Machinery Automation & Robotics Pty Ltd

"When the outcome has to be certain!"

final report

Project Code: P.PSH.0284

Prepared by: Darren Herbert Jonathan Cook

Date published: October 2008

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Beef Hock Cutting On Site Sensing Trials

This is an MLA Donor Company funded project.

Meat & Livestock Australia and the MLA Donor Company acknowledge the matching funds provided by the Australian Government to support the research and development detailed in this publication.

CONTENTS

1 TABLE OF CONTENTS....2
2 REVISION HISTORY....2
3 OBJECTIVE....3
3.1 Trial Objective....3
4 TRIAL INFORMATION....4
4.1 Location....4
4.1 Stabilisation System....4
5 TRIAL EQUIPMENT....5
5.1 3D Camera....5
5.2 3D Camera Lighting....5
5.3 Thermal Camera....5
5.4 Thermal Image Analysis Software....5
5.5 Thermal Backboard....6
5.6 Equipment Setups....6
6 TRIAL DATA COLLECTION....8
6.1 Camera Data....8
7 TRIAL RESULTS....9
7.1 Site Information....9
7.2 Technology Used....9
7.3 Results Data....12
8 ACTION PLAN....24
8.1 Stabilisation System....24
8.2 TYZX Camera....24
A. Appendix A....25

2 REVISION HISTORY

Document No.	Revision	Date	Comments	Author
9181-CTR-001	0	29-10-08	Initial Submission	D.Herbert
9181-CTR-001	1	31-10-08	Revised with additional detail	D.Herbert
9181-CTR-001	2	31-10-08	Results detail re-arranged	D.Herbert

3 OBJECTIVE

3.1 Trial Objective

The objective of theses trials is to gather data to evaluate whether the technologies at hand will allow for reliable operation of the robotic hock cutter, should the project proceed.

These trials will further examine the issues faced in regards to carcass orientation and general presentation of the hocks.

Miscellaneous colour photos of the trials conducted can be found in Appendix A.

4 TRIAL INFORMATION

4.1 Location

The trials were conducted on the kill floor at J.B.S. Swift's Dinmore plant during normal production with no outside influences effecting the sequence, timing or orientation of the carcasses.

4.1 Stabilisation System

The existing stabilisation system was used as per previous trials except for the addition of a leg diverter added to the upstream stimulation rails. This diverter proved effective in it's intent to ensure legs don't hang up on the bottom stimulation rail, but caused undue swinging in medium to large size carcasses.

Figure showing leg diverter.

A relatively minor alteration to this diverter would reduce it's swinging effect on the carcasses while still ensuring legs are not getting hung up.

The swinging of carcasses also contributed to some blurring of the thermal images but as the vision analysis results show below did not have adverse effects.

5 TRIAL EQUIPMENT

5.1 3D Camera

The 3D camera used was a TYZX Deepsea 16cm baseline stereo vision system. Custom VB code was produced to enable the ability to save data such as range and left monochrome images including distance information to a pre-determined folder and location.

The images and data were saved directly to a panel PC and later transferred to laptops for analysis.

5.2 3D Camera Lighting

The 3D camera lighting used was 4 off twin 4' cool white 36W fluorescent tubes driven by high frequency ballast and enclosed in IP56 poly enclosures.

5.3 Thermal Camera

The Thermal Camera used was a FLIR T400 Infrared Camera with standard 25^0 lens. The optional 45^0 lens was used to obtain wider angle images as detailed in results section below.

The images from the thermal camera were saved on board the camera as 320 x 240 pixel greyscale JPEG images. They were batch converted to 320 x 240 pixel greyscale Bitmap images for compatibility with the analysis software. A watermark was also added for ease of analysis.

5.4 Thermal Image Analysis Software

The software used to analyse the thermal images was VisionPro 5.0 & 5.1 running on laptops. The program to find the Dew Claw narrow was successfully tested and if deployed in a working system would require further development and adjustments to take into account any changes in equipment use setups.

The method for finding Dew Claw narrowing was used to best find the location the cut the hock due to the good results recorded.
It was considered unreliable the find the best location the cut the hock by the hoof to hide method as the thermal camera dead band is 2^0C and the temperature difference between the Hoof and Hide line is less than 1^oC.

5.5 Thermal Backboard

A thermal backboard was used to give a consistent background to the thermal images, the board was 2400mm H x 1500mm W and painted matt black to give the lowest possible emissivity.

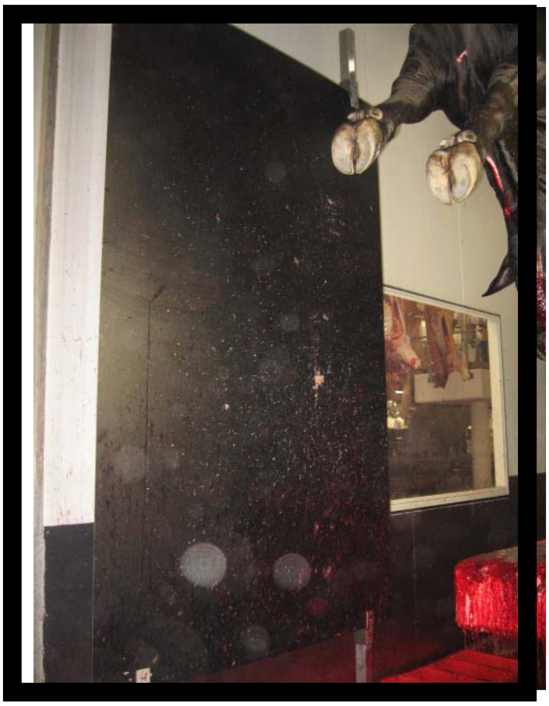


Figure showing backboard setup during trials.

5.6 Equipment Setups

Refer to Appendix A for drawings detailing the mounting arrangements of the cameras as referenced to the sets of data recorded.

Figure showing mounting arrangement of the Thermal Camera (above) and TYZX Camera (below).

The cameras were fixed mounted on a movable stand with their lens mounted as close as practical to one another.

