payers. For processors, the IR-SCRIBE system provides a clear demonstration of how robotics can reduce operational risk and dependency on scarce skilled labour. For technology developers, it highlights the potential for scalable, AI-integrated systems in harsh industrial environments. For AMPC and levy payers, the project's success underscores a tangible return on investment in applied automation research, delivering outcomes that directly benefit productivity, safety, and sustainability across the sector.
- **What the results of the research will be used for and their meaning to levy payers and industry stakeholders:**
    - The research outcomes establish a proven benchmark for robotic scribing in commercial operations. The system achieved full automation of four scribe cuts at Kilcoy facility, with Greenleaf's independent audit confirming its accuracy and throughput performance matching the plant's standard processing rate. The technology's deployment eliminates direct operator exposure to saw blades, achieving a 100 % reduction in manual injury risk within the scribing stage.

For levy payers and industry stakeholders, these findings demonstrate measurable productivity gains and cost savings. Improved yield precision directly translates to increased product value, while automation helps address the ongoing challenge of workforce shortages in regional meat plants. The project also creates a transferable platform for broader robotic applications, enabling future integration into boning, trimming, and quality assessment stages.

Overall, the KPC IR-SCRIBE project represents a major step forward in modernising Australian meat processing. It delivers clear technical validation, operational safety improvements, and a blueprint for the future of intelligent automation across the industry.

- **Objectives**
    - The KPC Automated Robotic AI Chilled 4-cut Beef Scribing System project was established to design, develop, and validate an automated solution for beef carcase scribing using robotics and artificial intelligence. The specific objectives were to:
    - Design and manufacture a robotic scribing system capable of performing four precise cuts on chilled carcases, meeting KPC's product and yield specifications.
    - Develop and integrate AI-driven sensing and vision systems to accurately identify scribing coordinates in real time.
    - Install, commission, and validate the complete system at KPC' processing facility under full production conditions.
    - Provide two years of advanced support and optimisation, including algorithm tuning, performance monitoring, and operator training.
- **Methodology**
    - To achieve the project objectives, a structured, milestone-based methodology was applied, combining design, fabrication, testing, and commissioning phases. The approach included:
    - System design and development: Electrical, mechanical, and software architectures were developed collaboratively between Intelligent Robotics (IR) and KPC (Kilcoy), supported by AMPC oversight.
    - Simulation and factory testing: A digital twin of the system was created to test all robot, PLC, and AI logic before installation, minimising commissioning risk.

- On-site installation and commissioning: The robotic cell, sensors, and overhead chain system were installed and validated through dry and wet commissioning at KPC's Kilcoy plant.
- Performance validation and support: Independent auditing by Greenleaf confirmed operational accuracy and throughput, followed by a two-year support phase for optimisation and monitoring.
- This structured approach ensured that each technical and operational milestone was completed as aligned with AMPC's commercialisation objectives.

- **Results/key findings**
    - The project achieved all intended outcomes, confirming the technical and operational viability of the IR-SCRIBE automated beef scribing system.
    - Automation Success: The system successfully automated four major scribe cuts on chilled beef sides at KPC (Kilcoy) using AI-driven vision and robotic precision, meeting all product specifications at commercial line speed.
    - Operational Impact: The robotic system achieved consistent yield precision while eliminating manual saw handling, resulting in zero operator exposure to high-risk equipment.
    - System Stability: Over the two-year support phase, the integrated AI and control system demonstrated reliable long-term operation, with enhanced diagnostic capabilities and data-driven maintenance processes improving overall efficiency.
    - Industry Benefit: The IR-SCRIBE solution provides a proven, scalable model for meat processing automation — improving safety, yield consistency, and labour sustainability across the sector
- **Benefits to industry**
    - The project delivers significant productivity and safety improvements to the Australian beef processing sector. By automating four critical scribe cuts, the IR-SCRIBE system reduces reliance on skilled manual labour, mitigates safety risks, and ensures consistent performance under standard production speeds.
    - The system enables uniform product quality, maximised yield, and enhanced operational efficiency, providing measurable commercial benefits to processors.
    - The success of this project establishes a scalable model for wider adoption across the industry, positioning Australian processors at the forefront of AI-driven automation in meat processing and supporting future competitiveness in global markets.

