final report

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Prepared by: James Charnley

Scott Automation and Robotics

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Meat and Livestock Australia Limited

Locked Bag 1961

NORTH SYDNEY NSW 2059

LEAP VI – Automated FQ Deboning System Stage 1 Concept Development

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Executive Summary

The objective of this product was to develop concepts for automated de-boning of lamb forequarters. This was achieved by first reviewing various Australian methods of manually de-boning lamb forequarters. These results informed the conceptual design of the proposed automated FQ processing solutions. Some of the key components to these high level concepts were tested by hand, using new processes and tools. From the results of these on-site experiemtns, two high level concept design(s) have been developed. An application for the next stage of development in this space will be submitted to MLA/AMPC for consideration.

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1 Background

For the past thirteen years Scott Technology has been developing their vision of a fully automated bone-in lamb concept jointly with Meat and Livestock Australia (and supported by various Australian processors) as depicted in Fig. 1. All components of this vision have had a first phase R&D development executed with resulting equipment output. A large proportion of the vision being commercialised (and continuing to be commercialised) in Australian meat processing facilities.

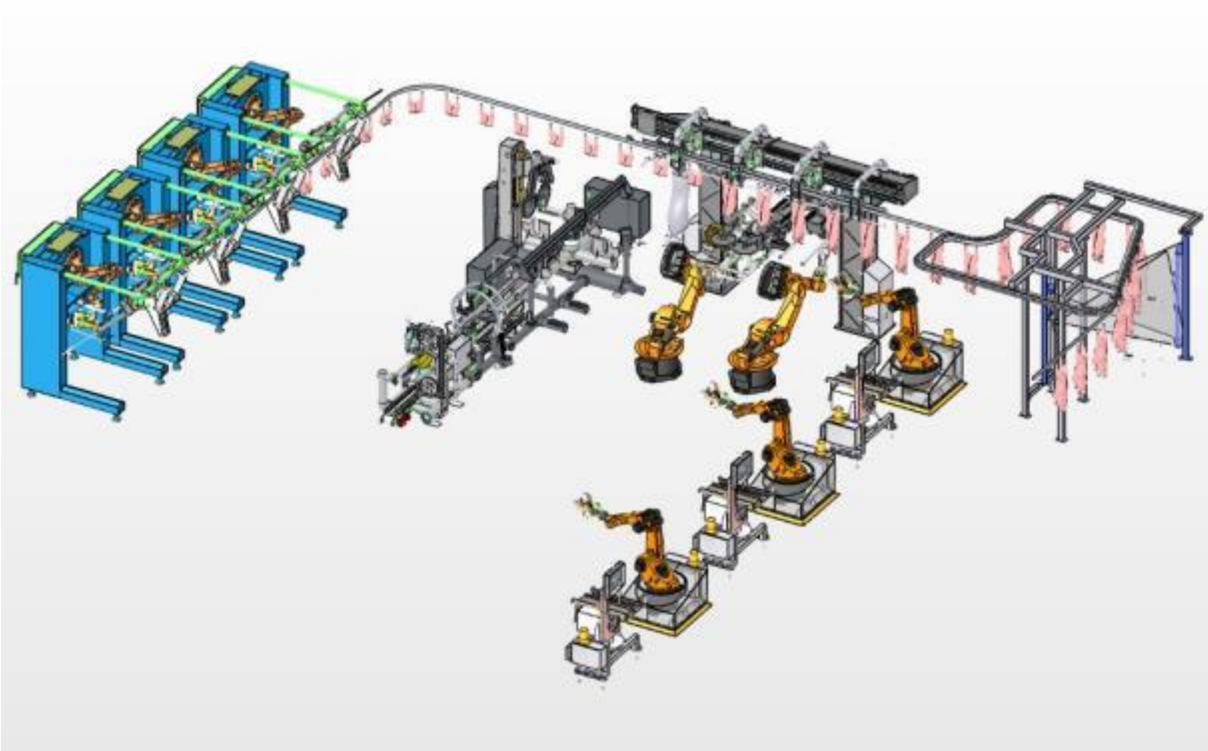

Fig. 1: Boning Room Vision (fully automated bone-in room)

At a high level the areas of a boning room are depicted in Fig. 2. The Fig. 1 vision (and resulting equipment) is down in Fig. 2 as “bone-in processing”. It can be ascertained from Fig. 2 that the next step in lamb boning automation is boneless automation.