6 TRIAL DATA COLLECTION

6.1 Camera Data

The cameras data was acquired by manual triggering of each camera with the synchronisation of each acquisition done verbally.

The synchronisation of each acquisition was done in two ways:-

6.1.1. Fixed Point

Using the 45^0 lens on the thermal camera, and it's increased field of view it was possible to trigger the cameras based on fixed point on the carcass hock rail.

6.1.2. In field of View

Using the standard 25^0 lens on the thermal camera, with it's limited field of view it was only possible to trigger the cameras based on whether the carcass legs were within the field of view of the thermal camera.

This can account for several of the thermal images being miss-acquired resulting in images without the legs being capture in the frame. The before mentioned swinging of the carcasses also contributed to this.

7 TRIAL RESULTS

7.1 Site Information

The below section details the results of the trials based on current site information and observations and their application to the robotic hock cutter.

7.1.1 Location

The location of the robotic hock cutter is pre-determined and will suit the installation of such.

7.1.2 Stabilisation System – Leg Diverter

As mentioned previously, the leg diverter requires modification to prevent the carcasses “hanging-up” on it.

7.1.3 Stabilisation System – Stabilisation Rails

It is the opinion of this trial that the stabilisation rails currently in place are causing the majority of the carcass orientation problems shown in the results below, namely the hock occlusion and instances where the carcass angle was severe enough that the hocks hit the back board. Although the carcasses that are indicated as being on an angle toward the cameras the Thermal image analysis software was still successful in finding the dew claw narrowing point.

The bottom stabilisation rail has gone through some previous trials to attempt to find the best position for it as it is adjustable.

7.2 Technology Used

The below section details the results of the trials based on the equipment used and it’s application to the robotic hock cutter.

7.2.1 3D Camera

The data from this camera is yet to be proved accurate to any degree. It was not possible to check distances recorded from the device during the trials as the measured object is constantly moving.

From static tests done at the workshop prior the trials going to site test measurements were taken with unexpected results. The static tests were to measure the distance recorded by the TYZX camera against a flat textured surface within the camera measurement range. With the subject 2000mm from the camera the TYZX data read back that it's measured distance was in error by 70mm as compared to real measurement.

The manufacturer of the TYZX camera has been contacted regrading this issue with no satisfactory conclusion as to the reasoning behind the large error except for the possibility that the camera is out of calibration.

Further work is required to prove the TYZX camera is suitable for the robotic hock cutting application.

7.2.2 3D Camera Lighting

The lighting used was successful to the degree of image quality only, the accuracy of data is yet to be tested.

7.2.3 Thermal Camera

The thermal camera data collected proved to be reliable when using the 45^0 lens to maintain the wider field of view. Due to site space restrictions and the mounting distance away from the subject the standard 25^0 lens did not provide the minimum field of view required.

The resolution of the image captured, 320 x 240 pixels, was proved by the analysis software to be sufficient, although higher resolution images could increase the throughput of the analysis.

7.2.4 Thermal Image Analysis Software

The thermal image analysis software is feature rich and includes tools and functions suited to this application.

7.2.5 Thermal Backboard

The thermal backboard was considered successful both for the thermal image collected and the 3D data. Due to the featureless appearance of the backboard the 3D camera had difficulty resolving measurement from it and therefore uncluttered the data.

A possible explanation for the different contrasts of the thermal images at the same temperature ranges is that the backboard became covered with particles from the horn cutting process. It is perceived this would not be an issue should the project go ahead as the horn cutter is to move further down the production line.

The backboard was also subject to ambient conditions but this also is not considered an issue as the analysis software has good contrast tools available including the possibility to calibrate the system based on ambient temperature.

7.2.6 Equipment Setups

From the results it is further proved that the best location for the camera equipment is as per Set 2 of the data below. This setup provides the best position to prevent leg occlusion including suiting the thermal cameras field of view and site mounting requirements.

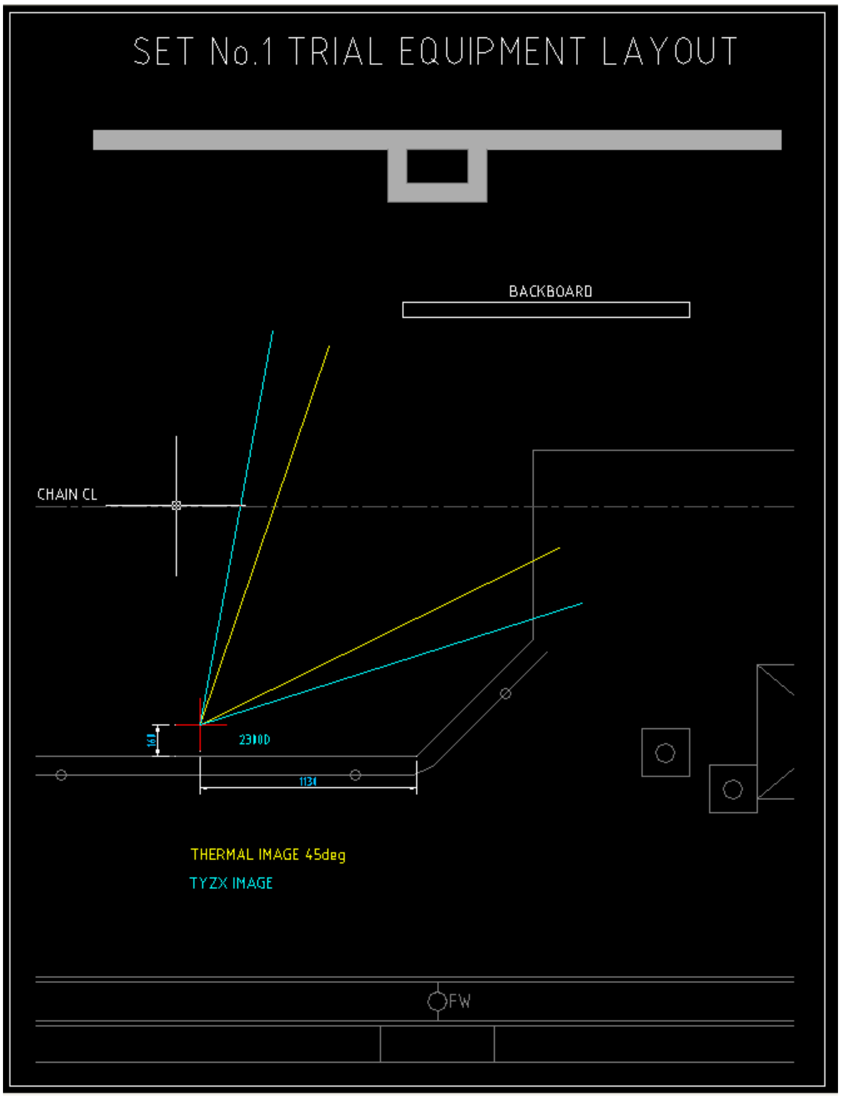
7.3 Results Data

7.3.1 Thermal Image Results

The below section details the results of the trials based on the data collected with the thermal camera.