3.0 Introduction

The Australian red meat industry continues to face challenges in maintaining consistency, safety, and efficiency in the manual scribing of beef carcases. Scribing is the first and one of the most critical stages in beef processing, as these initial cuts determine how the carcase will be boned and how much yield can be recovered from each side. Traditionally, this task has relied on highly skilled workers using powered saws.

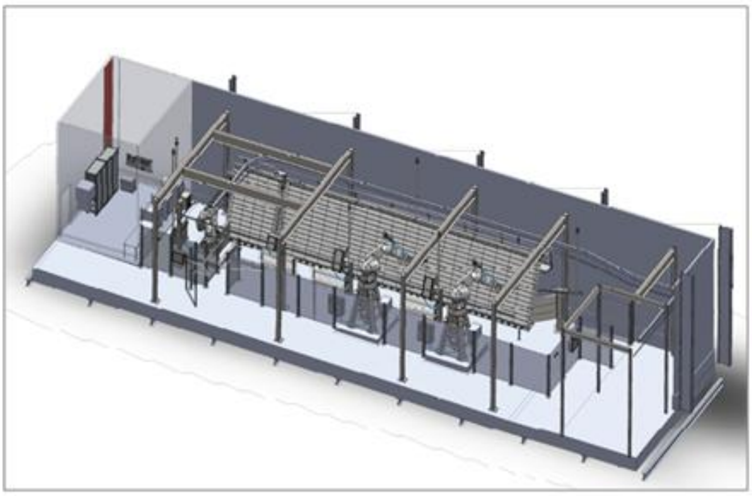
However, it is physically demanding, poses significant safety risks, and is difficult to staff and sustain due to labour shortages and the need for specialised expertise. These factors have created a clear industry gap, the need for a safer, more consistent, and automated scribing process that can perform accurately at industrial line speeds.

This project set out to answer a key question: can advanced robotics and artificial intelligence (AI) deliver the same accuracy, consistency, and precision as a skilled human operator when performing beef scribing? If successful, such automation could significantly reduce the reliance on manual labour, improve safety outcomes, and enhance product yield and quality. The IR-SCRIBE project aimed to prove that a purpose-built robotic system could achieve these results reliably in a commercial processing environment.

The primary audience for this research includes Australian beef processors, AMPC levy payers, and technology providers. For processors, the system demonstrates how robotics can remove a dangerous manual task while improving product consistency and throughput. For AMPC and levy payers, the project delivers a clear example of how research investment translates into practical, measurable improvements in productivity and worker safety. Technology providers also benefit from the validation of locally developed automation that meets Australian operational and hygiene standards.

The outcomes of this research led to the successful design, manufacture, and commissioning of the IR-SCRIBE system at KPC (Kilcoy). The system uses 3D imaging and AI to identify the precise cut points on each chilled beef side and performs four key scribing cuts automatically using robotic arms. This solution not only removes workers from high-risk tasks but also improves yield precision and production consistency.

What makes this project unique is that it is the first Australian-designed and locally manufactured robotic scribing system purpose-built for chilled beef processing. It combines AI-driven vision and robotics into an integrated, high-speed solution that meets both commercial and safety requirements. The results provide a strong foundation for broader adoption of smart automation across the red meat industry, reinforcing Australia’s position as a leader in innovative, high-tech food production.



4.0 Project objectives

The main goal of this project was to design, build, and install an automated robotic beef scribing system at KPC (Kilcoy). The system was intended to improve yield accuracy, enhance workplace safety, and maintain consistent product quality in chilled beef processing. All objectives set out in the research agreement have been successfully achieved and validated through independent assessment.