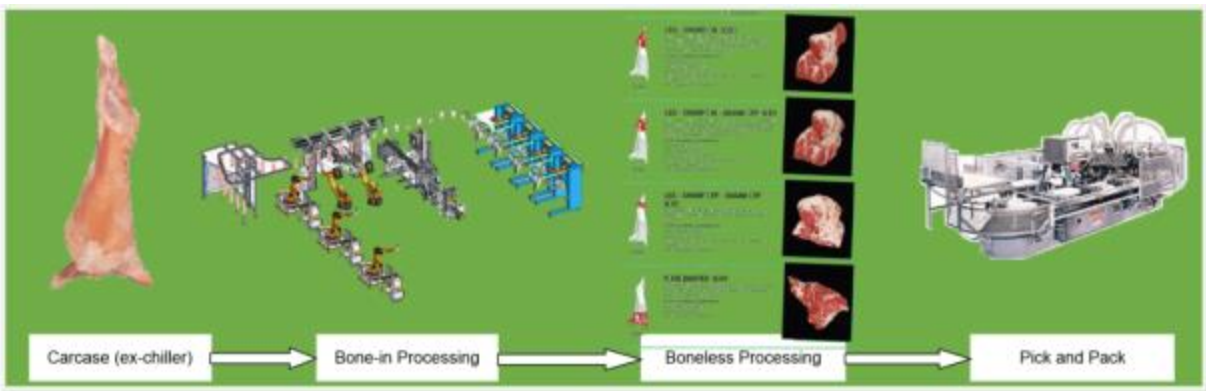

Fig. 2: Entire boning room process

JBS and ALC senior management have seen the Sunshine and Bordertown installations as a success from the perspective that MLA automation investments of the past can realise significant commercial benefits within a processing environment, and now want to take automation in lamb another significant step forward. As a result JBS and ALC now want to undertake new blue sky R&D with Scott and MLA/AMPC on areas of lamb automation that extend past the Fig. 1 bone-in vision, and commence automated boneless forequarter processing developments – Fig. 3 red circle.

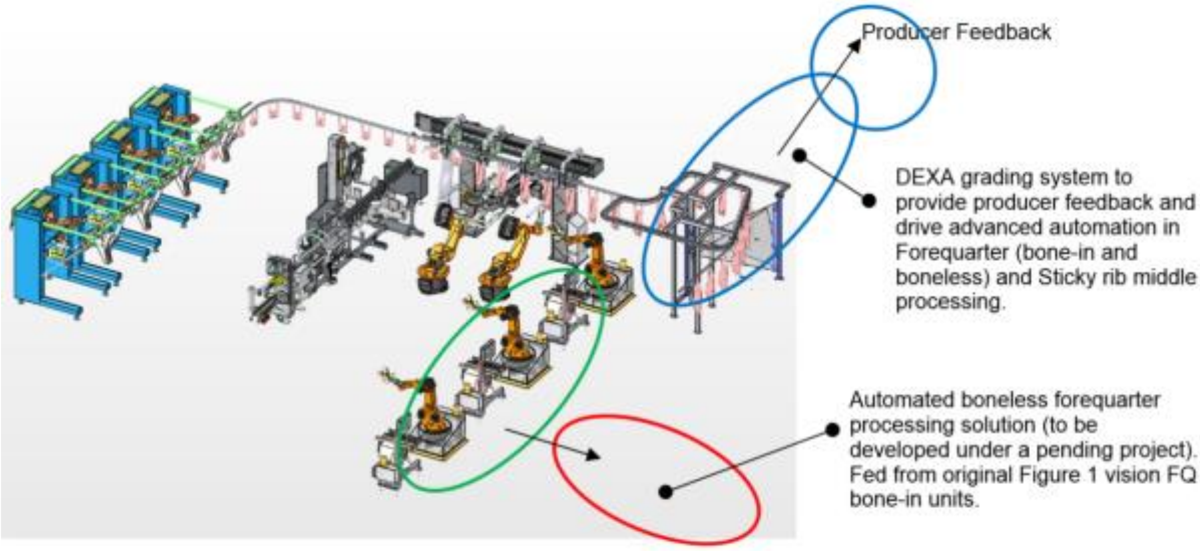

Fig. 3 Boning Room Vision (fully automated bone-in room, with producer feedback and boneless forequarter processing).