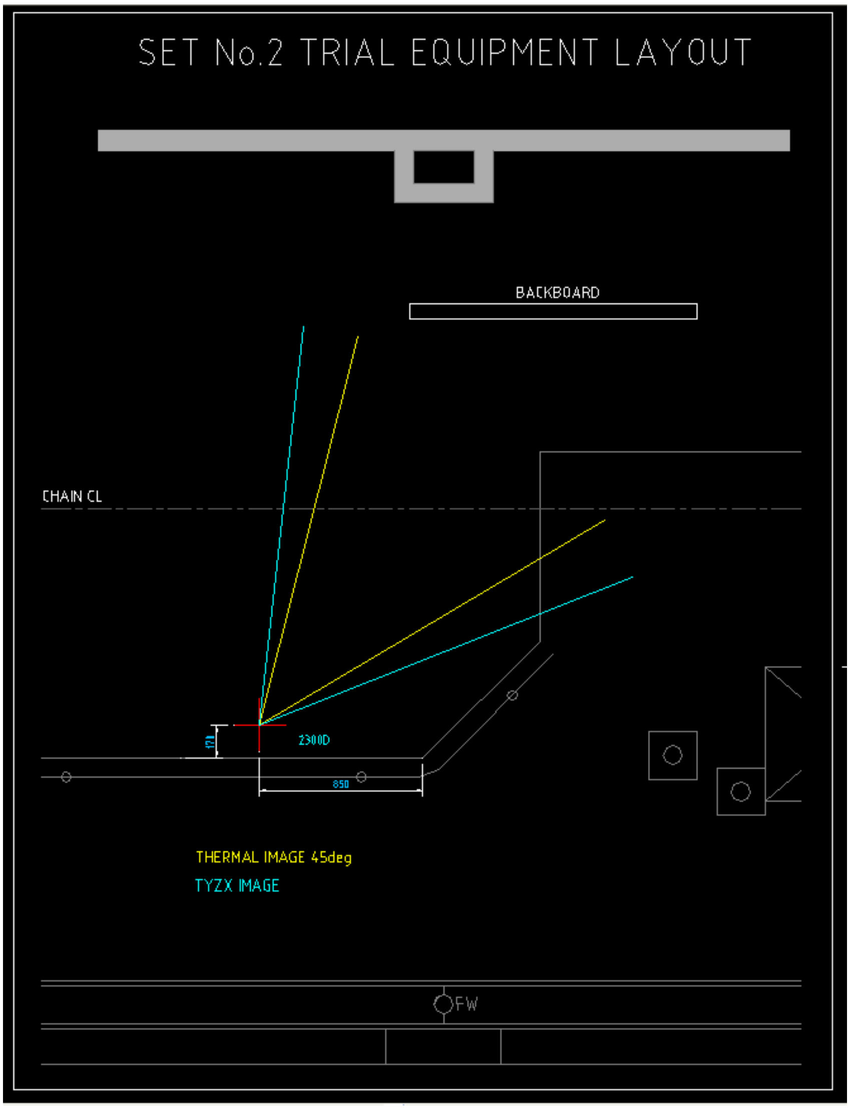
7.3.1.1 Trial Set No.1

Set	Hocks Successfully Found	Hocks Successfully Found (neglecting cases of occlusion)	Occlusion	Out of Window	Leg Angle Forward	Leg Angle Backward	Number of Trials
1	91.46%	97.33%	6.03%	3.02%	49.25%	10.55%	199