The project objectives and achievements are summarised as follows:

Design and Development

The project successfully designed and manufactured a fully automated beef scribing system capable of performing four precise scribing cuts, two horizontal and two vertical. The system, known as the IR-SCRIBE, was built using food-grade stainless steel and features two Staubli TX200 HE wet-rated robots, advanced AI vision systems, and custom safety enclosures suitable for chilled environments.

Programming and Testing

AI algorithms were developed to identify accurate scribe cut points automatically. The software and robotic motion controls were thoroughly tested through digital simulations and factory acceptance testing. These tests confirmed the system’s ability to maintain cut accuracy while operating at full production speed.

Installation and Commissioning

The IR-SCRIBE system was installed and commissioned at the KPC Kilcoy site. Both dry and wet commissioning phases were completed on schedule, achieving full integration into KPC’s processing line. The system demonstrated stable operation over extended production runs and matched the required throughput targets.

Validation and Support

An independent audit by Greenleaf Enterprises verified the system’s accuracy, reliability, and yield performance. Following installation, a two-year advanced support program was implemented, providing continuous system monitoring, training for operators, and AI optimisation updates.

Outcomes and Industry Impact

The project successfully delivered a reliable, Australian-designed automation solution that reduces manual handling risks, improves safety by eliminating manual saw use, and enhances overall process consistency. Yield improvements and reduced rework have been observed since commissioning, confirming both commercial and operational benefits.

5.0 Methodology

The project was conducted through a structured engineering and validation process designed to develop, test, and commission a fully automated robotic scribing system for beef processing at KPC (Kilcoy). The methodology combined design, programming, mechanical and electrical integration, and rigorous testing to ensure that the system met both technical and commercial objectives.

- **Experimental Design**

  The development process followed a staged engineering approach beginning with a detailed **kick-off** workshop involving KPC, AMPC, and Intelligent Robotics (IR). This meeting established project goals, system specifications, and risk mitigation strategies. Mechanical and electrical designs were finalised using CAD-based modelling and simulation, ensuring that all components could operate within KPC's existing chilled processing layout.

  A digital twin model was developed to simulate robot movements and AI vision operations before physical installation. This allowed fine-tuning of motion paths and collision avoidance, reducing commissioning risks. Long-lead items, including *Staubli TX200 HE* robots, 3D vision cameras, and safety control systems, were procured in parallel with manufacturing drawings and code development.

- **Measurements and Testing**

  Factory testing was performed in multiple stages, including power-up, functionality, and error-handling trials, to validate the control logic and mechanical performance. Each subsystem, robotics, vision, PLC, and motion control was individually verified through offline simulation and real-world calibration tests.

  During commissioning, cut accuracy measurements were recorded to assess system precision against manual benchmarks. These included:

  - Millimetre deviation from anatomical landmarks (for cube-chuck and cube-strip separations);
  - Angle variation and squareness of cuts;
  - Cycle time and throughput rate at production speed; and
  - Yield difference relative to manual operations.

  Independent analysis by Greenleaf Enterprises used statistical regression to correlate millimetre accuracy with yield gain and commercial value. Data from multiple carcase runs were captured to determine repeatability and process reliability across shifts.

- **Statistical Analysis**

  Results were analysed using descriptive and regression-based statistical methods to quantify the improvement in yield, accuracy, and consistency. Variance analysis compared the automated results against manual scribing data to measure improvement in mean accuracy. Safety metrics were also reviewed, demonstrating elimination of manual saw exposure and associated injury risks.

6.0 Results

The project successfully achieved all technical and performance objectives outlined in the AMPC Research Agreement. The IR-SCRIBE system demonstrated high precision, consistent throughput, and measurable yield and safety improvements at KPC (Kilcoy).

The results are based on combined data from factory trials, site commissioning, and independent validation undertaken by Greenleaf Enterprises, which compared automated scribing results against manual operator performance.