2 Project Objectives

At the conclusion of the project, ALC, JBS and Scott will have:

- Undertaken a high level review of the different Australian ways to debone a lamb forequarter (At JBS and ALC as a start),
- Developed various high level concepts of possible automation approaches to deboning of lamb forequarters, and
- Provided a final high level design(s) with budgets and application for the next stage to MLA/AMPC for consideration.

High level designs will look something similar to the 3D image in Fig. 1 (but not design).

3 Methodology

3.1 Review of Manual Forequarter Deboning Process from Automation Perspective

Site visits to JBS Brooklyn, JBS Bordertown, ALC Sunshine and ALC Colac where undertaken to document and record boneless forequarter specifications from an automation perspective.

All four sites utilise the four rib bone-in forequarter as the starting basis for boneless forequarter processing. The four rib forequarter from the Scott X-ray Primal can then either be used for bone-in or boneless cuts as depicted in Fig. 4.

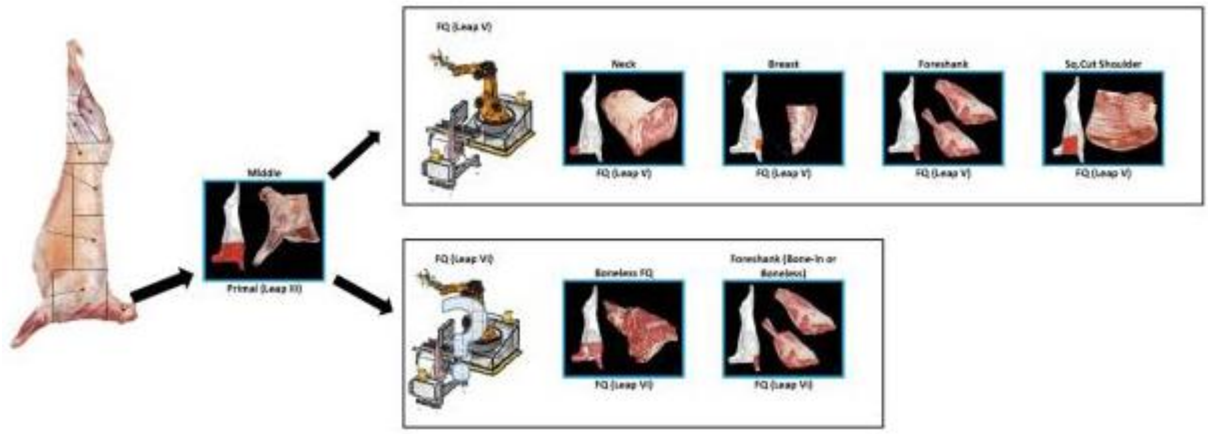

Fig. 4: Lamb forequarter processing cuts.

The traditional manual process for deboning a lamb forequarter is depicted in Flowchart 1 below and overleaf.

Flowchart 1 Lamb Forequarter Deboning – Traditional Manual Process

1. Place the forequarter on deboning table with back bone closest to boner.	
2. Mark/fleece down either side of the featherbones and neck bones.	
3. Rotate the forequarter and mark/fleece along the rib cage from the back bone to the end of the ribs down to the brisket/breast cutting line and then scribe along the brisket/breast cutting line.	

4.	Invert the forequarter and continue to mark/fleece the foreleg from the ribcage and neck bones.	
5.	First leg removed from rib cage and neckbones	
6.	Repeat second let removal process.	
7.	Removed rib cage and neck bones from two front legs.	

8. Trim excessive fat from under-breast area.

9. Trim excessive fat from front-breast area.

10. Trim excessive fat from front-breast area

11. Commence removing foreleg with scapula (shoulder bone) from forequarter meat.

12.	Continue leg removal.	
13.	Conclude leg removal.	
14.	Fat trim to specification.	
15.	Finished product. Note: The removed bone in forelegs can now also be processed as bone-in or boneless.	

3.2 Development of Design Scope for Approval by ALC, JBS and MLA

After discussions with both ALC and JBS, all agreed that if steps 1 to 7 inclusive, and if possible steps 11 to 13 inclusive could be substantially automated, then the easier trimming tasks could be conducted by operational staff. Thus the design scope for the remainder of the project had been identified.