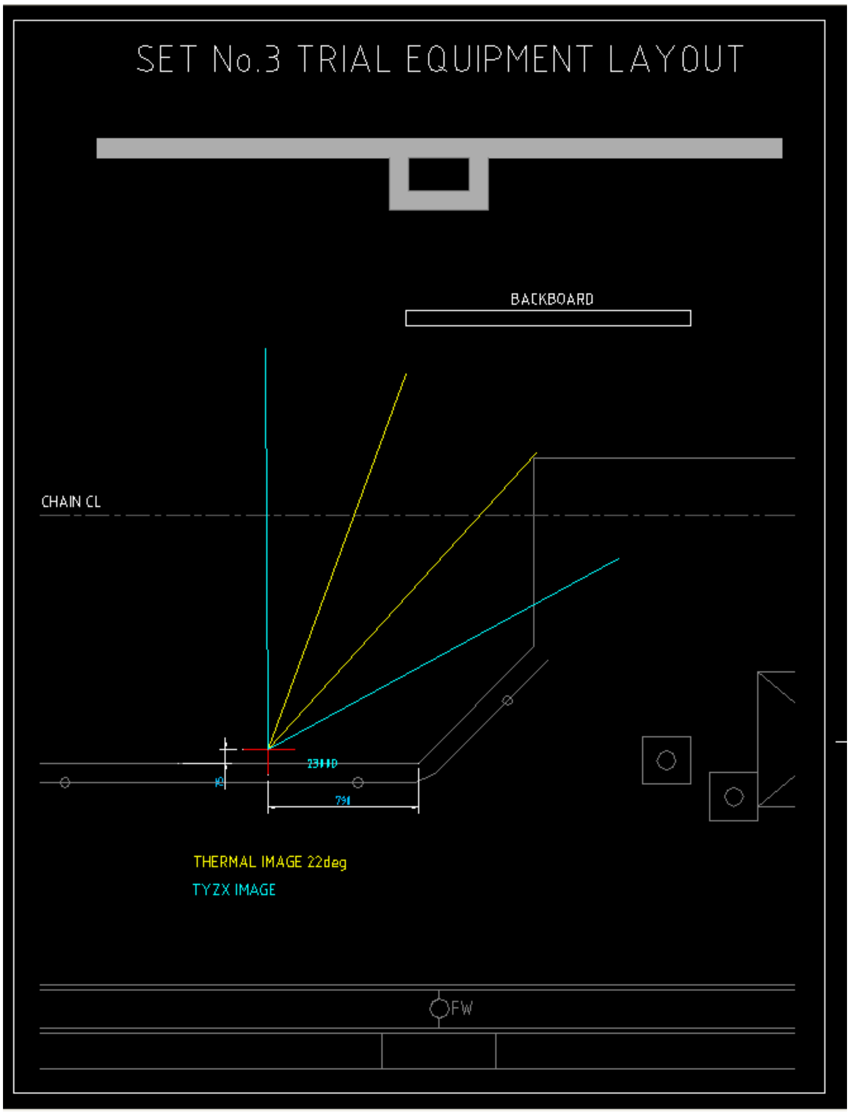
7.3.1.2 Trial Set No.2

Set	Hocks Successfully Found	Hocks Successfully Found (neglecting cases of occlusion)	Occlusion	Out of Window	Leg Angle Forward	Leg Angle Backward	Number of Trials
2	89.95%	98.53%	8.54%	0.00%	8.04%	40.20%	199



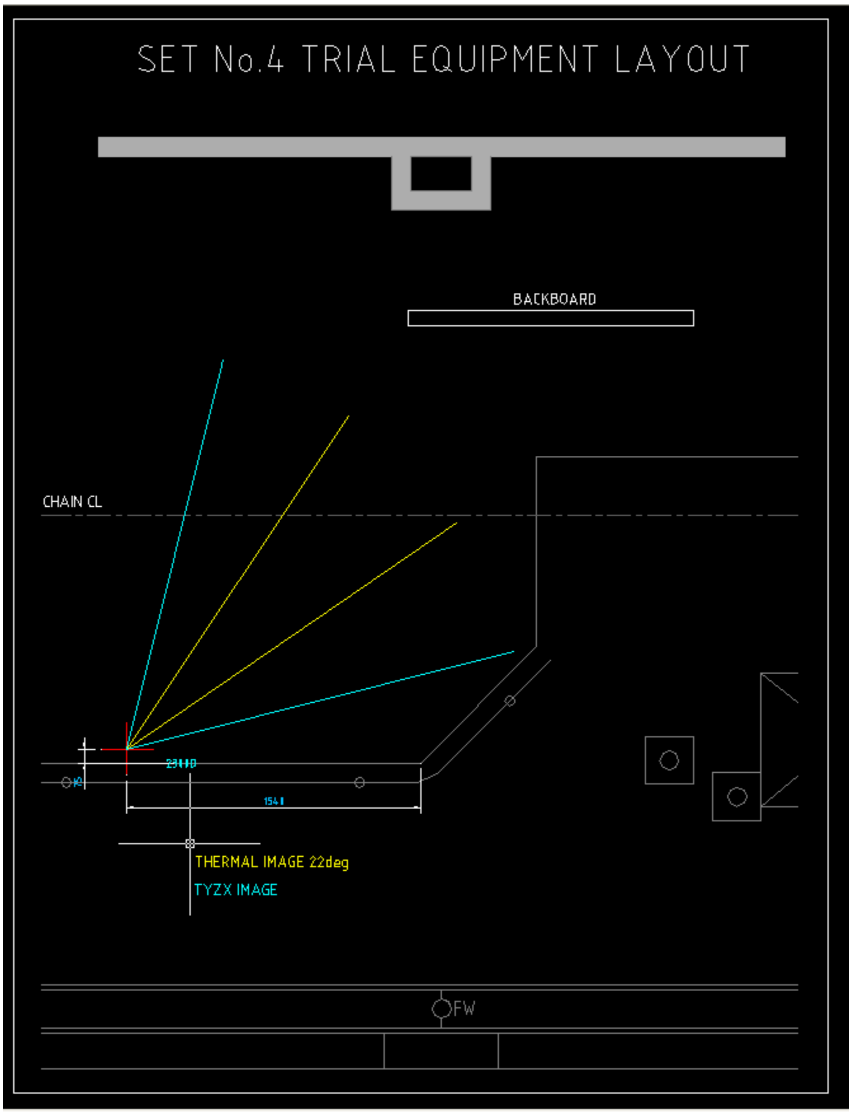
7.3.1.3 Trial Set No.3

Set	Hocks Successfully Found	Hocks Successfully Found (neglecting cases of occlusion)	Occlusion	Out of Window	Leg Angle Forward	Leg Angle Backward	Number of Trials
3	77.89%	84.70%	8.04%	0.00%	0.00%	37.69%	199