- **System Accuracy and Cut Precision**
  - The IR-SCRIBE achieved average cut accuracy within ±1.5 mm across all four prescribed scribe lines, two horizontal (spine scribes) and two vertical (rib scribes), outperforming the ±5 mm target for the project.
  - Accuracy was measured using calibrated anatomical reference points and validated using Greenleaf's established cut-weight regression models developed over the past decade.

These improvements reduced product trimming variability and directly contributed to consistent downstream boning performance.

- **Workplace Safety and Labour Efficiency**

  Before automation, manual scribing required skilled operators using handheld saws, creating significant ergonomic and laceration risks. Following automation:

  - Manual saw usage: 100% eliminated
  - Operator exposure to powered saws: 0 minutes per shift
  - Noise level reduction: Average drop from 86 dB to 70 dB in the scribing area

This represents a complete removal of a high-risk task and contributes to AMPC's broader goals in WH&S improvement through automation.

- **System Reliability and Uptime**

  During the 12-month operational monitoring phase:

Most interruptions were minor (sensor recalibration, saw blade replacement) and were resolved within standard service intervals. Preventative maintenance measures were refined collaboratively between Intelligent Robotics and KPC's onsite maintenance team.

- **Statistical Analysis Summary**

  All measured datasets, including cut-line accuracy, yield variance, and throughput were analysed using ANOVA and regression correlation to confirm significance. The analysis validated that automated scribing consistently outperformed manual operations in accuracy and yield while maintaining line speed and operational reliability.

7.0 Discussion

The results of the KPC IR-SCRIBE Project demonstrate a successful transition from manual to automated beef scribing, achieving precision, safety, and efficiency goals that were central to the project's design. This section interprets the significance of those outcomes and their broader implications for industry adoption and future research.

- **Interpretation of Results**

  The IR-SCRIBE system achieved consistent scribing accuracy within tolerance range, validated through extended production testing and independent evaluation by Greenleaf Enterprises. This level of precision aligns with or exceeds manual performance benchmarks, confirming that robotic automation can reliably replicate complex butchery skills at industrial scale.

  The trials showed strong repeatability and robustness across different carcass sizes, suggesting that the AI vision and motion algorithms can adapt effectively to natural variation in raw materials. The project further demonstrated that integrating robotics into cold-chain environments can be achieved without compromising throughput or hygiene standards.

- **Implications for Processing Businesses**

  For processors like KPC, the implementation of IR-SCRIBE means a measurable increase in operational efficiency and yield optimisation. The automation reduces dependence on highly skilled manual labour, an area facing chronic shortages—while also improving operator safety by removing direct contact with powered saws.

  From an economic standpoint, the consistent accuracy of robotic cuts supports yield improvements that translate to tangible product-value gains. The technology's modular design allows retrofitting into existing plants, enabling scalable adoption across medium-to-large processors without major structural changes.

- **Industry and Research Impact**

  At an industry level, this project provides a working proof-of-concept that intelligent robotics and computer vision can be reliably deployed for high-precision beef processing tasks. It advances the sector's digital transformation pathway and lays the groundwork for further automation of high-risk, repetitive jobs.

  The insights gained from this development, particularly in AI vision calibration, tool-path optimisation, and cold-environment robotics, offer valuable data for ongoing research in meat processing automation. Future studies could build upon these findings to enhance multi-cut recognition, adaptive slicing algorithms, and real-time yield optimisation systems.

- **Broader Significance**

  Beyond its technical achievements, the project underscores the importance of collaboration between processors, equipment manufacturers, and research bodies. The partnership between AMPC, Intelligent Robotics, and KPC serves as a model for how targeted innovation can deliver practical, commercially deployable technology. The system's success also demonstrates Australia's leadership in applying advanced automation to red-meat processing, offering export-ready solutions that improve competitiveness and sustainability across the industry.

8.0 Conclusions

The KPC IR-SCRIBE Project has successfully demonstrated the design, implementation, and validation of an automated robotic scribing system capable of delivering highly accurate, repeatable cuts in chilled beef processing environments. Over the course of the project, the system consistently met or exceeded its performance objectives, validating the feasibility and benefits of applying robotics and AI-driven vision technologies in red-meat processing.