There were two development approaches that were considered

1. Automate what is currently undertaken manually as depicted in the flowchart above.
2. Incorporate a solution as part of a bone-in processing solution (either the current Scott robotic forequarter process or the pending linear forequarter processing solution).

The later would allow greater utilisation of a Scott bone-in forequarter machine during a production day. Hence, if a dedicated machine is built for boneless and it is standalone/not integrated with the Scott forequarter bone-in solution then the FQ bone-in solution will be idle when JBS/ALC process boneless and vice versa.

Hence the design/approach options are:

- Option 1 – Standalone (not-integrated) Boneless FQ processing cell
- Option 2 – Integrated Bone-in & Boneless FQ linear processing system
- Option 3 – Integrated Bone-in & Boneless FQ robotics processing system

Fig. 5 below depicts how the bone-in and boneless processing solutions can integrate with each other.

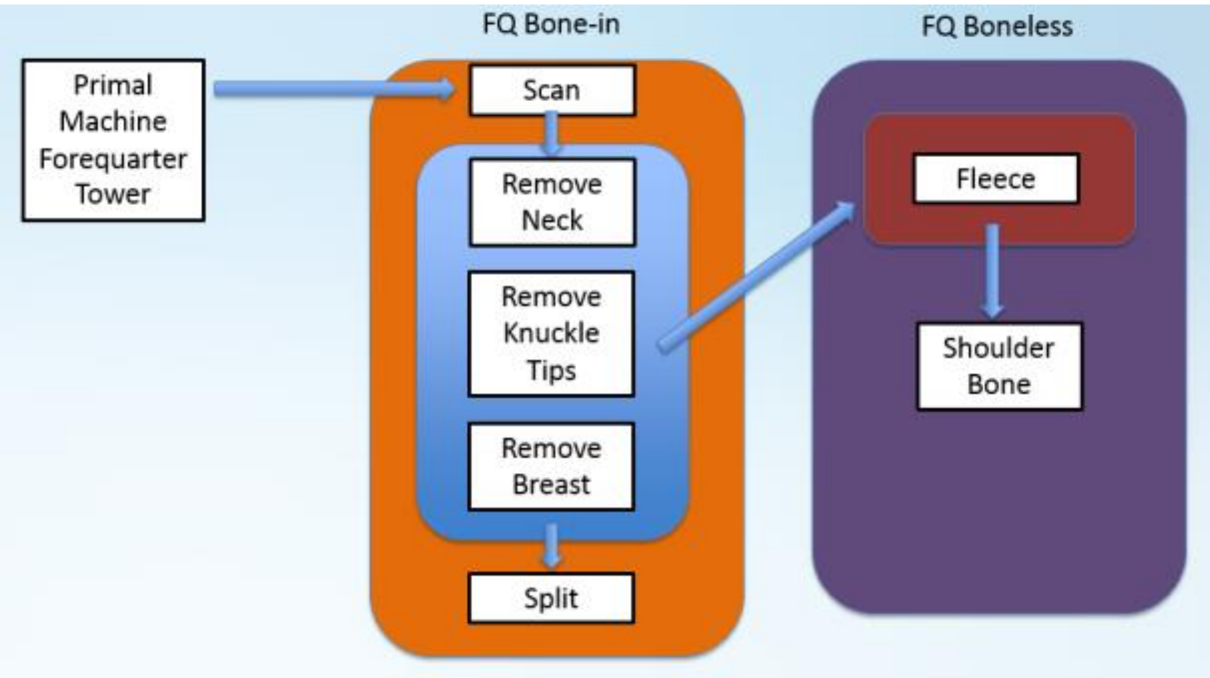

Fig. 5: Forequarter Bone-in and Boneless processing possible integration.

3.3 Boning Experiments and High Level Concept Drafts

A series of boning experiments were conducted at contributing processer sites. These experiments involved taking both intact forequarters and partially processed forequarters (with neck and breast removed beforehand) and stepping through each stage of the deboning process using tools and techniques that could be incorporated into an automated solution.

3.3.1 Proposed Automated Deboning of Unmodified Forequarter

Flowchart 2 below depicts key stages of one of the experimental processes conducted to simulate the automated deboning of an unmodified forequarter.