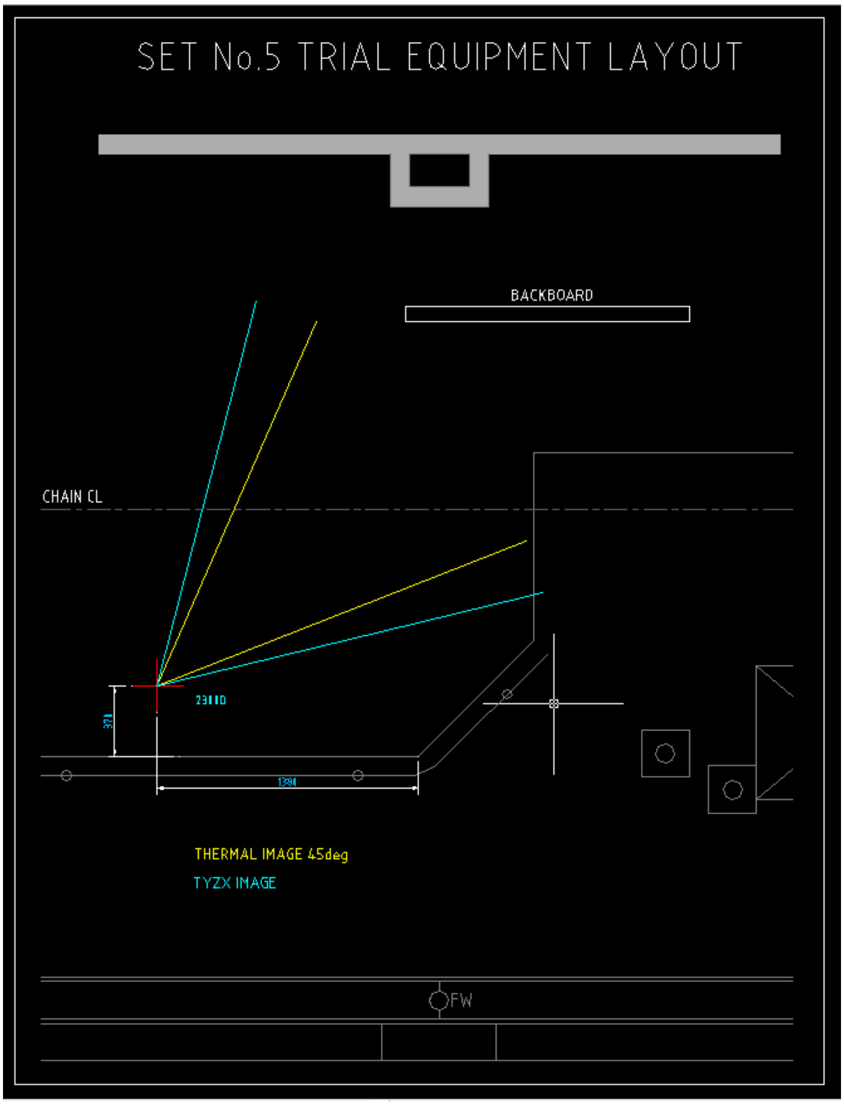
7.3.1.4 Trial Set No.4

Set	Hocks Successfully Found	Hocks Successfully Found (neglecting cases of occlusion)	Occlusion	Out of Window	Leg Angle Forward	Leg Angle Backward	Number of Trials
4	62.88%	65.01%	6.53%	8.54%	4.02%	39.70%	199



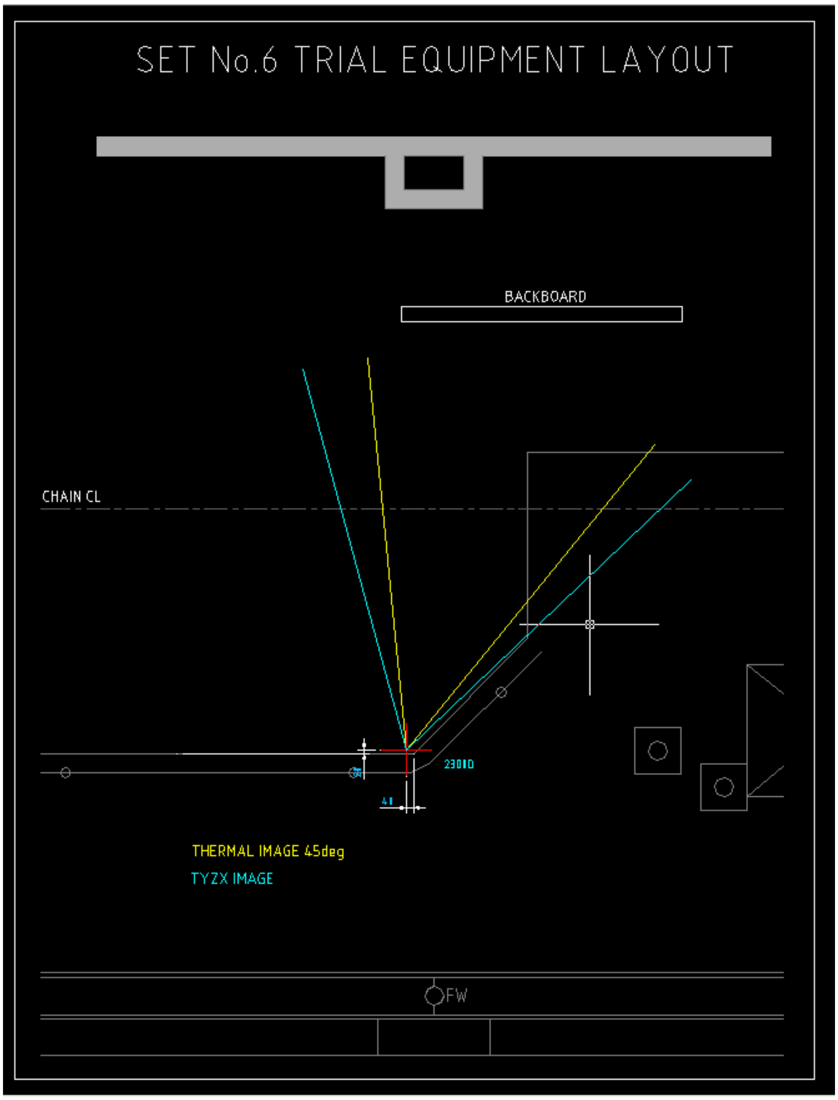
7.3.1.5 Trial Set No.5

Set	Hocks Successfully Found	Hocks Successfully Found (neglecting cases of occlusion)	Occlusion	Out of Window	Leg Angle Forward	Leg Angle Backward	Number of Trials
5	72.22%	72.96%	1.01%	0.00%	18.18%	1.01%	99



7.3.1.6 Trial Set No.6

Set	Hocks Successfully Found	Hocks Successfully Found (neglecting cases of occlusion)	Occlusion	Out of Window	Leg Angle Forward	Leg Angle Backward	Number of Trials
6	69.39%	97.16%	28.57%	0.00%	0.00%	36.73%	49



Below is a table based on the set 1 data collected that details where the analysis software will require refinement prior to deployment into an operating system.