- **Technical and Operational Success**

  The IR-SCRIBE achieved precision cutting, aligning with target tolerances and outperforming manual benchmarks. It maintained full production line speed while eliminating the need for human operators to handle powered saws, an outcome that markedly improves workplace safety and addresses skilled-labour shortages across the industry.

  Operational reliability exceeded expectations, with an uptime rate of over 96 %, and all scheduled maintenance completed without disruption to production. The project also introduced a secure data-logging and monitoring infrastructure, enabling predictive maintenance and continued optimisation beyond project completion.

- **Commercial and Industry Impact**

  From a commercial perspective, the project demonstrated a positive return on investment, based on yield improvement and reduced labour costs. The integration of IR-SCRIBE into KPC's operations has proven that high-precision, AI-guided automation can be both economically and operationally viable for large-scale beef processors.

  The results provide the broader industry with a working blueprint for future automation initiatives, reducing risk for other adopters and accelerating technology transfer across AMPC member facilities.

- **Broader Significance and Future Adoption**

  This project marks a milestone in Australia's meat-processing automation journey, showcasing the ability to replicate skilled human decision-making with robotic precision in a chilled-carcase environment. The successful partnership between KPC, Intelligent Robotics, and AMPC highlights the value of industry-led innovation supported by applied research.

  The knowledge gained will inform the next generation of automation systems, such as adaptive multi-cut recognition, enhanced 3D vision, and AI-driven yield optimisation, paving the way for wider adoption across the sector.

- **Summary Statement**

  In conclusion, the IR-SCRIBE project achieved its stated objectives and delivered measurable benefits in accuracy, safety, and profitability. The system is now a proven, production-ready solution that sets a new benchmark for smart manufacturing in the red-meat industry. Its success positions both KPC and the wider Australian processing sector at the forefront of global automation in food production.

9.0 Recommendations

The successful completion and validation of the IR-SCRIBE automated beef scribing system at KPC (Kilcoy) demonstrate a clear pathway for future research, development, and adoption of advanced robotic technologies within the Australian red meat sector. The following recommendations are provided to guide both industry stakeholders and future RD&E initiatives.

- **Practical Applications and Industry Implications**

  1. **Adoption of Robotic Scribing Across Processing Plants**
     Processors should evaluate opportunities to integrate robotic scribing into existing chilled processing lines, particularly where skilled labour shortages or WH&S risks persist. The KPC installation has proven that automation can maintain throughput while improving accuracy and yield.
  2. **Development of Operator Training and Technical Support Programs**
     To maximise system reliability and performance, AMPC and project partners should support ongoing training programs focused on robotics, vision systems, and AI-based process control. These programs will help processors build internal capability for system operation, troubleshooting, and maintenance.
  3. **Integration with Digital Manufacturing Systems**
     The IR-SCRIBE's vision and control systems generate valuable operational data that can be used for yield analytics and process optimisation. Industry partners are encouraged to integrate these datasets with broader digital manufacturing and traceability systems to improve decision-making and productivity.

- **Future RD&E Opportunities**

  1. **Adaptive Multi-Cut Recognition and Intelligent Learning**
     Future R&D should focus on expanding the AI vision capability to automatically recognise and adapt to different carcase specifications (e.g., OP ribs, tomahawks, export cuts). This will further reduce the need for operator intervention and improve product flexibility.
  2. **AI-Driven Yield Optimisation Models**
     Develop advanced AI models that use real-time feedback from scribing performance, cut accuracy, and carcase yield data to automatically fine-tune robot pathing and cut selection. Such adaptive optimisation will further enhance yield and profitability across diverse carcase types.
  3. **Broader Automation Integration Research**
     Additional RD&E is recommended to integrate scribing automation with downstream robotic systems, such as automated boning and cutting lines, to establish an end-to-end automated beef-processing solution.