Flowchart 2: Lamb Forequarter Deboning – Approximation of Automated Deboning of Unmodified FQ

1. Scribe along both sides of the feather bones.	
2. Scribe the breast separation line.	

3. Use the neck removal tool to drill the neck out of the forequarter.	
4. The removed neck.	
5. Knife and peal the forequarter meat off of ribs. Repleat for the seconds half.	
6. Process results in 4 pieces: 1. Neck, 2. Left side forequarter meat, 3. Right side forequarter meat, 4. Rib cage, chine and feather bones.	

3.3.2 Proposed Automated Deboning of Semi-Processed Forequarter

Flowchart 3 below depicts key stages of one of the experimental processes conducted to simulate the automated deboning of a semi-processed forequarter. This forequarter has had the neck, shank tips and breast plate removed. Product could be pre-processed to this state using the existing Lamb Forequarter Bone-in Automated System.

Flowchart 3: Lamb Forequarter Deboning – Approximation of Auto Deboning of Semi-Processed FQ

1. The neck could be removed using the Lamb Forequarter Bone-in Robot

2. The shoulders are removed first. This was conducted manually but could have been conducted using a robot.

3. The front breast of the FQ is removed. This could also have been conducted on the bone-in robot.

4. The ribs are cut to length. This task could have been conducted by the FQ Bone in Robot.

5. Due to the width of the chain on the current LCBS, the first rib could not fit onto the chain. Future LCBS or upgrades to existing machines would allow for processing of all 4 ribs.

6. The remaining part was processed on the unmodified LCBS, with the results show below.

3.3.3 Procesing the Loin, Rack and FQ ribs on the LCBS in a Single Pass

The possibility of a completely new processing technique came to light while these experiments were being conducted.

1. The forequarter and middle cut (usually performed on the head saw), would not need to be conducted.
2. The shoulders would be removed at this point.
3. A new cut, ahead of the first rib, would remove the front breast and the neck.
4. The remaining middle and forquarter (All ribs and loin) could then be processed on a modified LCBS.

How exactly the loins would present after this processing technique requires more experimentation. However, if the CFO process does not produce a acceptable loin product, the loin could always be removed before processing on the LCBS.

Some experiments have already been undertaken, results of which are shown below in Flowchart 4.

Flowchart 4: Producing CFO Loin, Rack and FQ ribs on the LCBS in a Single Pass

1. In this example only ribs 2-12 were processed. You can see rib 1 forward have been removed so that the remaining ribs can fit on the original LCBS.	
2. Ribs 2-12 loaded on the the original LCBS.	

3. The results of processing ribs 2-12 on the LCBS. There was some exces meat left on the chine at ribs 11-12 and so the eye meat was exposed. However, this could be rectified with further testing and calibration.

The image below showns a 10 rib rack/shoulder processed on the LCBS.

The reslting CFO loins, racks and shoulder racks can be easily sepperated by knife and either deboned or left bone in.

3.4 High Level Design and Further Development Budget Estimates

3.4.1 Lamb Forequarter Boneless – Robot Only

- The Forequarter (FQ) will need to be loaded onto the product clamping mechanism. This will either have to be done manually, or with a robot, or other mechanism.
- The Product Clamping Mechanism, similar to that which is currently in use on the LEAP II - Hindquarter Robot, will firmly secure the Lamb FQ.
- A knife wielding robot will likely need input data from a range of sources (physical contact, laser scans and perhaps original x-ray data) to accurately plot the path needed to conduct the de-boning.
- The product clamping mechanism could be duplicated and placed on a rotating carrousel, thereby permitting parallel/simultaneous unloading/loading and processing.
- Alternative options include:
  - Making the knife static (or on a very simple non-robotic mechanism with 1-2 DOF) and having the robot pick the FQ and move the FQ relative to the static knife to conduct the cuts. This removes the need for having a separate robot to load the product clamping mechanism.
  - Ideally the transfer mechanism between the Primal Machine and the LFB System would be able to mount the FQ onto the product clamping mechanism without the need of a robot or an operator.
- If the shoulders were going to be removed or partially processed by this automated system, the shank tips would have to be secured so that the system could be aware of and indeed control their positions if need be.
- There may be need to use the “neck removal drill” as seen in the processing experimentation videos.