	Number	Occlusion	Patmax	Findline	CopyRegion	Too High	Too Low	Out of Frame	Rails
No Hocks Found	15	11	1	0	0	0	0	1	2
One Hock Found	4	0	0	0	0	2	2	0	0

Below is a table based on the set 2 data collected that details where the analysis software will require refinement prior to deployment into an operating system.

	Number	Occlusion	Patmax	Findline	CopyRegion	Too High	Too Low	Out of Frame	Rails
No Hocks Found	18	16	1	0	1	0	0	0	0
One Hock Found	4	1	0	2	0	1	0	0	0

Below is a table based on the set 6 data collected that details where the analysis software will require refinement prior to deployment into an operating system.

	Number	Occlusion	Patmax	Findline	CopyRegion	Too High	Too Low	Out of Frame	Rails
No Hocks Found	14	12	2	0	0	0	0	0	0
One Hock Found	2	2	0	0	0	0	0	0	0

Below is a table that details the amount of occlusion found per set.

Set	Angled Forward	Angled Backwards	Number
1	8.33%	91.67%	12
2	5.88%	94.12%	17
3	0.00%	100.00%	16
4	7.69%	92.31%	13
5	100.00%	0.00%	1
6	0.00%	100.00%	14

Below is a table that details the error found by the analysis as to the cut position.

Set	Hocks Successfully Found	Mean Error Leg No1	Mean Error Leg No2	Number of Trials
2	89.95%	4.77mm	4.61 mm	199

The full set of results spreadsheets can be found in the project folder on the MAR server.

7.3.2 Thermal – 3D Image Results

The below section details the results of the trials based on the data collected with the thermal camera and then correlated to the 3D image data collected.

With the dew claw narrowing position indicated by the red crosshairs, two areas per leg are selected to sample the leg angle in the Z-axis (green circles) from the 3D data, with the results tabulated below.
The following figures also include an indication, by the magenta line, of the hock cut line.