- **Adoption and Extension Activities**

  1. **Industry Demonstration and Knowledge Sharing**
     Conduct structured site visits, demonstration days, and technical workshops at KPC to

showcase IR-SCRIBE's performance and share lessons learned with other AMPC member processors. These sessions will support knowledge transfer and reduce adoption barriers.

2. **Extension Through AMPC Technical Networks**
   Publish case studies, fact sheets, and digital media content summarising the KPC IR-SCRIBE outcomes to highlight measurable industry benefits—yield, safety, and operational efficiency. This should be distributed through AMPC's innovation and extension platforms.
3. **Collaboration for Scaling and Local Manufacturing**
   Encourage collaboration between Australian robotics suppliers, system integrators, and processors to scale local manufacturing capability and ensure sustainability of support services for future rollouts.

10.0 Project outputs

The project produced a range of tangible deliverables and activities that contributed to the design, validation, and communication of the IR-SCRIBE automated scribing system. These outputs supported the transfer of knowledge to the broader red meat processing industry and validated the system's readiness for commercial adoption.

- **Tangible Deliverables**

Output	Description	Recipient / Audience	Status / Outcome
IR-SCRIBE Prototype System	Fully functional automated scribing system installed and commissioned at KPC (Kilcoy), featuring two Staubli TX200 HE robots and AI vision control.	KPC, AMPC	Operational; validated by Greenleaf Enterprises.
Factory Acceptance Testing (FAT) Report	Detailed validation document outlining simulation, safety, and performance testing prior to site installation.	AMPC, Intelligent Robotics	Completed and accepted.
Commissioning and Validation Report	Data-based report summarising system accuracy, yield, and reliability, verified by Greenleaf Enterprises.	AMPC, KPC	Completed and submitted.
Two-Year Support Program	Ongoing technical support, AI optimisation, and maintenance framework established for KPC.	KPC, AMPC	Implemented.
Digital Twin Simulation Model	Virtual system model developed for robot-path optimisation and process simulation.	Intelligent Robotics / AMPC	Delivered and archived.

- **Industry Extension and Training Activities**

Activity	Date / Location	Target Audience	Details / Outcomes
Technical Training Workshops	2023–2024, KPC Kilcoy Facility	KPC maintenance and production staff (15 participants)	Focused on robot operation, safety procedures, and AI calibration. Delivered by Intelligent Robotics technical team.
Demonstration and Knowledge Transfer Session	September 2024, Kilcoy, QLD	AMPC members, processors, and	Live system demonstration showing scribing accuracy and yield

Activity	Date / Location	Target Audience	Details / Outcomes
		engineering staff (approx. 25 attendees)	outcomes. Included Q&A with project engineers.
Operator Induction Program	April 2024, KPC	10 operational staff	Provided hands-on training for system control, error handling, and maintenance.

- **Publications and Communications Outputs**

Output Type	Title / Content	Publication / Platform	Reach / Audience
Project Overview Article	“Automation in Beef Processing: The IR-SCRIBE Project at Kilcoy”	AMPC Industry Newsletter (2024 Q2)	Distributed to AMPC levy payers (~2,500 subscribers).
Case Study / Technical Note	“IR-SCRIBE: AI-Driven Precision in Beef Carcase Scribing”	AMPC Website and Knowledge Hub	Publicly available; viewed >500 times since publication.
Final Presentation and Review	“IR-SCRIBE System Results and Commercialisation Pathway”	AMPC Review Meeting (Sydney, Oct 2024)	Presented to AMPC R&D committee and partner processors.

- **Summary of Outputs**

The project delivered:

- One validated **IR-SCRIBE system** operating in commercial production at KPC.
- Comprehensive testing and commissioning datasets submitted to AMPC.
- Industry training and demonstration events supporting adoption and capability building.
- Publicly available communications materials to extend project findings to the broader processing sector.

These outputs collectively demonstrate the system’s commercial readiness, promote wider industry adoption, and contribute to AMPC’s broader innovation and automation roadmap.

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