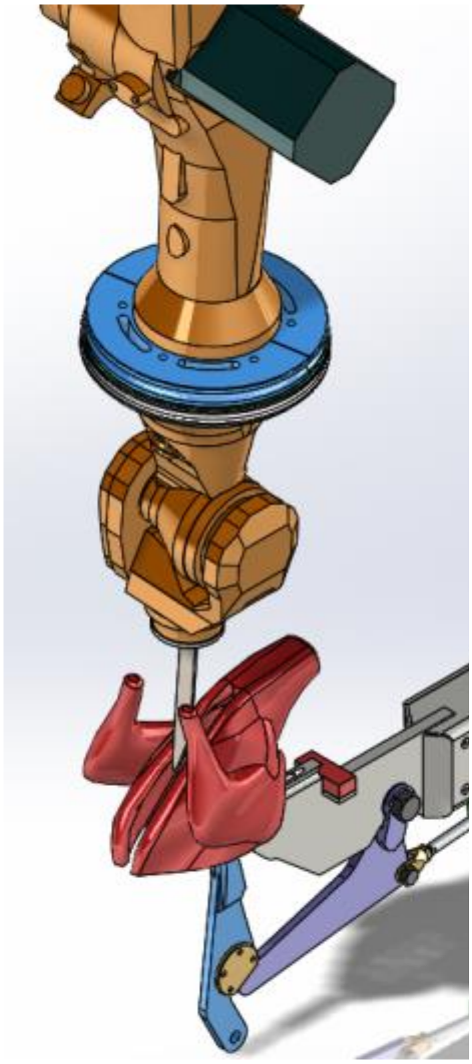

Fig. 6: Lamb Forequarter Boneless System – Robot Only

3.4.2 Lamb Forequarter Boneless – LCBS & Robotic Processing

- Pre-processing (removal of neck and breast) would be followed by processing on a modified LCBS. A robotic knife, similar to the system described above, would complete the boneout. This added complexity would be justified by higher yield results.
- The Lamb Chine Bone Saw (LCBS) is currently being toured to demonstrate the technology to processors across Australia. It has already proven its ability to conduct very high yield and high throughput CFO processing of lamb racks.
- A number of FQs with the neck, first rib, forelegs and brisket removed have already been tested on the existing Lamb Chine Bone Saw (LCBS) to demonstrate its ability to conduct CFO on ribs 2-4. The first ribs are too narrow to fit on the existing LCBS.
- A modified LCBS would be able to conduct the CFO process on a FQ with just the neck and breast removed. I.e. conducting CFO for ribs 1-4.
- Once the chine is removed, the removal of the ribs would be relatively simple, perhaps resulting in higher yield deboning.
- The forelegs and shoulders would have to be removed (or otherwise deboned) before or after this process to leave a completely boneless shoulder half.
- There may be need to use the “neck removal drill” as seen in the processing experimentation videos.