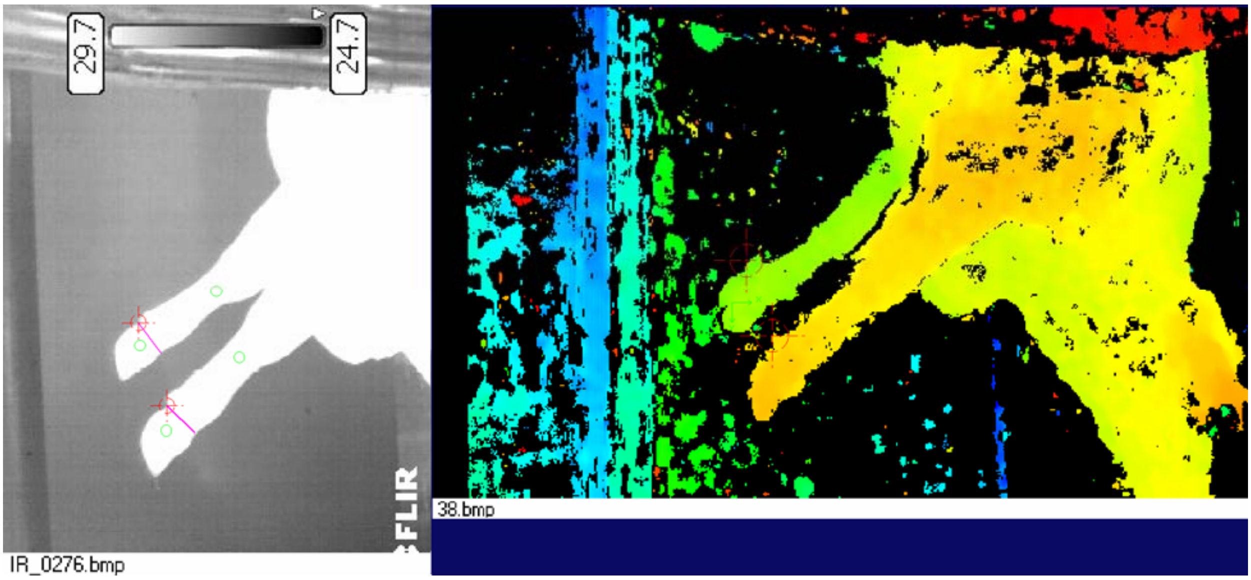


Figure 1

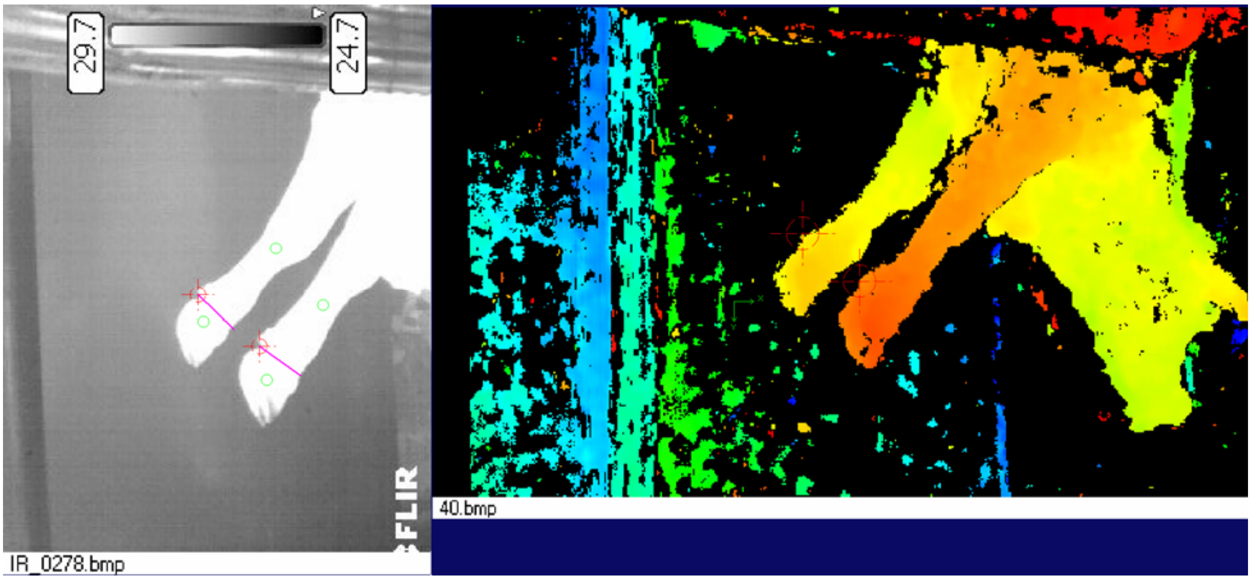


Figure 2

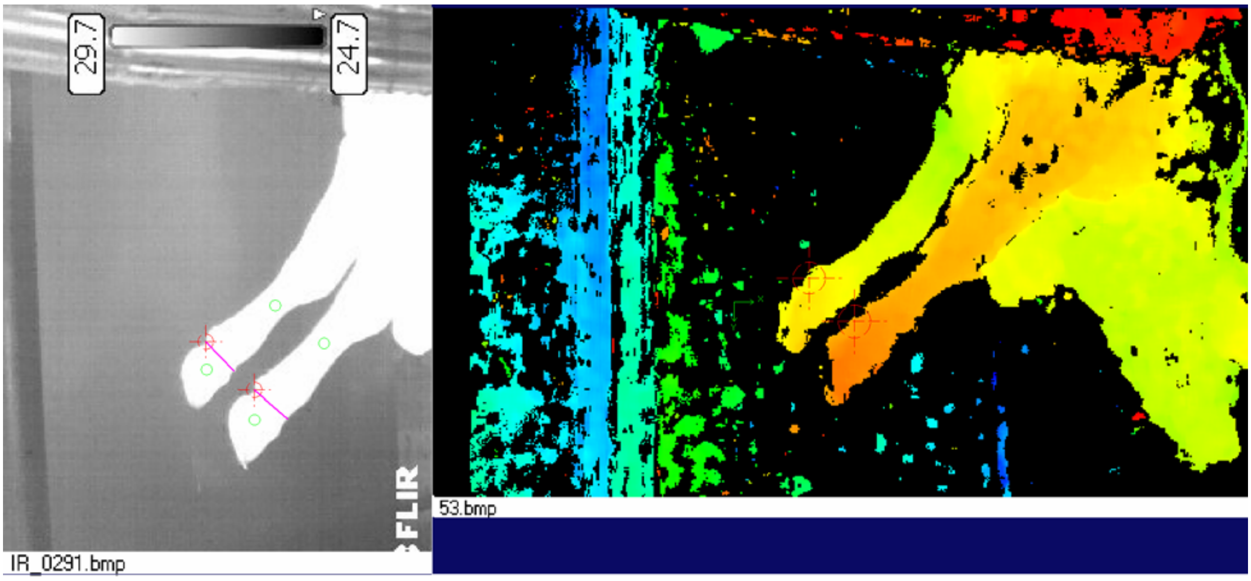


Figure 3

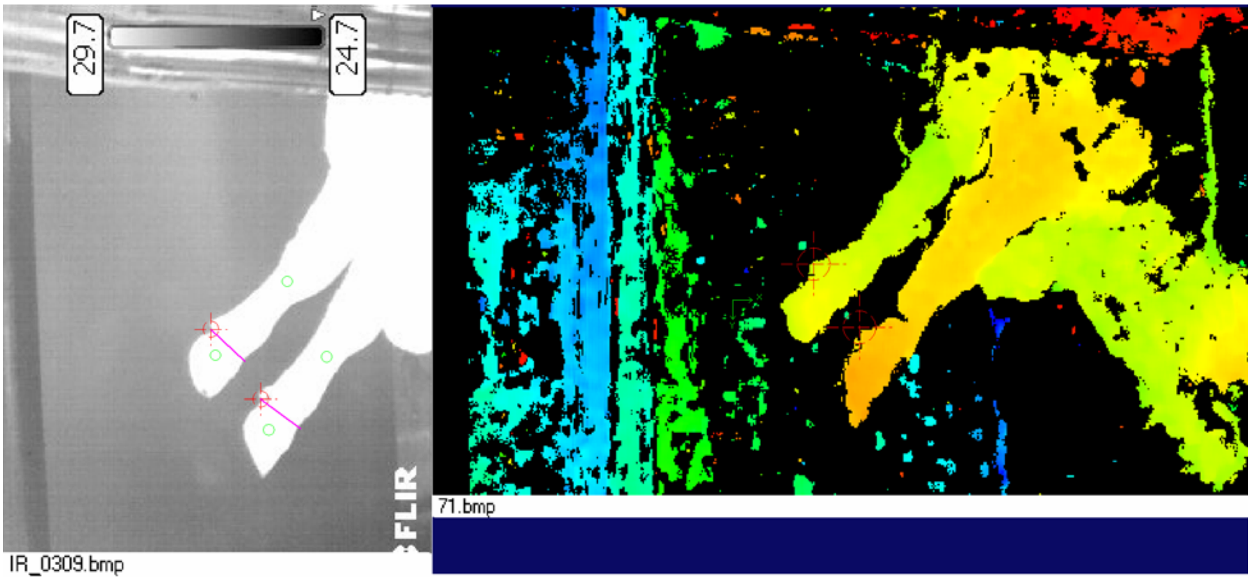


Figure 4

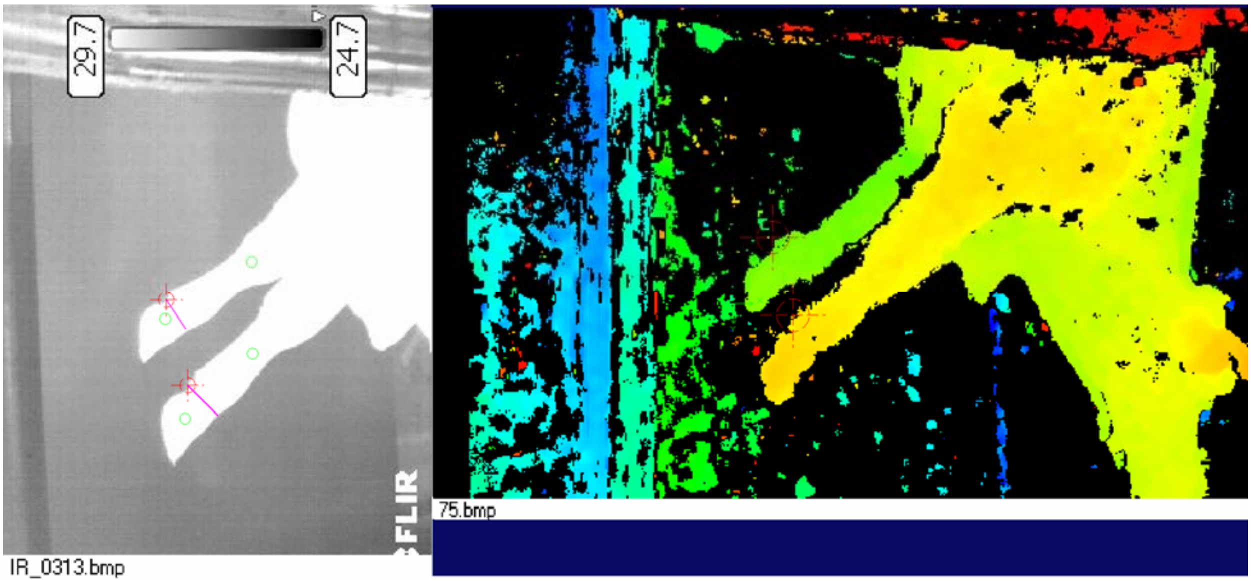


Figure 5

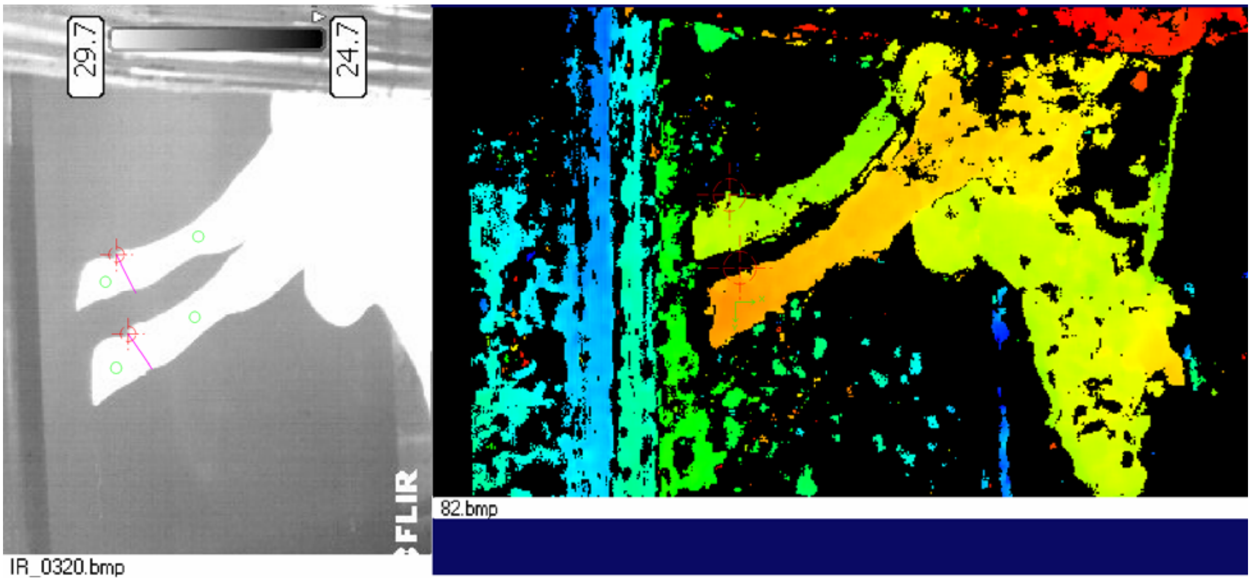


Figure 6

	Hock 1		Hock 2	
Figure	*Bottom*	*Top*	*Bottom*	*Top*
1	1903	1934	1620	1669
2	1625	1742	1392	1522
3	1691	1824	1495	1565
4	1682	1781	1482	1558
5	1970	2009	1645	1696
6	1833	1913	1512	1624

Table 1 - Z-values (mm)

	Hock 1						Hock 2					
Figure	*Bottom*			*Top*			*Bottom*			*Top*		
	x	**y**	**z**	**x**	**y**	**z**	**x**	**y**	**z**	**x**	**y**	**z**
1	500	500	1903	700	700	1934	500	500	1620	700	700	1669
2	500	500	1625	700	700	1742	500	500	1392	700	700	1522
3	500	500	1691	700	700	1824	500	500	1495	700	700	1565
4	500	500	1682	700	700	1781	500	500	1482	700	700	1558
5	500	500	1970	700	700	2009	500	500	1645	700	700	1696
6	500	500	1833	700	700	1913	500	500	1512	700	700	1624

Table 2 - Example hock vectors

	Hock 1			Hock 2		
Figure	**ά**	**β**	**γ**	**ά**	**β**	**γ**
1	45.34	45.34	83.75	45.83	45.83	80.17
2	45.34	45.34	67.53	50.02	50.02	65.32
3	45.34	45.34	64.82	46.65	46.65	76.10
4	45.34	45.34	70.71	46.93	46.93	74.96
5	45.34	45.34	82.15	45.90	45.90	79.78
6	45.34	45.34	74.21	48.89	48.89	68.40

Table 3 - Example calculated angles

NB: **ά** corresponds to the angle with the x-axis, **β** corresponds to the angle with the y-axis, **γ** corresponds to the angle with the z-axis

8 ACTION PLAN

8.1 Stabilisation System

Resolve stabilisation issues (to be discussed).

8.2 TYZX Camera

Resolve accuracy issues (to be discussed).

A. Appendix A

Image showing cutting region of a bull or Friesian Cow.

Image showing TYZX camera lighting.