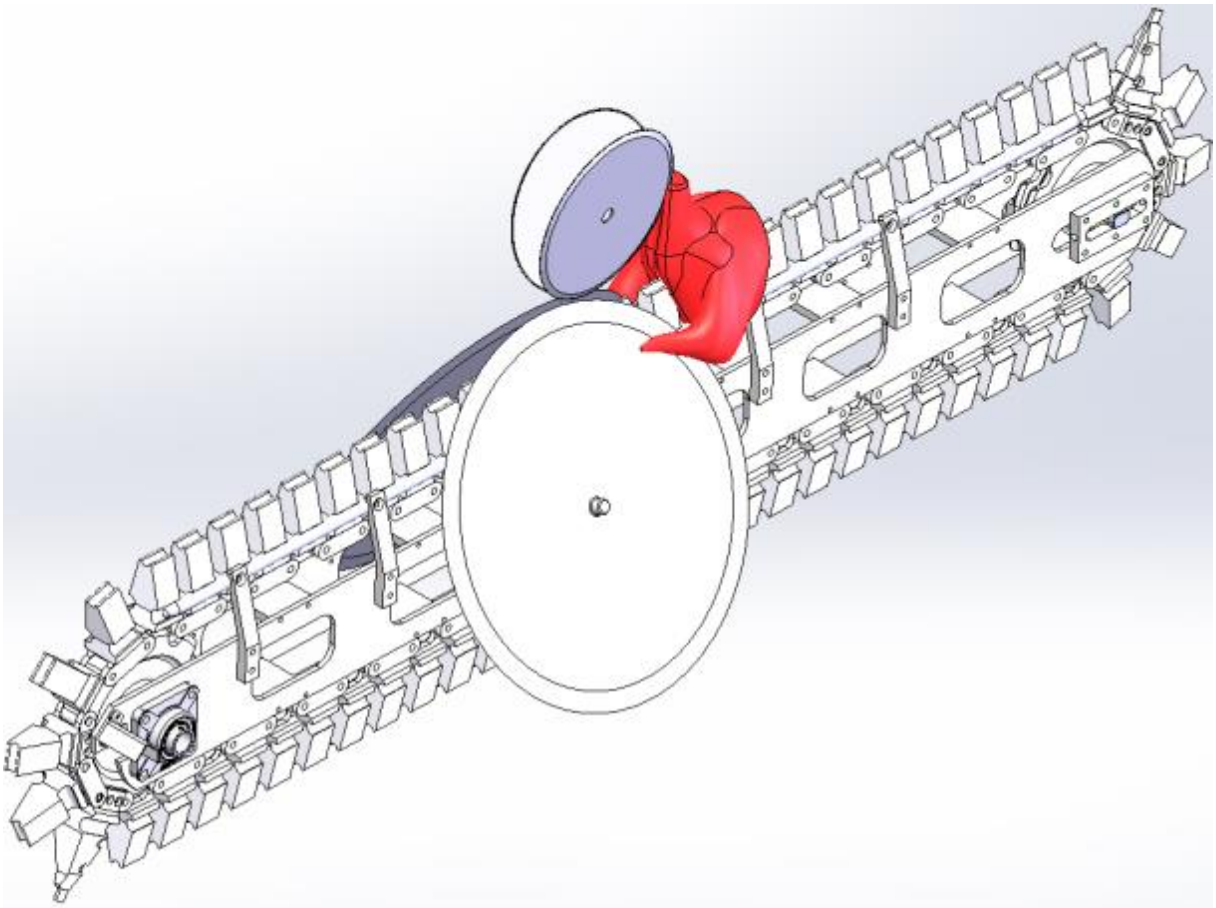

Fig. 7: Lamb Forequarter Boneless System – CFO Machine with Robotic Further Processing

4 Results

A high level review of the various Australian methods of deboning lamb forequarters was conducted. These results have informed the conceptual design of the proposed automated FQ processing solutions.

The high level concepts of possible automation approaches to deboning of lamb forequarters was tested using new processes and tools. Many of these experiments were video recorded for analysis purposes and some of the videos have been submitted with this report for general interest.

Two high level concept design(s) have been developed and described in this report. An application for the next stage of development in this space will be submitted to MLA/AMPC for consideration and will contain more detailed financial/budgetary information.

5 Discussion

There are two (2) main automated proceses being investigated at present.

- The first concept proposes to emulate the manual bone-out process as closesly as possible. The resulting product should not vary significantly from manually boned out FQ product. Unless the use of the “neck removal drill” is determined to be necessary or otherwise advantageous.
- The second concept would require some additional handling but takes advantage of some existing processing technology which consistenly produces high yield results. Admittedly, these results have only been achieved in the production of rack and loin product, but further testing may reveal that processing part of the FQ this way (with the neck removed with the “neck removal drill”) yields worthwhile results. The advantage of this process would be high yield chine and feather removal, and the recovery of inter costal meat. The recovery of intercostal meat requires the removal of individual ribs (disconnected from the chine) from the product and this in itself presents a significant challenge.

There is significant experimentation and development work that needs to be conducted before one of the above proposed processes can be identified as being the best return on investment based factors like throughput, yield, developmet costs and installation costs.

6 Conclusions/Recommendations

Now that the physical process of de-boning has been analysed and potential automated processes identified, a through opportunity analysis to determine the value to industry that automating this task could potentially generate should be conducted. The details of this opportunity analysis will undoubtedly dictate the level (increased complexity and cost returning greater yield and throughput) of automation that is currently worthwhile achieving.

7 Appendix

The following videos Lamb Forequarter Automated Deboning experiments have been made available for download:

- Full Debone 01
- Full Debone 02
- Full Debone 03
- Reverse Full Debone 01 Part 1
- Reverse Full Debone 01 Part 2